

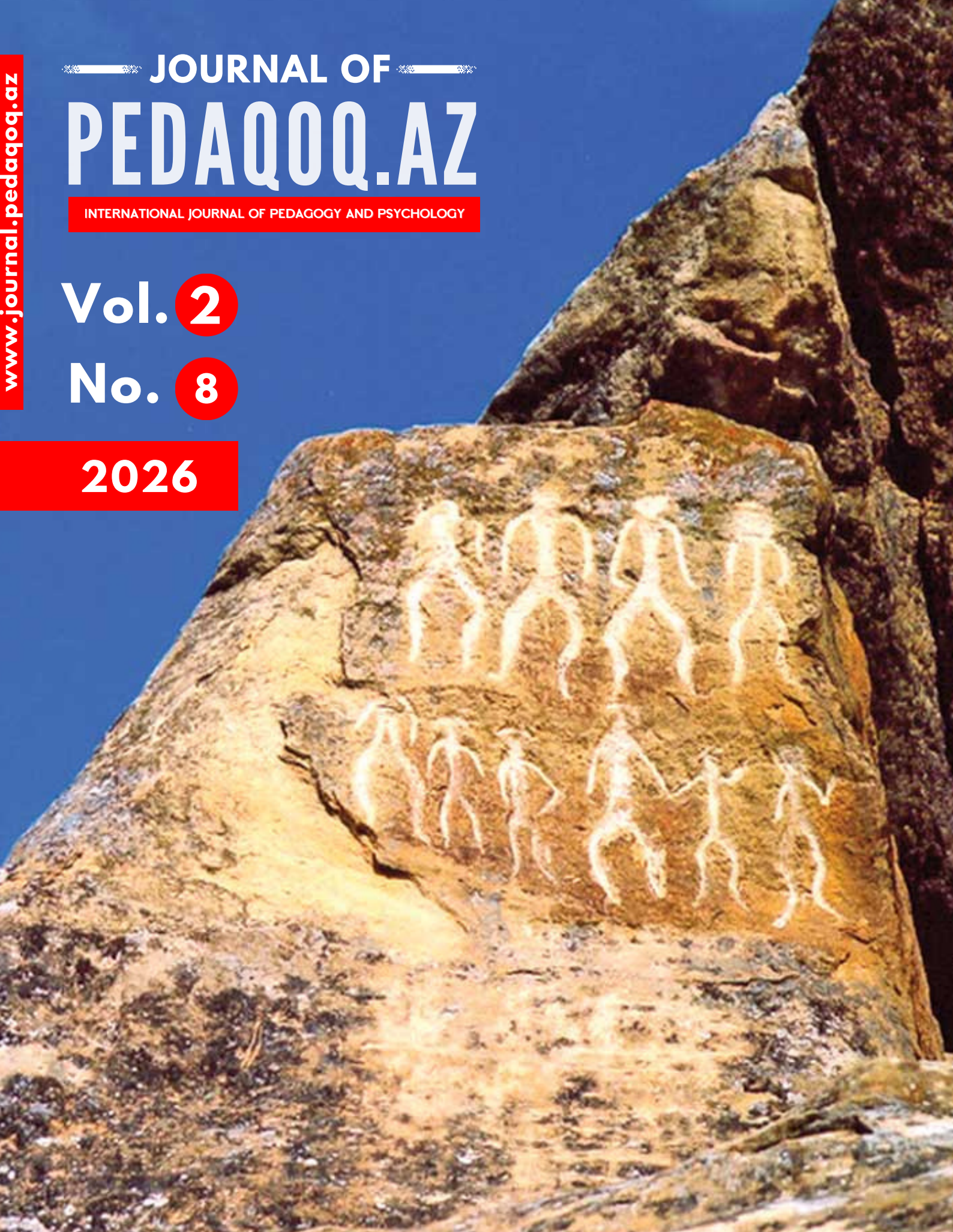
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THE TRANSFORMATION OF TEACHER PROFESSIONALISM IN THE ERA OF ARTIFICIAL INTELLIGENCE: FORMULATING A NEW COMPETENCY MODEL FOR THE 21ST CENTURY

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Keywords: artificial intelligence, teacher professionalism, teacher competencies, digital competence, AI literacy, AI-pedagogy, ethical responsibility, professional development, educational technologies

Abstract. This article examines the evolving nature of teacher professionalism against the backdrop of the rapid integration of artificial intelligence (AI) technologies into the educational process. AI is viewed not merely as a new digital tool, but as a transformative factor reshaping teachers' activities in planning, instruction, assessment, communication, and professional development. Beyond the ability to use technical tools, modern teachers are required to evaluate AI's capabilities and limitations, ensure ethical and responsible use, adhere to data protection standards, critically assess generative AI outputs, and uphold human-centric pedagogical decisions. The article analyzes UNESCO's 2024 AI Competency Framework for Teachers and the European Commission's DigCompEdu framework as a theoretical basis. The UNESCO framework defines 15 competencies across five key areas and outlines developmental levels - "acquire," "deepen," and "create" - for teachers. Based on these approaches, a new model of teacher professionalism is proposed. The model integrates components such as human-centric thinking, AI literacy, ethical responsibility, the integration of AI into pedagogy, critical-didactic decision-making, information literacy, and continuous professional development. The article's findings demonstrate that AI is not a mechanism that replaces the teacher; rather, it is a tool that expands the teacher's professional capabilities within an appropriate pedagogical framework.

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Introduction

The rapid development of artificial intelligence presents education systems with new professional and ethical demands alongside new opportunities. Generative AI systems have the capacity to generate text, structure ideas, create personalized learning materials, draft initial assessment samples, and optimize a portion of a teacher's daily workload. However, these capabilities render it insufficient to define the teacher's role merely as a user of technology. By introducing a global AI competency framework for teachers in 2024, UNESCO highlights the shift in the teacher-student relationship during the AI era toward a teacher-AI-student dynamic. The framework defines 15 competencies across five dimensions: human-centered mindset, AI ethics, AI fundamentals and applications, AI pedagogy, and AI for professional learning. These competencies are presented across three levels of development: acquiring, deepening, and creating. Within the DigCompEdu framework, the European Commission (Redecker & Punie, 2017, pp. 15–16) systematizes teachers' digital competence across six areas and 22 competencies. The framework presents technology not merely as a technical skill, but as a pedagogical competence linked to teaching, assessment, learner empowerment, and professional development. In this context, the central issue is the shift from the question "Can the teacher use AI?" to "For what pedagogical purposes, within what ethical framework, and with what professional responsibility does the teacher use AI?" The aim of this article is precisely to analyze this transformation and to systematize the key components of a new model of teacher competencies for the 21st century.

Main part. In the traditional education model, the teacher primarily acts as a source of knowledge, an organizer of the learning process, an evaluator, and a guide for student activities. However, the widespread adoption of AI dramatically expands

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the opportunities for acquiring knowledge. Consequently, the teacher's value lies less in merely presenting information and more in selecting, verifying, and contextualizing that information, as well as transforming it into pedagogical decisions tailored to the learner's development.

This change should not diminish the teacher's professional autonomy. On the contrary, the teacher remains the primary authority in determining whether the response generated by an AI tool is pedagogically appropriate. UNESCO (2024, pp. 16–20) emphasizes the preservation of human agency, respect for teachers' rights, inclusivity, and sustainability as core principles for the use of AI in education.

Thus, the role of the modern teacher expands in four directions: from a transmitter of knowledge to a designer of learning; from a user of digital tools to a professional possessing digital and AI literacy; from a mere assessor to a specialist making data-informed pedagogical decisions; and from a consumer of technology to a facilitator managing human-AI collaboration.

Key areas of new competencies for teachers. Human-centric mindset

In the era of AI, the most fundamental competency is keeping the human—rather than the technology—at the center. Teachers should link the opportunities provided by AI to students' creativity, independent thinking, social relationships, and emotional development. AI should support, not replace, a teacher's pedagogical judgment.

AI literacy

A teacher need not understand the inner workings of AI at a programmer's level, but must grasp its core principles, the capabilities and limitations of generative models, the potential for incorrect or fabricated answers, the impact of data quality on outcomes, and the risks of algorithmic bias. Such literacy prevents teachers from blindly accepting AI-generated results.

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Ethical and legal responsibility

The use of AI in education brings issues such as personal data protection, copyright, academic integrity, transparency, discrimination, and algorithmic bias to the forefront. Teachers must understand what information can be entered into AI systems, what data must remain confidential, and the circumstances under which AI-generated material cannot be cited as a source. Plans are also in place for 2026 to strengthen European-level guidance on the ethical, responsible, safe, and transparent use of AI in education and training, as well as to update the DigCompEdu framework to account for the rapid development of AI.

