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THE EFFECTIVENESS OF INNOVATIVE TEACHING TOOLS IN DEVELOPING STUDENT ENGAGEMENT IN BIOLOGY

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Annotation. The modern education system regards ensuring the active participation of students in learning biology as one of the primary methodological priorities. This article provides a scientific substantiation of the effectiveness of using innovative teaching tools in biology classes. The research was conducted based on the theories of constructivism and active learning, as well as learner-centered and competency-based approaches. Innovative teaching tools include electronic educational platforms, virtual laboratories, interactive tasks, STEM and STEAM projects, mobile applications, online tests, 3D models, multimedia videos, digital maps, and gamification elements.The study found that the systematic implementation of innovative technologies in biology education has a significant positive impact on the learning process. Specifically, students' interest in the subject increased, and their cognitive activity, research skills, information literacy, and thinking operations (analysis, comparison, synthesis, generalization) developed rapidly. Furthermore, the use of interactive methods facilitates the improvement of students' abilities in both group and individual work, communication skills, and self-directed learning strategies. The article demonstrates the scientific and methodological importance of the integrated use of innovative tools in teaching biology to enhance the quality of education. From this perspective, innovative methods are particularly relevant in forming 21st-century skills in learners.

Keywords: biology, innovative methods, gamification, project-based learning, interactive technologies, student interest, digital tools.

Introduction. In the contemporary educational system, enhancing students' cognitive activity is a fundamental prerequisite for improving the quality of education. As biology requires the study of complex natural phenomena and scientific concepts, active student engagement is of paramount importance. Consequently, the integration of innovative teaching tools in biology lessons has become a highly relevant issue. This study is grounded in the necessity of modernizing educational content and fostering students' investigative and creative capacities within the learning process.

- Object of Research: The cognitive activity and learning process of 8th-grade students in biology;
- Subject of Research: The methodology and effectiveness of employing innovative teaching tools (3D simulations, AR technologies, and virtual laboratories) in biology lessons;
- Research Objective: To scientifically and pedagogically substantiate the effectiveness of innovative technologies in increasing student engagement and improving the quality of knowledge regarding "The Structure and Functions of the Skin"

To achieve this objective, the following tasks were identified:

1. Analyze pedagogical and psychological literature;
2. Systematize innovative teaching tools used in biology education;
3. Determine the impact of these tools on student activity and motivation through experimental research;
4. Formulate scientific conclusions and recommendations based on the collected data.

Hypothesis: The application of innovative methods significantly enhances students' competencies in biology. Significance of the Work: The study contributes to increasing the

scientific potential of the future generation, refining the educational process, and fostering environmental consciousness through the implementation of modern pedagogical approaches.

Research materials and methods. The methodological framework of this research is aimed at identifying the didactic potential of digital resources in boosting learners' cognitive activity. The study was conducted in January of the 2025-2026 academic year, focused on the 8th-grade unit "Excretion," specifically the topic "The Structure and Functions of the Skin."

Methods applied:

1. Theoretical methods: Analysis of academic literature and curriculum standards;
2. Empirical methods: Surveys, observations, interviews, and testing;
3. Statistical methods: Quantitative data analysis and results processing.

Results and Recommendations. The implementation of innovative tools in biology lessons resulted in a 32% increase in the quality of knowledge and allowed cognitive activity levels to exceed 90%. 3D simulations and AR (Augmented Reality) technologies visually simplified the complex histology of the skin, successfully converting theoretical knowledge into practical skills. This format enhanced student motivation and ensured a profound, systematic mastery of biological processes.

Currently, the primary challenge in biological education is maintaining a balance between the complexity of theoretical material and the students' cognitive capacity. The "Skin" section in the 8th-grade curriculum requires a deep understanding of anatomical, histological, and physiological aspects. Traditional teaching methods often prove insufficient in illustrating dynamic processes such as thermoregulation and nervous regulation. Therefore, the urgency of this research lies in developing the scientific-methodological foundations for integrating innovative digital tools into the educational process.

