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FORMATION OF PROFESSIONAL COMPETENCE OF FUTURE BIOLOGY TEACHERS BASED ON THE "FLIPPED CLASSROOM" TECHNOLOGY

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Abstract. The article examines the pedagogical potential of the "flipped classroom" technology in developing the professional competence of future biology teachers. The relevance of the study is determined by the transition of modern education toward digital formats, the expansion of blended learning, and the growing requirements for the quality of teacher training. Under conditions of digitalization, the need to develop a comprehensive set of competencies among future biology teachers increases significantly, including subject knowledge, methodological skills, digital literacy, and research abilities. The flipped classroom approach is considered as an innovative tool enabling an effective combination of independent study of theoretical materials with active practical work in the classroom. The purpose of the research is to substantiate the effectiveness of the flipped classroom technology in forming professional competencies of future biology teachers and to analyze the dynamics of changes in students' learning activities. The methodological framework includes an experimental study involving biology students, as well as methods

of pedagogical observation, diagnostic testing, questionnaires, and comparative analysis. The findings indicate a significant increase in all types of professional competencies among students in the experimental group compared to the control group. A marked improvement was observed in students' independence, research activity, ability to formulate questions, participation in discussions, and the use of digital tools. The data demonstrate that the flipped classroom model transforms the nature of learning activities, stimulating the development of critical thinking, reflection, and practice-oriented skills. The practical significance of the study lies in the development of a competence model for future biology teachers adapted to the flipped classroom environment, as well as methodological recommendations for its implementation in higher pedagogical education. The results can be applied in teacher training programs, academic courses, digital platforms, and professional development institutions.

Keywords: flipped classroom, professional competence, future biology teacher, digital literacy, active learning, pedagogical experiment, methodological training

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«ТӨҢКЕРІЛГЕН СЫНЫП» ТЕХНОЛОГИЯСЫ НЕГІЗІНДЕ БОЛАШАҚ БИОЛОГИЯ МҰҒАЛІМІНІҢ КӘСІБИ ҚҰЗЫРЕТТІЛІГІН ҚАЛЫПТАСТЫРУ

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Аннотация. Мақалада болашақ биология мұғалімдерінің кәсіби құзыреттілігін дамытуда «төңкерілген сынып» технологиясының педагогикалық мүмкіндіктері зерттеледі. Зерттеудің өзектілігі білім берудің цифрлық формат-

тарға көшуімен, аралас оқытудың кеңеюімен және педагог кадрларын даярлау сапасына қойылатын талаптардың артуымен айқындалады. Цифрландыру жағдайында болашақ биология мұғалімдерінде пәндік дайындықты, әдіс-темелік дағдыларды, цифрлық сауаттылықты және зерттеушілік қабілеттерді қамтитын құзыреттер кешенін қалыптастыру қажеттілігі күшейе түсуде. «Төңкерілген сынып» технологиясы теориялық материалды студенттердің өз бетімен меңгеруін аудиториядағы белсенді практикалық жұмыс түрлерімен тиімді ұштастыратын инновациялық құрал ретінде қарастырылады. Зерттеудің мақсаты – «төңкерілген сынып» технологиясының болашақ биология мұғалімдерінің кәсіби құзыреттерін қалыптастырудағы тиімділігін дәлелдеу және студенттердің оқу іс-әрекеті динамикасын талдау. Әдіснамалық негізін биология мамандығы студенттерімен жүргізілген эксперимент, педагогикалық бақылау, диагностикалық тестілеу, сауалнама және салыстырмалы талдау әдістері құрайды. Зерттеу нәтижелері эксперименттік топ студенттерінің барлық негізгі кәсіби құзыреттерінің бақылау тобына қарағанда айтарлықтай артқанын көрсетті. Студенттердің өзіндік жұмыс деңгейі, зерттеушілік белсенділігі, сұрақ қою қабілеті, пікірталастарға қатысуы және цифрлық құралдарды қолдануы едәуір жақсарды. Бұл технология оқу әрекетінің сипатын өзгертіп, сыни ойлауды, рефлексияны және тәжірибеге бағытталған дағдыларды дамытуға ықпал ететінін дәлелдейді. Зерттеудің практикалық маңызы – «төңкерілген сынып» жағдайына бейімделген болашақ биология мұғалімдерінің құзыреттілік моделін және оны жоғары педагогикалық білім беру жүйесінде қолдануға арналған әдістемелік ұсынымдарды әзірлеу. Алынған нәтижелер мұғалім даярлау бағдарламаларында, оқу курстарында, цифрлық білім беру платформаларында және біліктілікті арттыру орталық-тарында пайдаланылуы мүмкін.