AI-pedagogical competence

Merely using an AI tool does not equate to AI pedagogy. The key factor is selecting the technology to suit a specific pedagogical objective. Through AI, teachers can create personalized assignments, adapt materials for learners at different proficiency levels, support the ideation process, and enrich project-based learning. UNESCO (2024, pp. 35–37) defines AI pedagogy as the integration of AI with pedagogy in a way that supports student-centered learning, personalization, critical thinking, and problem-solving.

Critical thinking and information literacy

Automatically accepting AI-generated content as accurate poses a significant pedagogical risk. Therefore, teachers must develop skills in verifying sources, cross-referencing facts, and evaluating authorship and credibility. This competence must also be fostered in students.

Continuous professional development

The rapid evolution of ICT means that digital skills acquired by a teacher once will not suffice for the long term. Professional development must be continuous; teachers need to experiment with new tools, evaluate their pedagogical impact, exchange experiences with colleagues, and reflectively analyze their own practice.

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DigCompEdu also identifies continuous digital professional development as a distinct area of teacher competence (Redecker & Punie, 2017, pp. 15–16).

A new model of teacher competencies for the 21st century

The model proposed in this article is built upon the logic of UNESCO's ICT competency frameworks and the DigCompEdu approach, yet it adopts a more holistic view of the teacher's professional practice. The model comprises seven key components:

- 1) Human-centric pedagogical thinking – prioritizing human agency and student development in the use of AI.
- 2) AI literacy – a basic understanding of the capabilities, limitations, and operating principles of AI systems.
- 3) Ethical and safe use – addressing privacy, authorship, academic integrity, transparency, and the prevention of discrimination.
- 4) AI-integrated pedagogical design – the purposeful integration of AI tools into lessons, assignments, projects, and assessment processes.
- 5) Critical-didactic decision-making – verifying AI outputs and justifying pedagogical decisions made by the teacher.
- 6) Human-AI collaboration – the teacher managing AI as a supportive partner and aligning its outputs with pedagogical goals.
- 7) Continuous professional development – the ongoing updating of competencies in line with new technologies.

Development levels of the competency model

A three-stage development approach is appropriate for the model's implementation. The first stage is "acquisition": the teacher learns the fundamental concepts of AI, safety guidelines, and simple applications. The second stage is "deepening": the teacher systematically integrates AI into teaching, assessment, and personalization. The third stage is "creation": the teacher develops new pedagogical scenarios using AI, tests innovative approaches, and contributes to the professional development of

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colleagues. This staged approach aligns with UNESCO's (2024, pp. 21–27) "Acquire–Deepen–Create" development logic.

The impact of AI on a teacher's daily activities

In lesson planning, AI can assist teachers in developing ideas, activity scenarios, and tasks of varying difficulty levels aligned with lesson objectives. However, rather than directly using ready-made content, the teacher should adapt it to meet curriculum requirements, age-specific needs, and the actual needs of the class.

Regarding assessment, AI can generate initial drafts of rubrics, sample questions, and structured suggestions for personalized feedback. Nevertheless, the final assessment decision must remain the teacher's professional responsibility.

In terms of personalized learning, AI can help prepare materials tailored to diverse learning needs. This capability is also significant for inclusive education, though the possibility of the technology producing biased or inaccurate results must be taken into account.

An institutional approach to teacher training

The development of teacher competencies should not be limited to the efforts of individual teachers alone. Educational institutions must establish clear policies, ethical guidelines, data security protocols, and professional development programs regarding the use of AI. It is also crucial to involve teachers in the decision-making process concerning AI. UNESCO (2024, pp. 43–51) indicates that the framework can be used in the development of national competency standards, teacher training programs, and assessment mechanisms.

Challenges and Risks

The integration of AI into education presents several risks: the spread of misinformation, excessive reliance on technology by teachers and students, issues regarding academic integrity, personal data protection, the digital divide, and algorithmic bias. These risks should be mitigated not by rejecting the technology, but through pedagogical and institutional governance mechanisms.

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The guiding principle can be stated as follows: AI should not make decisions in place of the teacher; rather, it should assist the teacher in making more informed decisions.

Implementation Prospects for Azerbaijan's Education System

Developing AI competencies within Azerbaijan's education sector can be viewed as advancing teachers' digital professionalism to a new level. In this regard, it is advisable to incorporate modules on AI literacy, working with generative AI, ethical usage, data security, AI-assisted lesson design, and the verification of AI-generated outputs into teacher professional development programs.

Meanwhile, in higher pedagogical education institutions, practical AI-related projects, micro-teaching sessions, reflective assignments, and analyses of ethical scenarios could be implemented for future teachers. Such an approach can ensure the integration of technology into the system of pedagogical competencies, rather than teaching it as a separate subject.

Conclusion

Artificial intelligence does not eliminate the teacher's role in the education system; rather, it transforms the content and structure of their professional practice. Modern teachers are required to possess not only technological proficiency but also a human-centric mindset, AI literacy, ethical responsibility, critical evaluation skills, pedagogical design capabilities, and a commitment to continuous professional development.

The proposed new competency model envisions reconstructing teacher professionalism on a pedagogical-humanistic foundation rather than a purely technological one. The core idea of the model is not for AI to replace the teacher, but to expand the teacher's professional capabilities. In this context, the teacher of the future is not merely a specialist who uses digital tools, but a professional capable of directing human-

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-technology collaboration toward pedagogical goals, making ethical decisions, and taking responsibility for the quality of learning.

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THE ROLE OF LEARNING MOTIVATION IN STUDENTS' ACADEMIC ACHIEVEMENT

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Keywords: learning motivation, academic achievement, student, education, intrinsic motivation, extrinsic motivation, learning activity, pedagogical process

Abstract. The article examines the role of learning motivation in the formation of students' academic achievement from pedagogical and psychological perspectives. In the modern educational process, not only students' knowledge and skills but also their interest in learning, educational goals, and effort play an important role. Learning motivation is one of the main factors that directs students' educational activities and supports their active participation in the learning process. The article analyzes the essence of learning motivation, intrinsic and extrinsic motivation, pedagogical factors affecting motivation, and the relationship between motivation and academic achievement.

Based on the scientific works of Azerbaijani researchers, it is argued that a high level of motivation can positively influence students' participation in the learning process, independent learning skills, and academic outcomes.

Teacher-student relationships, teaching methods, assessment, and a supportive learning environment also play an important role in the development of motivation. The article emphasizes the importance of using interactive and student-centered teaching methods, providing positive feedback, and considering students' individual characteristics in order to increase learning motivation.

Introduction

One of the key objectives of the modern education system is not merely to transmit specific knowledge to students, but also to develop them as independent thinkers who demonstrate an interest in learning and are capable of applying the knowledge they acquire in practical activities. In this regard, student motivation is one of the important factors affecting the effectiveness of the learning process. Learning motivation can be defined as the combination of internal and external factors that encourage students to learn, acquire new knowledge, achieve the goals set before them, and actively participate in educational activities. A student's ability to achieve high academic performance depends not only on their intellectual capabilities. Their attitude toward learning, goal orientation, self-confidence, and the effort they make to overcome challenges also play an important role. Azerbaijani researcher M. Haziyeva, who examined students' learning motivation in higher education institutions, notes that motivation plays an important role in the effectiveness of the educational process [Haziyeva, 2024].

The author indicates that students' motivation is influenced by factors such as their individual characteristics, learning conditions, teacher–student relationships, and the organization of instruction. Similarly, Ülkar Farzaliyeva's study on students' academic motivation demonstrates that students with higher levels of motivation tend to achieve higher levels of academic performance [Farzaliyeva, 2025].

The author considers academic motivation to be one of the important determinants of students' behavior in the educational process. The main purpose of this article is to analyze the role of learning motivation in students' academic achievement based on approaches existing in Azerbaijani pedagogical literature and to identify effective pedagogical strategies for enhancing student motivation.

Main part.

The Nature of Learning Motivation

Motivation is one of the fundamental psychological factors that determines the direction and persistence of human activity. In the educational process, motivation manifests itself in students' attitudes toward learning, the goals they set, and the effort they make to achieve those goals.

Learning motivation directs students toward acquiring knowledge and actively participating in the learning process. When students recognize the relevance of the knowledge they acquire to their future professional activities, their attitude toward learning and their interest in education may become stronger. M. Haziyeva notes that the formation of students' learning motivation in higher education institutions is influenced by both students' subjective characteristics and teachers' characteristics, as well as by the organization of the learning process and teacher-student relationships [Haziyeva, 2024]. Learning motivation can be broadly divided into intrinsic and extrinsic motivation. Intrinsic motivation is associated with the personal satisfaction students derive from acquiring new knowledge, learning, and developing their abilities. Extrinsic motivation, on the other hand, is related to grades, rewards, social recognition, teachers' and parents' expectations, future career prospects, and other external factors. Both forms of motivation play a certain role in students' academic activities. However, intrinsic motivation can be considered particularly important for sustained and long-term engagement in learning.