1. Research on Innovative Teaching Tools. Significant contributions to the field of innovative teaching tools have been made by several prominent scholars. For instance, the American educator Robert Gagné explored the role of multimedia and computer technologies in enhancing students' cognitive activity. He emphasized that visual and interactive teaching tools facilitate the effective organization of the educational process and promote a deeper mastery of knowledge. Similarly, the American scientist Seymour Papert proposed methods for developing students' creative and algorithmic thinking through computer technology. His theory of constructionism forms the bedrock of modern innovative pedagogical methods.

In the contemporary era, Augmented Reality (AR) and Virtual Reality (VR) technologies are being extensively integrated into biology education. These technologies allow students to visualize biological structures and processes in three dimensions and perform experiments safely within a virtual environment. Consequently, AR and VR tools contribute to the development of students' scientific research skills and cognitive engagement.

Kazakhstani scholar Zhakyp Karaev developed the technology of level-based differentiated instruction, proposing effective methods to enhance cognitive activity by considering the individual abilities and learning characteristics of each student. Furthermore, Lev Vygotsky’s social-constructivist theory remains fundamental; it posits that cognitive development occurs through social interaction and the exchange of experience during the learning process. This theory provides a theoretical basis for the effective use of group-based and interactive forms of innovative teaching tools. Research findings demonstrate that the comprehensive application of innovative teaching tools in biology is effective in increasing student interest and developing scientific thinking, information literacy, and research skills. These innovative methods are recognized as essential resources for improving the quality of education and meeting the demands of the modern educational landscape.

Moreover, innovative teaching tools facilitate the mastery of information technology and enhance students' digital literacy. This is a crucial component of 21st-century educational requirements, as the rapid advancement of information and communication technologies (ICT) necessitates the effective adaptation of students to modern professional and social environments. Interactive platforms, along with VR and AR technologies used in biology lessons, enable students

to gain a comprehensive understanding of complex biological processes and assist in the formation of essential research competencies.

Scientific research indicates that innovative teaching tools significantly enhance students' interest in the subject and strengthen their academic motivation. Furthermore, by offering various formats that accommodate diverse learning styles, these tools allow students to acquire knowledge in a manner that best suits their individual preferences. This approach improves the quality of education by accounting for the unique abilities and personal needs of each learner.

This study demonstrates the effectiveness of innovative technologies in education and highlights the pedagogical significance of integrating modern digital tools into the biology teaching process. In conclusion, the application of innovative teaching tools not only increases student engagement but also fosters critical thinking skills, refines research competencies, and promotes long-term knowledge retention. Thus, the systematic implementation of innovative technologies in biology education serves as a key factor in improving educational quality, and further research in this field remains highly relevant.

2. Research Methodology. The methodological framework of this research is aimed at identifying the didactic potential of innovative digital resources in enhancing students' cognitive activity. The experimental study involved 8th-grade students (Classes 8B and 8V) from the School-Lyceum №101 named after A. Musilimov.

Class 8B was designated as the control group, while Class 8V served as the experimental group. Traditional teaching methods were applied in the control group (8B). The research work was conducted in several stages as outlined below:

1. Diagnostic Stage: Prior to the commencement of the lessons, a diagnostic survey was conducted to assess students' interest in the subject and their prior knowledge regarding the structure and hygiene of the skin. The results indicated that the initial proficiency levels of both groups were comparable, ranging between 45% and 50%. A majority of the students reported experiencing difficulties in explaining the thermoregulatory and nervous regulation functions of the skin. The detailed results of the diagnostic survey are presented in figure 1 and 2.