Learning Motivation and Academic Achievement

Academic achievement refers to the knowledge, skills, and outcomes that students acquire through the educational process. A number of factors influence the development of these outcomes, including students' individual characteristics, the learning environment, teachers' activities, instructional methods, the assessment system, and motivation.

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In her study, Ü. Farzaliyeva notes that students with higher levels of motivation also demonstrate higher levels of academic achievement [Farzaliyeva, 2025]. According to the author, academic motivation is one of the important determinants of students' behavior in the educational process.

Highly motivated students tend to prepare more actively for classes, make greater efforts to complete assigned tasks, seek additional information, and persist in the face of difficulties. These characteristics contribute to the improvement of their academic outcomes.

On the other hand, academic success itself may also increase students' motivation. When students successfully complete a task and achieve a positive outcome, their self-confidence increases. This, in turn, may encourage them to demonstrate greater enthusiasm for completing subsequent tasks. Thus, a reciprocal relationship can be observed between motivation and academic achievement.

The Role of the Teacher in the Motivation Process

Teachers' activities play a significant role in the development of students' learning motivation. A teacher is not merely a transmitter of knowledge but also a pedagogical agent who guides students' learning activities and supports their development.

A. Hasanova considers motivation to be an important component of the learning process and emphasizes that teachers can increase students' interest in learning through the use of various instructional methods [Hasanova, 2023].

Teachers' respectful treatment of students, willingness to listen to their opinions, recognition of their achievements, and presentation of mistakes as opportunities for development contribute to the creation of a positive learning environment.

F. Sadigova, in her study of motivation and the development of self-confidence in education, notes that assessment practices and teacher attitudes can influence learners' motivation [Sadigova, 2021]. The author particularly emphasizes that negative and humiliating attitudes may have an adverse effect on learners' self-confidence and motivation.

Therefore, teachers should consider not only students' outcomes but also the effort they demonstrate and their progress over time. Positive and constructive feedback can increase students' confidence in their abilities and encourage them to adopt a more active attitude toward learning.

The Impact of Modern Instructional Methods on Motivation

The instructional methods used to enhance students' motivation are also of considerable importance. In addition to traditional instruction, the use of interactive, problem-based, project-based, and collaborative learning methods can promote students' more active participation in the learning process.

L. Mammadova, in examining the impact of project-based teaching on the development of students' learning motivation, notes that during project work students engage in independent activities, determine goals and objectives, and plan their own work [Mammadova, 2023]. The author demonstrates that the project-based method contributes to the development of such qualities as goal orientation, responsibility, and active engagement among students.

From this perspective, students' participation as active learners rather than passive listeners is important for enhancing motivation. Discussions, group work, projects, presentations, and problem-solving activities provide students with opportunities to apply their knowledge in practical contexts. Demonstrating the practical relevance of learning can also contribute to increased motivation. When students recognize that the knowledge, they acquire is useful for their future professional careers, their interest in learning tends to increase. Therefore, teachers should relate theoretical information to real-life contexts and professional activities whenever possible.

Ways of Enhancing Students' Motivation

To enhance students' learning motivation, their individual characteristics and interests should first be taken into consideration. Since students do not have identical levels of motivation or the same interests, teachers should employ a variety of pedagogical approaches.

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A second important direction is ensuring that learning objectives are clear to students. When students understand what they are learning and why they are learning it, they tend to approach the learning process with greater responsibility.

A third direction is the implementation of interactive and student-centered methods. Group work, projects, discussions, and problem-based tasks increase students' active participation. L. Mammadova's research also emphasizes the positive impact of project-based teaching on students' practical activities and motivation [Mammadova, 2023].

A fourth direction involves positive feedback and fair assessment. Recognizing students' achievements and presenting their mistakes as opportunities for development may increase their self-confidence and interest in learning.

Thus, the development of students' motivation does not depend on a single factor. The interaction among the student, teacher, learning content, instructional methods, and educational environment constitutes one of the key conditions for the sustainable development of motivation.

Conclusion

The analysis demonstrates that learning motivation is one of the important pedagogical and psychological factors influencing students' academic achievement. Students' success is associated not only with their level of knowledge and intellectual abilities but also with their interest in learning, goal orientation, self-confidence, and the effort they make. An analysis of the works of Azerbaijani researchers indicates that students' motivation is influenced by the learning environment, teacher-student relationships, assessment practices, instructional methods, and individual characteristics [Haziyeva, 2024; Farzaliyeva, 2025; Hasanova, 2023; Sadigova, 2021].

To improve students' academic achievement, it is important to support them not only through external motivational incentives but also by fostering intrinsic interest and a genuine need for learning.

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In this regard, the use of interactive and student-centered methods, the provision of positive feedback, and the creation of a supportive psychological environment by teachers are of particular importance. In conclusion, the purposeful development of learning motivation can be regarded as one of the key conditions for improving the effectiveness of students' learning activities and enhancing their academic achievement.

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Abstract. The acquisition of biological concepts is a fundamental component of effective biology education and plays an important role in the development of students' scientific thinking, conceptual understanding, and ability to apply biological knowledge in different contexts. The abstract and interconnected nature of many biological concepts creates methodological challenges for learners, particularly when they encounter microscopic, molecular, dynamic, and complex biological processes. In this context, the association and analogy methods represent important methodological tools that can facilitate the meaningful acquisition and systematic organization of biological knowledge. The present study examines the methodological possibilities of association and analogy in the process of mastering biological concepts and analyzes their potential contribution to conceptual understanding. Association enables learners to establish meaningful connections between newly acquired information and previously existing knowledge, experiences, concepts, visual representations, and biological phenomena. Analogy, in turn, creates a cognitive bridge between familiar and unfamiliar systems by emphasizing relevant structural, functional, or process-based similarities. The analysis demonstrates that the integrated application of these methods can facilitate the understanding of abstract biological concepts, improve the retention of biological terminology,

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strengthen relationships among concepts, and support the development of students' analytical, comparative, generalization, synthesis, and knowledge-transfer skills. The methods also have significant potential for identifying and correcting misconceptions because associative and analogical activities can reveal students' initial conceptual representations and provide opportunities for their scientific restructuring. Particular attention should be given to the appropriate selection of analogies, the explanation of their limitations, and the integration of associative and analogical techniques with observation, experimentation, visualization, discussion, conceptual mapping, and problem-based learning. It is concluded that the systematic and scientifically controlled use of association and analogy can contribute to the transition from mechanical memorization toward meaningful, interconnected, and learner-centered biology education, thereby supporting the development of scientific literacy and deeper conceptual understanding.

Introduction

The effective acquisition of biological concepts is one of the fundamental objectives of biology education, as conceptual understanding constitutes the basis for interpreting biological phenomena, establishing causal relationships, and applying scientific knowledge to new and unfamiliar situations. Biology is characterized by a complex system of concepts that range from relatively observable phenomena, such as organismal structures and physiological processes, to highly abstract and microscopic processes, including cellular regulation, genetic information transfer, molecular interactions, ecological relationships, and evolutionary mechanisms. The diversity, hierarchical organization, and interdependence of biological concepts create considerable methodological challenges for both teachers and learners. Consequently, contemporary biology education requires instructional approaches that do not merely transmit factual information but facilitate meaningful conceptual construction, logical organization, comparison, interpretation, and transfer of knowledge.