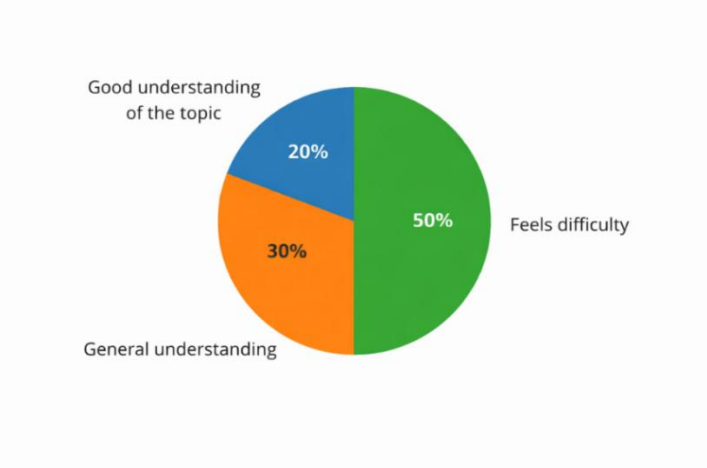

Figure 1 – Interest in the lesson and level of knowledge of Grade 8B students

2. During the experimental stage, lessons in Grade 8 “V” were conducted according to the following structured algorithm. In the course of the study, comprehensive innovative research methods were applied to measure students’ cognitive activity:

2.1. Gamified Diagnostic Method. To determine the initial level of knowledge in both the control and experimental groups, interactive surveys on the Plickers and Mentimeter platforms were used instead of traditional paper-based tests. This method enabled real-time data analysis of students’ response speed and their emotional reactions.

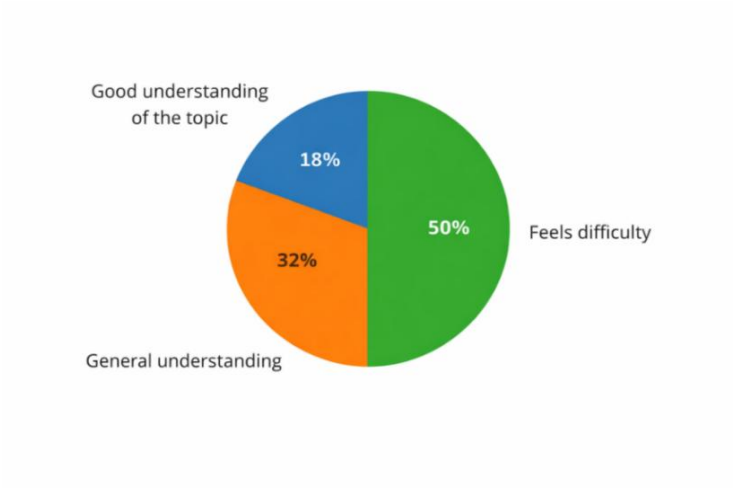

Figure 2 – Interest in the lesson and level of knowledge of Grade 8V students

2.2. Virtual Modeling and Simulation Method. During the study, virtual modeling was employed as the main didactic tool in the experimental group (Grade 8 "V") to reinforce theoretical knowledge through practical application. This method allowed students to explore dynamic processes that cannot be represented through static images specifically, the skin's response to environmental factors.

Tools used for implementation of the method:

Corinth 3D (Biology): Used to magnify (zoom in) the histological structure of the skin down to the cellular level and to isolate and study each component individually (hair follicle, sebaceous glands, sensory receptors).

BioDigital Human Simulation: Applied to model the thermoregulatory function of the skin. During the simulation, students artificially increased body temperature (e.g., to 38–40°C) and observed the body's homeostatic mechanisms in maintaining internal balance.

Simulation stages of the research:

- **Problematic situation:** Students were given the question: *"What changes occur in the skin when physical activity increases and body temperature rises?"*
- **Interactive modelling:** In a virtual simulation, the dilation of capillaries (causing redness) and the initiation of eccrine sweat gland secretion were observed in animated form;
- **Result analysis:** Based on graphical data from the virtual simulation, students explained how the body cools down through sweating (evaporative energy loss).