Biological concepts are not isolated units of knowledge; rather, they form interconnected conceptual systems in which individual concepts acquire meaning through their relationships with other concepts. For example, understanding the

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concept of “ecosystem” requires learners to establish relationships among organisms, populations, communities, abiotic factors, energy flow, nutrient cycling, and ecological interactions. Similarly, comprehension of the concept of “cellular respiration” depends on the integration of previously acquired knowledge concerning cell structure, enzymes, metabolism, energy transformation, and ATP. If these relationships are not established, students may memorize definitions without developing a scientifically coherent understanding of biological processes [Farrugia & Musumeci, 2022]. Therefore, the methodological organization of conceptual learning is of particular importance in biology teaching. One of the important methodological possibilities for facilitating the acquisition of biological concepts is the use of association methods. Association provides learners with an opportunity to connect new information with previously acquired knowledge, experiences, images, characteristics, relationships, and concepts. From a pedagogical perspective, associative learning can support the formation of meaningful cognitive links between unfamiliar biological information and existing cognitive structures. When a new concept is introduced, its connection with a familiar concept, phenomenon, object, process, or visual representation can reduce cognitive difficulty and facilitate comprehension. Thus, association can be considered not simply a memorization technique but an instructional mechanism through which conceptual networks are gradually constructed and strengthened. The methodological significance of association becomes especially evident in teaching biological terminology and complex conceptual systems. Biology contains a large number of terms originating from Latin and Greek, as well as specialized concepts that may initially appear unfamiliar to students. Terms such as “photosynthesis,” “mitochondrion,” “homeostasis,” “osmosis,” “symbiosis,” “biodiversity,” and “biogeochemical cycle” may represent significant cognitive challenges when presented independently of meaningful contexts. Associating these terms with their functions, structural characteristics, etymological meanings, visual images, examples, or previously studied concepts can facilitate their semantic understanding and long-term retention. Consequently, association may contribute to the transition from mechanical

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memorization to conscious and meaningful learning[Hernandez, & Espitia, 2021]. Another important methodological approach in the acquisition of biological concepts is the analogy method. Analogy involves establishing similarities between a new or relatively unfamiliar object, structure, process, or relationship and another object or system that is already familiar to the learner. In biology education, analogies are particularly valuable because many biological processes cannot be directly observed or easily represented through ordinary classroom experiences. Teachers can therefore use familiar systems as cognitive models for explaining abstract biological phenomena. For example, the cell may be compared metaphorically with a well-organized production or management system, where different organelles perform specialized functions; the cell membrane can be compared with a selectively controlled boundary; DNA may be conceptually related to an information-storage system; and the circulatory system may be associated with a transportation network. Such analogies can make abstract biological relationships more accessible to learners. The educational value of analogy, however, depends on its scientifically appropriate application. An analogy highlights similarities between two domains, but the objects being compared are never completely identical. Therefore, effective biology instruction requires teachers to distinguish between the useful correspondence and the limitations of an analogy. If learners interpret an analogy as an exact representation of a biological system, misconceptions may emerge. For this reason, analogical instruction should involve not only identifying similarities but also explicitly discussing differences and boundaries. This methodological principle is particularly important when explaining complex processes such as genetic regulation, natural selection, ecological succession, cellular signaling, and energy transformation. Association and analogy are closely interconnected instructional mechanisms, although they are not identical. Association primarily establishes links between concepts, experiences, representations, and previously acquired knowledge, whereas analogy emphasizes structural, functional, relational, or process-based similarities between a familiar and a less familiar domain. In practice, these approaches can complement each other. A teacher may first activate a

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learner's existing associations and then use an analogy to construct a conceptual bridge toward new biological knowledge. Such integration can create a more coherent learning environment in which students are encouraged to compare, classify, interpret, generalize, and transfer knowledge [Manas, 2023]. The relevance of these methods is also related to the cognitive characteristics of conceptual learning. Learners do not enter the classroom as passive recipients of information; they possess prior knowledge, intuitive explanations, personal experiences, and sometimes alternative conceptions about biological phenomena. These prior conceptions can influence how new scientific information is interpreted. When a new biological concept is introduced, students may assimilate it into an existing but scientifically inaccurate conceptual framework. Association and analogy can therefore be used diagnostically as well as instructionally. By asking students to identify associations or construct analogies, teachers can reveal how learners conceptualize a biological phenomenon and identify potential misconceptions that require correction. For example, students may associate the concept of "adaptation" exclusively with the conscious ability of an organism to change in response to environmental conditions. Through carefully designed analogies and comparisons, teachers can guide students toward understanding adaptation as a population-level evolutionary process resulting from heritable variation and differential reproductive success. Similarly, the concept of "food chain" may initially be associated with a simple linear sequence, whereas an appropriately constructed conceptual network can help students understand the interconnectedness characteristic of food webs. These examples demonstrate that association and analogy can function as tools for conceptual restructuring rather than merely as aids to memorization. The use of analogy is particularly significant in teaching topics situated at different levels of biological organization. At the molecular level, analogies may assist in explaining DNA replication, enzyme-substrate interactions, protein synthesis, and molecular signaling. At the cellular level, they can facilitate understanding of organelle functions, membrane transport, cellular communication, and metabolic pathways. At the organismal level, analogies can clarify physiological regulation,

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nervous coordination, and homeostasis. At the ecological level, they can support understanding of population interactions, energy flow, nutrient cycles, ecosystem dynamics, and ecological succession. Thus, the methodological potential of analogy extends across the entire conceptual structure of biology. Association methods similarly possess considerable potential for organizing biological knowledge into interconnected systems. Concept maps, semantic networks, keyword associations, classification schemes, visual organizers, question–answer relationships, and contextual examples can be used to establish connections among biological concepts. For instance, when studying biodiversity, learners can associate the central concept with species diversity, genetic diversity, ecosystem diversity, conservation, ecosystem stability, ecological services, and anthropogenic pressures. Such organization promotes the development of hierarchical and relational knowledge structures and enables students to understand not only what a concept means but also how it relates to other concepts. The methodological effectiveness of these approaches is further strengthened by the use of visual and multimedia resources. Biology is inherently visual, and many biological structures and processes can be represented through diagrams, models, animations, photographs, microscopic images, conceptual schemes, and simulations. Visual representations can serve as associative stimuli and as sources for constructing analogies. For example, an animation of membrane transport can be linked to the analogy of controlled passage through a selective barrier, while a diagram of the circulatory system can be associated with a transportation network. However, visual and analogical representations should remain scientifically accurate and pedagogically purposeful. Their role should be to facilitate conceptual understanding rather than to replace scientific explanation. The methodological application of association and analogy is also consistent with learner-centered approaches to biology education. Instead of receiving ready-made definitions, students can be encouraged to generate their own associations, formulate analogies, explain similarities and differences, construct conceptual maps, and justify their reasoning. Such activities transform students from passive recipients into active participants in the learning process. They

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also support higher-order cognitive skills, including analysis, comparison, synthesis, evaluation, and application. In this context, the teacher assumes the role of facilitator who guides students toward scientifically valid conceptual structures while allowing them to construct meaning through active cognitive engagement. Another important advantage of these methods is their potential contribution to interdisciplinary learning. Biological concepts frequently overlap with concepts from chemistry, physics, geography, mathematics, environmental science, and medicine. Association can help students connect biological knowledge with concepts acquired in other subjects, while analogy can provide a common cognitive framework for interpreting phenomena across disciplines. For instance, diffusion and osmosis can be connected with physical principles of particle movement; biochemical reactions can be related to chemical reaction mechanisms; population growth can be interpreted through mathematical models; and ecosystem processes can be connected with geographical and environmental concepts. Such interdisciplinary associations contribute to the formation of an integrated scientific worldview. Nevertheless, the use of association and analogy in biology teaching requires methodological planning. Not every association is pedagogically productive, and not every analogy accurately represents the target biological concept. Excessively simplified analogies may distort scientific meaning, while arbitrary associations may promote superficial memorization. Therefore, teachers should select associations and analogies according to the learning objectives, students' age and cognitive development, the complexity of the biological concept, and the level of prior knowledge. It is also essential to evaluate whether the selected analogy emphasizes the relevant structural or functional relationship and whether its limitations can be clearly communicated. From the perspective of assessment, association and analogy can also provide alternative mechanisms for evaluating conceptual understanding. Traditional assessments frequently focus on the reproduction of definitions, classifications, and factual information. In contrast, tasks based on association and analogy can reveal whether students understand relationships among concepts and whether they are capable of transferring knowledge

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to new contexts. Students may be asked to create an analogy for a biological process, explain the correspondence between two systems, identify the limitations of a given analogy, construct a concept map, or provide associations connecting a central concept with related biological processes. Such assessment approaches can provide more comprehensive information about the depth and organization of learners' conceptual knowledge. The development of digital technologies has expanded the methodological possibilities for implementing association and analogy in biology education. Interactive concept-mapping platforms, digital simulations, virtual laboratories, animated models, educational games, and artificial intelligence-supported learning environments can provide learners with opportunities to explore biological relationships dynamically. Digital environments can also enable students to manipulate representations, compare biological systems, generate conceptual networks, and receive immediate feedback.