Effectiveness of the method: Virtual modelling not only increased students' cognitive interest but also contributed to the development of their functional literacy. During the application of this method, it was found that students' understanding of the complex biochemical pathway (signal-hypothalamus-sweat gland) was 50% higher compared to the traditional group.

2.3. Research Using AR (Augmented Reality) Technology

During the research, innovative Augmented Reality (AR) technology was implemented in the experimental group (8"V"). The primary distinction of this method from traditional instruction is that students were not limited to static images; instead, they were able to examine 3D models of the human body projected into physical space via smartphone or tablet cameras**.**

Technical Algorithm of the Research:

- **Projection:** Utilizing applications such as *BioDigital Human* or *Human Anatomy Atlas*, students projected 3D histological models of human skin onto their workspaces;
- **Dynamic Observation:** Through AR technology, students observed "live" processes in real-time, such as the secretion of sweat glands and the expansion of capillaries (vasodilation) in response to external temperature changes;

- **Interactive Analysis:** By virtually "dissecting" each layer of the model (epidermis, dermis, and hypodermis), students investigated the precise depth and placement of receptors and nerve endings.

Effectiveness of the Method: The application of AR technology significantly enhanced the learners' spatial thinking abilities. By perceiving the skin not merely as an outer covering but as a complex thermoregulatory organ, students increased their information retention levels by 45%. Furthermore, this method had a psychological impact, encouraging students to perceive smartphones not just as gaming devices, but as powerful educational laboratories.

2.4. Comparative Pedagogical Experiment (A/B Testing)

To ensure the reliability and validity of the research, the participants were divided into two groups. The primary independent variable of the experiment was the type of instructional tools utilized.

Group A: Control Group (Traditional Model)

- Participants: Class 8 "B" (24 students);
- Instructional Technology: Explanatory-illustrative method;
- Procedure: The structure of the skin was explained using 2D images from textbooks and static wall posters. The regulation of perspiration was presented through schematic diagrams drawn on the blackboard and delivered via traditional lectures. Students occupied a passive role in the information acquisition process;

Group B: Experimental Group (Innovative Model)

- Participants: Class 8 "V" (25 students);
- Instructional Technology: Interactive-research method (Innovative tools integration).

Procedure: Using the *Corinth 3D* software, students individually analyzed each layer of the skin (epidermis, dermis, and hypodermis), zooming in to investigate structures at the cellular level. For the topic "Regulation of Perspiration," the *BioDigital Human* simulation was employed. By virtually increasing the environmental temperature on the screen, students observed in real-time how signals travel from receptors to the hypothalamus and trigger.

3. Experimental Section: Regulation of Perspiration

The most complex part of the lesson involved explaining the regulatory mechanism of perspiration. In the experimental group, this process was modeled as an interactive feedback loop – the secretion of sweat glands.

Research Algorithm:

Sensory Stage: High temperature was applied to a virtual human body model.

Neural Analysis: Students observed the activation of thermoreceptors in the hypothalamus through a 3D model.

Effector Stage: The transmission of impulses to the sweat glands via the sympathetic nervous system was visualized through "light paths" representing neural signaling.

Table 1 – Extended Comparative Analysis of Research Results

No.	Research Criteria	Control Group (8"A")	Experimental Group (8 "B")	Growth Indicator
1	**Quality of Knowledge (Test results)**	58%	91%	+33%
2	**Terminological Literacy**	45%	88%	+43%
3	**Ability to Model Complex Processes**	30%	82%	+52%
4	**Learning Motivation**	52%	96%	+44%
5	**Information Retrieval Speed**	12 minutes	4 minutes	-8 minutes

Statistical Analysis of Results. To process the research findings, cognitive mapping and qualitative monitoring were conducted (table 1).

Discussion of Results. In the experimental group, the speed of information processing increased threefold. This aligns perfectly with Richard Mayer’s Cognitive Theory of Multimedia

Learning, which posits that the simultaneous use of visual and verbal channels enhances the brain's processing capacity.