Nevertheless, technology itself does not guarantee conceptual understanding. Its educational effectiveness depends on the pedagogical design of activities and the extent to which digital tools are integrated into meaningful conceptual learning processes. In contemporary biology education, the need to strengthen scientific literacy further increases the importance of these methodological approaches. Scientific literacy requires learners not only to remember biological facts but also to interpret evidence, establish relationships, explain phenomena, evaluate scientific claims, and apply knowledge to real-world problems. Association and analogy can contribute to these competencies by helping learners organize information, recognize relationships, construct explanatory models, and transfer knowledge between contexts. Consequently, their value extends beyond the acquisition of individual biological concepts and contributes to the broader development of scientific thinking. The methodological potential of association and analogy is particularly significant in addressing the problem of conceptual fragmentation. Students may successfully memorize individual definitions while failing to understand how those concepts interact within a biological system. Associative techniques can help connect individual

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concepts into coherent networks, while analogical reasoning can provide structural models through which relationships become more comprehensible. The combined use of these approaches therefore has the potential to promote deeper, more systematic, and more durable learning. In this regard, the study of the methodological possibilities of association and analogy in mastering biological concepts represents an important direction in the development of biology teaching methodology. The theoretical and practical analysis of these methods can contribute to the development of instructional strategies that correspond to the cognitive nature of biological knowledge and the contemporary requirements of learner-centered education. Their systematic application may facilitate conceptual comprehension, improve retention, support the correction of misconceptions, stimulate cognitive activity, and enhance students' ability to transfer biological knowledge to new situations. Therefore, the purpose of examining the methodological possibilities of association and analogy methods in the acquisition of biological concepts is to determine how these approaches can be systematically incorporated into biology instruction to improve conceptual understanding and cognitive activity. Particular attention should be paid to the principles of selecting and constructing appropriate associations and analogies, their application to abstract and complex biological concepts, their role in overcoming misconceptions, and their potential for developing comparison, generalization, analysis, synthesis, and knowledge-transfer skills. A methodologically grounded combination of association and analogy can consequently become an effective component of contemporary biology education, supporting the transition from reproductive learning toward meaningful, interconnected, and scientifically informed conceptual understanding.

Main part. The process of mastering biological concepts represents a complex cognitive and methodological task because biological knowledge is characterized by a high degree of abstraction, systematic organization, and interconnection among concepts. Unlike the simple memorization of isolated facts, genuine conceptual

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learning requires students to understand the structural, functional, causal, spatial, temporal, and evolutionary relationships that exist between biological phenomena. In this context, the association and analogy methods possess considerable methodological potential because they enable learners to establish meaningful connections between new knowledge and previously acquired information. Their effective application can contribute to the development of systematic biological thinking, facilitate the comprehension of abstract concepts, strengthen long-term retention, and promote the transfer of knowledge to new learning situations.

Association plays an important role in the formation and development of biological concepts because new information is more easily understood when it is connected with knowledge already present in the learner's cognitive structure. In biology lessons, students constantly encounter unfamiliar terms, structures, processes, and phenomena. If these elements are presented independently, students may attempt to memorize them mechanically without understanding their relationships. However, when a new concept is associated with a familiar object, phenomenon, characteristic, function, image, or previously learned concept, the learning process becomes more meaningful.

The methodological essence of association lies precisely in the creation of such cognitive connections. For example, when students study the concept of "mitochondrion", connecting it with cellular respiration and energy production provides a meaningful framework through which the structural and functional significance of the organelle can be understood. Similarly, the concept of "chloroplast" can be associated with photosynthesis, chlorophyll, light energy, and glucose formation. These associations allow learners to perceive biological concepts as interconnected components of a broader system rather than as isolated units of information [Marcos-Merino, Esteban Gallego, & Ochoa de Alda, 2021].

The significance of association is particularly evident in the teaching of biological terminology. Biology contains a large number of specialized terms, many of which originate from Greek and Latin and may initially be difficult for students to remember.

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Mechanical memorization of such terminology does not necessarily lead to conceptual understanding. Therefore, the teacher can establish semantic, functional, structural, and visual associations between terms and their meanings. When students associate the concept of “herbivore” with plant-based nutrition, “carnivore” with animal-based nutrition, and “omnivore” with both plant and animal food sources, the terminology becomes integrated into a meaningful conceptual network. In this way, association contributes not only to the retention of terminology but also to the understanding of the relationships underlying biological classification and ecological organization.

The effectiveness of association is also related to the activation of prior knowledge. Every learner enters the biology classroom with a certain amount of knowledge derived from previous lessons, everyday observations, personal experiences, and other subjects. This prior knowledge provides the cognitive basis upon which new concepts can be constructed. Consequently, before presenting a new topic, the teacher can activate students’ existing knowledge through questions, brainstorming, visual stimuli, examples, or short discussions. For instance, before introducing the concept of ecosystem, students may be asked what they associate with a forest, lake, desert, or agricultural landscape. Their responses may include plants, animals, water, soil, air, sunlight, microorganisms, temperature, and human activity. The teacher can subsequently organize these associations into the scientific concept of an ecosystem and demonstrate the relationships among biotic and abiotic components. Such an approach facilitates the gradual transition from everyday representations to scientifically structured knowledge.

Association can also contribute significantly to the formation of conceptual systems. Biological concepts are rarely independent; they are organized into hierarchies and networks. Understanding “ecosystem,” for example, requires knowledge of populations, communities, organisms, biotic and abiotic factors, trophic relationships, energy flow, nutrient cycling, and ecological interactions. If students learn these concepts separately, their knowledge may remain fragmented. Associative activities can connect these elements and demonstrate their mutual relationships.

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Concept maps, semantic networks, graphical organizers, keyword chains, and visual schemes can therefore be used as effective methodological tools. When students construct such networks themselves, they must determine which concepts are related and explain the nature of those relationships. This transforms learning from passive reception into active cognitive construction [Sezer & Karataş, 2022].

The analogy method provides another important methodological mechanism for facilitating the acquisition of biological concepts. Analogy is based on identifying relevant similarities between a familiar system and an unfamiliar biological structure, process, or relationship. Its educational value is particularly significant in biology because many biological phenomena occur at microscopic, molecular, or highly complex levels and cannot be directly observed. Students may find it difficult to construct mental representations of DNA replication, enzyme activity, membrane transport, genetic regulation, cellular signaling, or energy transformation solely through verbal explanations. Carefully selected analogies can provide cognitive models that make these processes more accessible.

One of the most useful applications of analogy can be observed in the teaching of cell biology. The cell may be conceptually compared with a highly organized system in which different components have specialized functions. The nucleus can be associated with the storage and regulation of genetic information, mitochondria with energy production, ribosomes with protein synthesis, and the cell membrane with selective control over the movement of substances. Such a comparison helps students understand that cellular structures are functionally differentiated but operate as parts of an integrated system. The analogy makes the relationships between structure and function more accessible and provides students with a mental framework for understanding cellular organization.

However, the pedagogical effectiveness of analogy depends on the teacher's ability to control its boundaries. An analogy is never an exact representation of the biological phenomenon being studied. It highlights selected similarities while ignoring other characteristics. If students interpret the analogy literally, misconceptions may

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arise. Therefore, after introducing an analogy, the teacher should explicitly discuss both similarities and differences. For example, when the cell is compared with an organized system, it should be emphasized that organelles do not consciously perform their functions and that cellular activity is determined by biochemical and molecular mechanisms. In this way, analogy serves as an introductory cognitive bridge rather than a replacement for scientific explanation.

A similar approach can be applied to the teaching of DNA and genetic information. DNA can be associated with an information-storage system because it contains hereditary information encoded in the sequence of nucleotides. Such an analogy may help students understand the concepts of information storage, replication, transmission, and expression. Nevertheless, students should also understand that biological information differs fundamentally from digital information and that DNA functions through complex molecular and biochemical interactions. Thus, the analogy provides an initial conceptual framework, while scientific explanation establishes the precise meaning of the biological process.

The teaching of membrane transport also provides significant opportunities for analogical reasoning. The movement of molecules across biological membranes is often difficult for students to visualize because the processes occur at a microscopic level. Diffusion can be explained through the familiar observation that particles tend to spread from areas of higher concentration toward areas of lower concentration. Osmosis can subsequently be represented through the movement of water across a selectively permeable barrier. Such analogies can help learners construct a mental representation of concentration gradients and selective permeability. However, these simplified representations must ultimately be connected with accurate biological explanations concerning molecular movement, membrane structure, concentration differences, and transport mechanisms.

The combined use of association and analogy is particularly effective because the two methods perform complementary cognitive functions. Association allows students to establish links between concepts, whereas analogy provides a model for

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understanding relationships between systems or processes. For example, in teaching cellular respiration, students can first establish associations among mitochondria, glucose, oxygen, ATP, carbon dioxide, and energy release. An analogy can then be used to represent cellular respiration as a controlled energy-conversion system. The associative component ensures that students understand the relevant terminology and relationships, while the analogy provides an integrated conceptual model. The teacher can subsequently return to the scientific description and clarify the biochemical stages of the process.

These methods are also highly relevant to the teaching of genetics. Genetics involves a complex conceptual hierarchy consisting of DNA, genes, alleles, chromosomes, genotype, phenotype, mutation, recombination, inheritance, and genetic variation. Students often experience difficulty distinguishing these concepts because they are closely related. Association can help establish their hierarchical relationships. DNA can be connected with genetic information, genes with functional units of hereditary information, chromosomes with organized genetic material, and alleles with alternative forms of genes. Once these associations are established, analogy can be used to illustrate hereditary information as a set of biological instructions transmitted between generations. The analogy can facilitate comprehension, while the teacher must ensure that students understand the molecular basis and limitations of the comparison. The analogy method is also valuable in explaining the processes of transcription and translation. Students may initially struggle to understand how information stored in DNA is converted into a functional protein. A carefully structured analogy can represent the process as the transfer and interpretation of information, where DNA represents a source of stored information, RNA acts as an intermediate carrier, and the ribosome functions as a molecular site where the information is interpreted to assemble amino acids into a protein. Such a model can make the sequence of events easier to understand. At the same time, the teacher should emphasize that the analogy represents functional correspondence rather than literal equivalence and should subsequently explain the actual molecular mechanisms.

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Association and analogy have equally important applications in ecology. Ecological concepts are highly interconnected and frequently require learners to understand relationships rather than individual objects. Concepts such as population, community, ecosystem, food chain, food web, trophic level, energy flow, nutrient cycling, ecological succession, biodiversity, ecosystem stability, and resilience cannot be fully understood independently. Associative learning can connect these concepts into a coherent system. When students study biodiversity, for example, the central concept can be associated with genetic diversity, species diversity, ecosystem diversity, conservation, ecosystem services, habitat loss, pollution, climate change, and ecological stability. Such associations help learners understand biodiversity as a multidimensional concept.

Analogy can further facilitate the understanding of ecological systems. A food web can be compared conceptually with an interconnected network rather than a simple linear chain. This comparison helps students understand that organisms can occupy different trophic relationships and that changes in one population may affect multiple other populations. Similarly, nutrient cycling can be compared with a continuous circulation system in which matter moves among organisms, soil, water, and the atmosphere. Energy flow, in contrast, can be conceptualized as a directional process. Such comparisons help students distinguish between the cycling of matter and the flow of energy, an important conceptual distinction in ecology.

The methods also possess considerable potential for teaching evolutionary biology. Evolutionary concepts are often misunderstood because students may interpret them through everyday ideas about intentional change. The concept of adaptation, for example, may be incorrectly understood as an individual organism consciously changing in response to environmental needs. Through association, the teacher can connect adaptation with variation, heredity, natural selection, differential reproductive success, and environmental conditions. Analogy can then be used to illustrate the process of selection through carefully controlled examples. The teacher should explicitly clarify that evolutionary change occurs at the population level over

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generations and is not the result of conscious intention.

One of the most important methodological possibilities of association and analogy is their role in overcoming misconceptions. Students often possess pre-existing explanations that differ from scientifically accepted concepts. These misconceptions may persist even after formal instruction if the new information is simply memorized rather than integrated into the existing conceptual structure. Associative tasks can help reveal students' initial ideas, while analogy can provide a framework for restructuring those ideas. For example, if students associate evolution primarily with individual transformation, the teacher can examine these associations and guide learners toward the scientifically correct understanding of population-level evolutionary change.

The diagnostic potential of associative activities is particularly important. When students are asked to write or verbally express the first concepts they associate with a biological term, teachers can identify gaps in knowledge and alternative conceptions. For example, students may associate "respiration" exclusively with breathing rather than with cellular energy metabolism. This response indicates that the learner may not clearly distinguish between respiratory gas exchange and cellular respiration. The teacher can use this information to establish new associations between oxygen consumption, glucose oxidation, ATP production, carbon dioxide formation, and cellular metabolic processes. Consequently, association functions not only as a teaching method but also as an assessment and diagnostic mechanism.

The active participation of students significantly increases the effectiveness of these approaches. Instead of receiving analogies prepared entirely by the teacher, students can be encouraged to construct their own analogies. They may be asked to explain what familiar system resembles a biological process and why. They should then identify the similarities, differences, and limitations of their proposed analogy. This activity develops analytical and evaluative thinking because students must distinguish relevant from superficial similarities. It also encourages them to communicate scientific ideas in their own words.

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Group work can provide an additional methodological dimension. Different groups of students can develop different analogies for the same biological concept and then compare their models. For instance, one group may represent the cell as an organization, another as a transportation system, and another as a technological network. Students can discuss which aspects of each analogy are useful and which may be misleading. Through such comparison, learners recognize that scientific models are selective representations and that different models may emphasize different characteristics of the same phenomenon.

Visual methods can further strengthen associative and analogical learning. Biology is a highly visual science, and students frequently require diagrams, photographs, microscopic images, animations, models, and conceptual schemes to understand complex structures and processes. Visual representations can become associative anchors that connect terminology with structural characteristics. Analogical diagrams can subsequently demonstrate functional relationships. For example, a diagram of the cell can be supplemented with a conceptual comparison showing the functional relationships among organelles. The important methodological principle is that visual representations should complement scientific explanation rather than replace it.

The integration of association and analogy with experimental and inquiry-based learning can further increase their educational value. Students may first observe a biological phenomenon through an experiment and then be asked to identify associations and construct an analogy explaining the observed result. For example, after observing osmosis in plant tissues, students can associate the observed changes with water movement, concentration differences, cell membranes, and turgor. They can then formulate an analogy to explain the process. In this case, direct observation provides empirical evidence, association organizes the observations conceptually, and analogy supports the construction of an explanatory model.

The methods can also contribute to interdisciplinary education. Biology is closely connected with chemistry, physics, mathematics, geography, environmental science,

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and medicine. Association can help students connect biological concepts with knowledge acquired in other subjects, while analogy can provide a common framework for interpreting related processes. Diffusion and osmosis can be associated with physical principles of particle movement; biochemical reactions can be connected with chemical processes; population growth can be interpreted using mathematical relationships; and ecosystem dynamics can be connected with geographical and environmental processes. Such interdisciplinary connections contribute to the formation of a more integrated scientific worldview.

The effectiveness of association and analogy also depends on the teacher's methodological competence. The teacher must consider the age, cognitive development, prior knowledge, interests, and learning difficulties of students when selecting examples and analogies. An analogy that is effective for university students may be inappropriate for younger learners. Similarly, a highly technical analogy may increase rather than reduce cognitive difficulty. Therefore, the teacher should select familiar and conceptually relevant domains and ensure that the analogy highlights the essential characteristics of the target biological concept.

Another important methodological condition is the gradual movement from familiar representation to scientific abstraction. Association and analogy should serve as transitional mechanisms. First, students encounter a familiar phenomenon or model; then they establish relationships with the new biological concept; subsequently, the teacher introduces the scientifically precise terminology and explanation. This sequence prevents students from remaining dependent on simplified representations and promotes the development of formal scientific understanding.

Assessment of biological conceptual learning should also incorporate association and analogy. Traditional assessment frequently emphasizes factual recall, definitions, classifications, and identification of structures. Although these forms remain useful, they do not always reveal the depth of conceptual understanding. Tasks requiring students to construct a concept map, develop an analogy, explain similarities and differences, or identify the limitations of a model can provide more comprehensive

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information about the organization of their knowledge. Such assessment can determine whether learners are capable of applying concepts rather than merely reproducing them.

A particularly effective methodological model involves several interconnected stages. Initially, the teacher activates students' prior knowledge through questions and associative tasks. The new biological concept is then introduced through observation, explanation, experiment, or visual representation. Students subsequently connect the new concept with previously learned concepts and construct an associative network. A suitable analogy is then introduced to clarify the structure or process. Students analyze similarities and differences between the familiar and biological systems, after which the teacher provides the scientifically precise explanation. Finally, learners apply the concept to a new situation and reflect on the learning process. Such a sequence transforms association and analogy into components of a systematic instructional strategy.

The combined application of these methods can produce important educational outcomes. Students may demonstrate improved comprehension of abstract concepts, stronger retention of terminology, greater ability to establish relationships among biological processes, and improved transfer of knowledge to unfamiliar situations. Furthermore, the methods can stimulate cognitive activity and support the development of analysis, comparison, classification, generalization, synthesis, evaluation, and scientific reasoning. These skills are particularly important for biology because biological phenomena are rarely understood through a single isolated fact; they require the integration of evidence and relationships across different levels of biological organization.

At the same time, the methodological use of association and analogy requires caution. Excessive simplification can result in scientific inaccuracies, while inappropriate analogies can generate new misconceptions. An analogy should therefore never be treated as an exact description of the biological phenomenon. Similarly, associations should be meaningful rather than arbitrary. The teacher should

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constantly evaluate whether a particular association or analogy contributes to the learning objective and whether students have correctly understood its scientific limitations.