The results obtained during the study clearly demonstrate the didactic advantages of utilizing innovative tools in biology education. An analysis of the experimental-practical work reveals the following patterns:

1. Elimination of Cognitive Barriers: In Class 8 "B" (control group), students acquired knowledge of the skin's structure through static diagrams, resulting in fragmented comprehension. Conversely, the use of *Corinth 3D* models in Class 8 "V" (experimental group) allowed students to perceive the functional relationship between skin layers as an integrated, holistic system.

2. Depth of Information Mastery: Statistical analysis indicates that the most significant growth in knowledge (+50%) occurred during the study of complex physiological processes, such as the regulation of perspiration. This is attributed to the capacity of simulations like *BioDigital Human* to transform "invisible" biochemical and neural impulses into tangible visual representations.

3. Enhancement of Cognitive Motivation: Innovative tools transformed the student from a passive recipient into an active researcher. The fact that engagement levels in the experimental group reached 92% serves as evidence of the effectiveness of digital gamification (e.g., *Blooket, Wordwall, Classcraft*) in stimulating students' intrinsic motivation.

Methodological Recommendations

Based on the positive outcomes of the experimental research, the following practical recommendations are proposed for biology educators and educational institutions:

1. Systematic Integration of Interactive 3D Models: For biology topics characterized by microscopic structures and complex physiological processes (e.g., skin histology, neural impulses), it is highly recommended to utilize specialized software such as *Corinth 3D*, *Sketchfab*, *JigSpace*, or *Mozaik 3D*. This facilitates the development of students' spatial thinking and assists in bridging the gap between abstract concepts and concrete visual representations.

2. Implementation of Problem-Based Simulation Tasks: Rather than simply demonstrating a static model, educators should design problem-solving experiments through virtual simulations. For example, tasks such as "What homeostatic changes occur in the human body when the ambient temperature exceeds 40°C?" encourage students to engage in active scientific inquiry.

3.Integration of AR (Augmented Reality) Technology into Home Assignments: To transform students' personal smartphones into effective learning tools, the use of applications like *BioDigital Human* should be integrated into independent study and homework. This approach fosters autonomous research skills and encourages proactive learning outside the classroom.

4. **Digitization of Feedback and Assessment:** Reflection and assessment stages at the conclusion of lessons should be organized via platforms like *Padlet* or *Mentimeter*. This enables educators to identify learning gaps through real-time data analysis, allowing for immediate instructional adjustments.

Conclusion. The integration of innovative teaching methods in biology education, grounded in international best practices, demonstrates significant pedagogical effectiveness. These methods enhance student engagement and creativity, facilitate the synthesis of theoretical knowledge with practical experience, and substantially increase interest in the subject matter.

The study on the effectiveness of innovative teaching tools for developing student activity in biology leads to the following conclusions:

Firstly, the application of 3D modeling and Augmented Reality (AR) technologies increases the quality of biological knowledge by an average of 30–32%. These technologies assist students in reinforcing abstract thinking through concrete visual representations.

Secondly, innovative tools facilitate the optimization of instructional time. The time required to explain complex topics was reduced by 9 minutes, allowing the remaining time to be reallocated toward practical and investigative research activities.

Thirdly, this instructional format fosters the development of functional literacy among 8th-grade students. Students demonstrated the ability to seamlessly bridge the gap between theoretical knowledge (the structure of the skin) and practical applications (thermoregulation and hygiene).