Consequently, association and analogy can be regarded as complementary methodological instruments for improving the acquisition of biological concepts. Association facilitates the connection of new information with existing cognitive structures, while analogy provides a conceptual bridge between familiar experience and unfamiliar biological systems. When these methods are systematically integrated with observation, experimentation, visualization, discussion, conceptual mapping, problem solving, and assessment, they can contribute to deeper and more durable conceptual learning. Their educational value is particularly pronounced in the teaching of abstract and complex areas of biology, including cell biology, genetics, molecular biology, physiology, evolution, and ecology. A scientifically controlled and pedagogically purposeful application of these approaches can therefore support the transition from mechanical memorization toward meaningful conceptual understanding and the development of scientifically literate, analytically capable, and cognitively active learners.

Conclusion

The acquisition of biological concepts is a complex and multidimensional process that requires the effective organization of students' cognitive activity and the establishment of meaningful relationships between new and previously acquired knowledge. The analysis of the methodological possibilities of association and analogy demonstrates that these approaches can play an important role in improving the quality of biology education. Their educational significance is particularly evident in the teaching of abstract, complex, and interconnected biological concepts that cannot always be understood through direct observation or traditional verbal explanation alone. Association provides learners with opportunities to connect new biological

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information with existing knowledge, personal experiences, visual representations, previously learned concepts, and meaningful examples.

Through such connections, biological terminology and concepts become integrated into coherent cognitive structures rather than being memorized as isolated units. Associative activities can facilitate the understanding of relationships among biological structures, functions, processes, and phenomena and can consequently contribute to stronger retention and more meaningful learning. The use of concept maps, semantic networks, brainstorming, associative questions, visual schemes, and contextual examples further increases the methodological effectiveness of this approach. Analogy, in turn, provides an important cognitive bridge between familiar experiences and unfamiliar biological phenomena. Its particular value is associated with the explanation of microscopic, molecular, dynamic, and abstract processes that are difficult for learners to visualize directly. Carefully designed analogies can make concepts related to cell structure, genetic information, membrane transport, metabolism, ecological interactions, and evolutionary processes more accessible. At the same time, the analysis emphasizes that analogy should be used with methodological caution. Since an analogy represents only selected similarities between two systems, teachers must explicitly explain its limitations and distinguish the analogy from the scientifically precise description of the biological phenomenon. The combined use of association and analogy has greater methodological potential than the isolated application of either approach. Association activates and organizes learners' prior knowledge, whereas analogy provides a model through which new relationships can be interpreted. Their integration allows the teacher to move progressively from familiar experiences and concrete representations toward abstract scientific concepts. This process supports conceptual development and helps students understand not only the meaning of individual biological terms but also the structural and functional relationships connecting them. Another important conclusion is that association and analogy can contribute to the identification and correction of biological misconceptions. Students frequently approach biology lessons with incomplete or

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scientifically inaccurate explanations derived from everyday experience or previous learning. Associative tasks can reveal these initial conceptions, while carefully selected analogies can provide alternative cognitive frameworks for reconstructing them.

Therefore, these methods can serve simultaneously as instructional, diagnostic, and developmental tools. The methodological potential of association and analogy is also reflected in their contribution to higher-order cognitive skills. When students construct associations, compare biological systems, develop analogies, identify similarities and differences, evaluate the limitations of models, and apply concepts to unfamiliar situations, they engage in analysis, synthesis, comparison, generalization, evaluation, and knowledge transfer. Consequently, these methods extend the objectives of biology teaching beyond factual memorization and contribute to the development of scientific reasoning and biological literacy. The effectiveness of these methods ultimately depends on the teacher's methodological competence and the appropriateness of their application. Associations should be meaningful and scientifically relevant, while analogies should be selected according to students' developmental level, prior knowledge, and the specific characteristics of the biological concept being studied. Teachers should avoid excessive simplification and should always follow analogical explanations with scientifically accurate clarification. In this context, association and analogy should be viewed as supportive cognitive tools rather than substitutes for scientific explanation, experimentation, observation, or evidence-based reasoning.

Overall, the methodological application of association and analogy can significantly enrich contemporary biology education. Their systematic integration into learner-centered, inquiry-based, visual, experimental, and technology-supported teaching environments can facilitate conceptual understanding, strengthen knowledge retention, reduce conceptual fragmentation, support the correction of misconceptions, and improve students' ability to apply biological knowledge in new contexts.

Thus, association and analogy represent valuable methodological resources for transforming biology learning from predominantly reproductive memorization into a

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meaningful, interconnected, reflective, and scientifically oriented process. Their purposeful and scientifically controlled use can contribute to the development of learners who are capable not only of recalling biological concepts but also of understanding their relationships, explaining biological processes, constructing scientific models, and applying acquired knowledge to real-world biological and environmental problems.

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**FORMATION OF TOLERANCE AS A FACTOR IN THE SUCCESSFUL SOCIALIZATION
OF STUDENTS IN THE CONDITIONS OF INCLUSIVE EDUCATION**

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Abstract. Inclusive education in higher education has undergone a gradual and dynamic transformation, evolving from segregated approaches toward integration and, subsequently, comprehensive inclusion and equal participation. This study examines the major stages and dynamics of the development of inclusive education in higher education institutions, focusing on the factors that have shaped this transformation. Particular attention is given to changes in educational policies and legislation, institutional practices, accessibility, inclusive teaching approaches, teacher preparedness, assistive technologies, and student support services. The study also considers contemporary challenges that may hinder the effective implementation of inclusion, including institutional, financial, infrastructural, and attitudinal barriers.

The successful progression of inclusion requires sustained institutional commitment, effective policy implementation, professional development of academic staff, and collaboration among policymakers, university administrators, educators, and students. The study concludes that understanding the historical stages and contemporary dynamics of inclusive education is essential for developing accessible, equitable, and sustainable higher education systems that respond to the diverse needs of all students.

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Introduction

Modern inclusive education aims to ensure equal access to education and create conditions for the successful socialization of all students. In practice, coeducation of children with different abilities can be accompanied by certain psychological and social difficulties. Children may not always understand the behavioral or developmental characteristics of their classmates, may feel awkward when interacting, may be cautious, or, conversely, may withdraw from a child who is different from the majority. One of the most important factors for effective interaction in an inclusive educational environment is tolerance, which promotes respect for individual differences, reduces social distance, and fosters a positive psychological climate. Research into the development of tolerance has important theoretical and practical significance, as it allows us to identify the pedagogical and psychological conditions for the successful socialization of students. In modern society, increasing attention is being paid to creating conditions for the coeducation and development of children with diverse educational needs. Inclusive education involves not only providing children with the opportunity to study in a regular school, but also creating an environment in which every student feels accepted and a significant participant in the educational process.

Main part. The modern world is living and developing at an increasingly rapid pace, subjecting everyone to a kind of “natural selection” based on quality and quantity. Regardless of how numerous we are, we are all influenced by the realities and demands of contemporary society in every sphere of life. Every person is unique:

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we differ not only in appearance and character, but also in our abilities, needs, pace of learning, capacity to perceive information, and potential for self-realization.

It is precisely this diversity that creates different levels of individual needs and requires the development of conditions in which everyone can realize their potential. In the field of education, this approach is embodied in the concept of inclusive education, which is based on recognizing the value of every child and their right to quality education regardless of individual characteristics, health status, or educational needs. In other words, this reflects the ongoing process of democratization of education. Inclusion as a principle of the democratization of contemporary society has been addressed in the works of V. Wocken, A. Gintz, T. Furiyeva, A. Arbek, M. Brodbork, A. Medvedova, and many others.

To this day, the issue of inclusion remains highly relevant. On the contrary, increasing efforts are being made to create optimal conditions for the socialization of every member of society. This process is based on the Convention on the Rights of the Child, adopted by United Nations General Assembly Resolution 44/25 on November 20, 1989; the United Nations Convention on the Rights of Persons with Disabilities, adopted by the United Nations General Assembly on December 13, 2006, which establishes provisions concerning inclusive education; as well as the Salamanca Statement and Framework for Action on Special Needs Education (Salamanca, Spain, June 7–10, 1994).

The fundamental principle underlying the aforementioned international legal instruments is the recognition and affirmation of the right of individuals with special educational needs to access education in mainstream schools. The inclusion of children with developmental disabilities and special educational needs into the educational and social environment of their typically developing peers has significant axiological

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implications. Since childhood is “the period of the most intensive and effective human development” [Смирнова К., 2008], the integration of children with special needs into the community of mainstream schoolchildren is of particular importance for their education and upbringing. In this context, the concept of “inclusion” becomes increasingly significant. It has come to be used as a synonym for “integration,” or the two concepts are used together as “inclusion/integration” [Фуряева Т., 2025]. In other words, inclusion refers to the “incorporation” of individual elements into a common process; within the context of the present study, this means creating appropriate conditions for students with special needs and abilities.