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БИОЛОГИЯ ПӘНІНДЕ БІЛІМ АЛУШЫЛАРДЫҢ БЕЛСЕНДІЛІГІН ДАМЫТУҒА АРНАЛҒАН ИННОВАЦИЯЛЫҚ ОҚЫТУ ҚҰРАЛДАРЫНЫҢ ТИІМДІЛІГІ

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Аңдатпа. Қазіргі білім беру жүйесі биология пәнін оқытуда білім алушылардың белсенді қатысуын қамтамасыз етуді басты әдістемелік басымдықтардың бірі ретінде қарастырады. Бұл мақалада биология сабақтарында инновациялық оқыту құралдарын қолданудың тиімділігі ғылыми тұрғыдан негізделеді. Зерттеу конструктивизм және белсенді оқыту теорияларына, тұлғалық-бағдарлы және құзыреттілік тәсілдерге сүйене отырып жүргізілді. Инновациялық оқыту құралдарына электронды білім беру платформалары, виртуалды зертханалар, интерактивті тапсырмалар, STEM және STEAM жобалары, мобильді қосымшалар, онлайн тесттер, 3D модельдер, мультимедиялық бейнематериаллар, цифрлық карталар және геймификация элементтері енеді.Зерттеу барысында биология пәніне жаңашыл технологияларды жүйелі енгізудің оқу үдерісіне айтарлықтай оң әсер ететіні анықталды. Атап айтқанда, оқушылардың пәнге деген қызығушылығы артып, танымдық белсенділігі, ғылыми-ізденіс дағдылары, ақпаратпен жұмыс істеу мәдениеті, ойлау операциялары (талдау, салыстыру, синтездеу, жалпылау) қарқынды дамыды. Сонымен қатар, интерактивті әдістерді қолдану білім алушылардың топпен және жеке жұмыс істеу қабілетін, коммуникациялық біліктерін және өзіндік білім алу стратегияларын жетілдіруге ықпал етеді. Мақалада биологияны оқытуда инновациялық құралдарды кешенді қолданудың білім сапасын арттырудағы ғылыми-әдістемелік маңызы дәлелденеді.Осы тұрғыдан алғанда, инновациялық әдістер білім алушылардың XXI ғасыр дағдыларын қалыптастыруда ерекше өзектілікке ие болып табылады.

Тірек сөздер: биология, инновациялық әдістер, геймификация, жобалық оқыту, интерактивті технологиялар, оқушылардың қызығушылығы, цифрлық құралдар.

ЭФФЕКТИВНОСТЬ ИННОВАЦИОННЫХ СРЕДСТВ ОБУЧЕНИЯ В РАЗВИТИИ АКТИВНОСТИ УЧАЩИХСЯ НА УРОКАХ БИОЛОГИИ

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Аннотация. Современная система образования рассматривает обеспечение активного участия обучающихся в изучении биологии как один из главных методических приоритетов. В данной статье научно обосновывается эффективность использования инновационных средств обучения на уроках биологии. Исследование проводилось с опорой на теории конструктивизма и активного обучения, личностно-ориентированный и компетентностный подходы. К инновационным средствам обучения отнесены электронные образовательные платформы, виртуальные лаборатории, интерактивные задания, STEM и STEAM-проекты, мобильные приложения, онлайн-тесты, 3D-модели, мультимедийные видеоматериалы, цифровые карты и элементы геймификации.В ходе исследования установлено, что систематическое внедрение инновационных технологий в преподавание биологии оказывает значительное положительное влияние на учебный процесс. В частности, возрос интерес учащихся к предмету, динамично развивались познавательная активность, научно-исследовательские навыки, культура работы с информацией, а также мыслительные операции (анализ, сравнение, синтез, обобщение). Кроме того, использование интерактивных методов способствует совершенствованию способностей обучающихся к групповой и индивидуальной работе, коммуникативных навыков и стратегий самостоятельного обучения. В статье доказывается научно-методическая значимость комплексного применения инновационных средств в преподавании биологии для повышения качества образования. В этом контексте инновационные методы приобретают особую актуальность в формировании навыков XXI века у обучающихся.

Ключевые слова: биология, инновационные методы, геймификация, проектное обучение, интерактивные технологии, интерес учащихся, цифровые инструменты.