Eight principles of inclusive education have been identified:

1. The value of a person does not depend on their abilities or achievements.
2. Every person is capable of feeling and thinking.
3. Every person has the right to communicate and to be heard.
4. All people need one another.
5. Genuine education can only take place within the context of real interpersonal relationships.
6. All people need support and friendship from their peers.
7. For all learners, progress is more likely to be achieved through what they can do rather than by focusing on what they cannot do.
8. Diversity enriches all aspects of human life [12].

The main idea underlying the principles of inclusive education is that successful learning is possible only through meaningful interpersonal interaction. “Inclusive education is the provision of equal access to education for all learners, taking into account the diversity of educational needs and individual abilities” [13]. The humanistic foundation of inclusive education is based on the unconditional value of

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every individual, the right to communication, and the importance of social relationships. According to T. Furiayeva, “the lifeworld of a person in a special life situation represents a world of ‘another cultural form.’ It is characterized by atypical means of communication, spatial confinement, and limited access to broader cultural communication” [Фуряева Т., 2026].

Inclusive education is a process associated “with specific transformations of the living environment of children with disabilities in various educational institutions” [Inclusive Education, 2016], while the practice of integrated education is based on “the idea of accepting the individuality of each learner and, consequently, education should be organized in such a way as to meet the special needs of every child” [Inclusive Education, 2016].

In classrooms where typically developing students and children with special abilities and educational needs study together, a distinctive psychological environment emerges. This situation should be considered from two perspectives.

The first perspective: How may typically developing children perceive children with disabilities?

At the beginning of the educational process, their attitudes may be ambiguous. Some children may experience interest, curiosity, or uncertainty, especially if they have not previously interacted with children with developmental or physical disabilities. A child may ask direct questions or pay particular attention to differences in behavior or appearance.

Students may demonstrate different reactions. Some may express a desire to help and provide support, while communication may be accompanied by caution or fear of doing something wrong. Others may distance themselves because of a lack of understanding. Teasing, rejection, and other negative reactions may also occur.

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The nature of these reactions depends on such factors as the children's age, level of upbringing and social development, family environment, and the teacher's attitude and position.

The second perspective: How may a child with a disability feel in a mainstream school?

For a child with a disability, entering a mainstream school can be emotionally challenging. The child may experience anxiety, insecurity, fear of rejection, or fear of becoming the target of ridicule. The situation can be particularly difficult when the child feels different from their classmates and is unable to perform certain tasks or participate in activities on an equal basis with their peers.

The child may have thoughts such as: "Will they accept me?", "Will they be able to become friends with me?", "Will they make fun of me?"

If the child receives support from teachers, psychologists, parents, and classmates, they can gradually develop a sense of belonging, self-confidence, independence, and positive self-esteem. The opportunity to make friends, study, and play together with other children helps the child perceive themselves not solely through the lens of disability, but primarily as a full participant in school life.

When a teacher explains to students that all people are different but equally valuable, a more natural and positive attitude gradually develops.

When an inclusive classroom is properly organized, typically developing students also have the opportunity to develop tolerance, empathy, cooperation skills, and acceptance of individual differences.

Under these circumstances, the main psychological task of an inclusive school is not merely to bring children together physically in the same classroom, but to create conditions for their psychological acceptance of one another.

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It is particularly important that a child with a disability should not be perceived exclusively as “different” or as someone who “needs help,” but rather as a full member of the school community. At the same time, typically developing students need guidance in understanding the characteristics of their classmate and learning to interact with them without pity or excessive overprotection. Successful inclusion occurs when differences between children are perceived not as barriers to communication but as a natural part of human diversity.

Simply being physically present in a group is not sufficient. If a child does not have the opportunity to participate in joint activities, their presence in a mainstream educational institution may not result in genuine social integration.

In classrooms where typically developing children and children with physical and developmental differences study together, a distinctive children's subculture emerges - a “meaningful space of values, attitudes, modes of activity, and forms of communication implemented in children's communities within a particular historical and social context of development” [Мардахаев Л., 2025]. The principal connecting mechanism of integration within such student communities is tolerance, understood as “acceptance of other people's opinions, beliefs, ideas, and behavior” [Dictionary of Terms in General and Social Pedagogy, 2006].

An atmosphere of tolerance in contemporary inclusive education has its own axiological significance. The purposeful efforts of teachers, parents, and students play a key role in developing tolerance in educational institutions. Tolerance in an inclusive environment should not remain merely passive acceptance of the “other” or “others”; rather, it should develop into an active recognition of the rights of every member of the community.

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The formation of tolerance involves several key components, including breaking down stereotypes, developing empathy, mutual assistance, and dialogue. The teacher plays a particularly important role in fostering tolerance among students. Their personal example of treating everyone equally and respectfully becomes a fundamental model for all members of the classroom community. In other words, the teacher should create a comfortable and tolerant environment for every participant in the educational process.

The question of the influence of the environment on personality development has deep theoretical foundations. Psychology has made numerous attempts to overcome one-sided explanations of psychological development based exclusively on hereditary factors. In particular, W. Stern proposed the theory of the convergence of two factors, according to which development is determined by the interaction between internal predispositions and external conditions [8].

According to this approach, hereditary predispositions determine certain developmental possibilities; however, appropriate conditions are necessary for these possibilities to be realized. Education, upbringing, and the surrounding environment create a space in which a child's potential can develop.

In the context of inclusive education, this principle acquires particular significance. A child's individual characteristics should not be regarded as an absolute limit to their development. On the contrary, a properly organized educational and social environment can expand the child's opportunities for participation in various forms of activity.

“Children's predispositions merely indicate future possibilities, providing a certain range within which education and the environment operate, determining actual development” [Урунтаева Г., 2013].

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Within an inclusive educational environment, particular importance should be given to methods that create an atmosphere of cooperation and mutual support. These may include joint projects and team-based learning activities, in which every student makes a meaningful contribution; games and class discussions that model real-life situations; film screenings; dramatizations; “kindness” lessons; and participation in social and charitable initiatives.

Art therapy also plays an important role in the educational process. Its main functions include the cathartic function (cleansing and liberation from negative emotional states); the regulatory function (reducing psychological tension, regulating psychosomatic processes, and modeling a positive psycho-emotional state); and the communicative-reflective function (addressing communication difficulties, developing appropriate interpersonal behavior, and supporting healthy self-esteem) [8].

Under these conditions, the influence of the environment on adaptation and personality development as a full participant in the educational process - including learning, play, and communication - becomes particularly important. Therefore, the teacher's task is not limited to identifying the individual characteristics of a learner; it also involves creating conditions in which these characteristics do not become a cause of social isolation.

The formation of tolerance in inclusive education is both a pedagogical task and a key factor in the successful socialization of all categories of students.

Thus, the formation of tolerance in inclusive education should be viewed not merely as a pedagogical task, but as a key factor and catalyst for the successful socialization of all learners. An inclusive environment creates a unique space for the natural dismantling of social stereotypes, the development of empathy, and the acquisition of skills for constructive intercultural and interpersonal dialogue.

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The study allows us to conclude that this process cannot be spontaneous and requires a systematic approach. Successful socialization can only be achieved when the principles of tolerance permeate all levels of the educational process: from joint project-based activities in the classroom to the active involvement of parents and continuous psychological support for teachers. The implementation of inclusion, supported by purposeful development of a culture of respect for diversity, makes it possible to foster a mature and adaptive individual who is prepared for full participation in contemporary society. Ultimately, the humanization of the school within an inclusive approach lays the foundation for building an inclusive society in which the value of every individual is recognized as unconditional.

The very concept of “tolerance” holds significant importance in nature and society. It makes it possible for different species, conditions, perspectives, and beliefs to co-exist. Tolerance is an essential prerequisite for establishing channels of communication and fostering development. Where tolerance and acceptance of another person’s identity and individual characteristics are absent, there is no room for cooperation or development.

Conclusion

In educational institutions with an inclusive orientation, tolerance is an essential condition and quality underlying coexistence and dialogue.

Tolerance is particularly important in the educational environment, where the fundamental patterns of human behavior and communication are formed. It is during childhood that ideas about tolerance, fairness, respect, mutual assistance, and acceptance of others begin to develop. By interacting with classmates who differ from

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them in their abilities, appearance, character, or behavioral characteristics, children learn to understand that differences are a natural part of human society.

The development of tolerance contributes to the formation of a humane society in which diversity is perceived not as an obstacle, but as a natural and meaningful part of shared life. In this sense, fostering tolerance at school contributes not only to the successful socialization of the child but also to the development of a more equitable and inclusive society.

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