Түйін сөздер: төңкерілген сынып, кәсіби құзыреттілік, болашақ биология мұғалімі, цифрлық сауаттылық, белсенді оқыту, педагогикалық эксперимент, әдістемелік дайындық

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ФОРМИРОВАНИЕ ПРОФЕССИОНАЛЬНОЙ КОМПЕТЕНТНОСТИ БУДУЩИХ УЧИТЕЛЕЙ БИОЛОГИИ НА ОСНОВЕ ТЕХНОЛОГИИ «ПЕРЕВЕРНУТЫЙ КЛАСС»

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Аннотация. Статья посвящена исследованию педагогических возможностей технологии «перевернутый класс» в развитии профессиональной компетентности будущих учителей биологии. Актуальность работы определяется переходом современного образования к цифровым форматам, внедрением смешанного обучения и усиливающимися требованиями к качеству подготовки педагогических кадров. В условиях цифровизации значительно возрастает необходимость формирования у будущих учителей биологии комплекса компетенций, включающих предметную подготовку, методические умения, цифровую грамотность и навыки исследовательской деятельности. Технология «перевернутый класс» рассматривается как инновационный инструмент, позволяющий эффективно сочетать самостоятельное изучение теоретического материала с активной практической работой в аудитории. Цель исследования заключается в обосновании эффективности технологии «перевернутый класс» в формировании профессиональных компетенций будущих учителей биологии и анализе динамики изменений учебной деятельности студентов. Методология основания включает экспериментальную работу с участием студентов биологических специальностей, а также методы педагогического наблюдения, диагностического тестирования, анкетирования и сравнительного анализа. Полученные результаты свидетельствуют о значительном росте всех видов профессиональных компетенций у студентов экспериментальной группы по сравнению с контрольной. Зафиксировано существенное увеличение уровня самостоятельности, исследовательской активности, способности формулировать вопросы, участия в обсуждениях и использования цифровых инструментов. Данные демонстрируют, что технология «перевернутый класс» изменяет характер учебной деятельности, стимулирует развитие критического мышления, рефлексии и практико-ориентированных навыков. Практическая значимость исследования заключается в разработке модели компетентности будущего учителя биологии, адаптированной к условиям технологии «перевернутый класс», а также методических рекомендаций по её внедрению в систему высшего педагогического образования. Результаты могут быть использованы в программах подготовки учителей, учебных курсах, цифровых платформах и учреждениях повышения квалификации.

Ключевые слова. перевернутый класс, профессиональная компетентность, будущий учитель биологии, цифровая грамотность, активное обучение, педагогический эксперимент, методическая подготовка

Introduction. Modern education is undergoing a period of profound transformation driven by the integration of digital technologies, changes in the ways information is accessed, and the increasing demands placed on the professional preparation of teaching staff. In the context of digitalization and the transition to blended and interactive learning formats, the need to develop competencies in future biology teachers becomes especially important. These competencies must enable them to effectively organize the educational process, foster learner autonomy, develop research skills, and maintain a high level of motivation toward studying the subject. One of the most effective pedagogical technologies that meets these requirements is the flipped classroom model.

The flipped classroom involves a redistribution of the traditional structure of a lesson: theoretical material is studied by students in advance through online resources, while classroom time is dedicated to practical activities, analysis, problem-solving, laboratory investigations, and reflection. This approach shifts the focus from passive knowledge reception to active, independent, and collaborative learning, aligning with contemporary constructivist and competency-based pedagogical frameworks.

In the preparation of future biology teachers, the application of the flipped classroom model is particularly significant. Biology as an academic discipline integrates fundamental scientific knowledge, research methods, and practical skills that require a high degree of engagement, autonomy, and critical analysis. Therefore, traditional teaching formats often prove insufficient for developing professional competencies that include subject knowledge, methodological flexibility, digital literacy, the ability to organize students' research activities, and the application of modern educational technologies.

A number of studies indicate that the flipped classroom enhances students' learning autonomy, improves the assimilation of complex biological concepts, contributes to the development of critical thinking and collaborative skills, and strengthens the digital competencies of future teachers (Bishop and Verleger, 2013; Tucker, 2016). At the same time, the effective implementation of this technology requires a well-designed methodology, careful selection of digital resources, appropriate structuring of the learning process, and consideration of individual learner characteristics.

Despite the growing interest in the flipped classroom model, the question of how effectively this technology contributes to the formation of professional competence in future biology teachers remains insufficiently studied in Kazakhstani pedagogical practice. Particularly relevant is the investigation of methodological conditions, success factors, opportunities, and limitations associated with applying this technology in the university-level teacher education system.

In this regard, the aim of this study is to analyze the pedagogical potential of the flipped classroom in shaping the professional competence of future biology teachers, to identify its advantages, methodological possibilities, and the conditions necessary for its effective implementation in higher education.

Literature Review. The problem of developing the professional competence

of future biology teachers is examined in modern pedagogical science within the framework of educational digitalization, the integration of active learning methods, and the implementation of innovative technologies. In recent years, the flipped classroom model has become an object of extensive investigation in both international and domestic literature, as it aligns with the principles of competency-based learning and ensures a high level of student engagement.

The flipped classroom is commonly defined as a pedagogical model in which the core component of theoretical instruction is shifted outside the classroom, while face-to-face time is devoted to interactive learning activities (Bishop and Verleger, 2013). This approach integrates elements of online learning with active, problem-based student engagement (Bishop and Verleger, 2013).

The model is also associated with personalized learning, increased learner autonomy, and the opportunity for students to work at an individual pace (Bergmann and Sams, 2012; Tucker, 2016). Evidence suggests that the flipped format supports the development of critical thinking, collaboration, and independent analysis of instructional material (Bergmann and Sams, 2012; Tucker, 2016). In higher education, the flipped classroom is regarded as an effective instrument for developing the professional competencies of future educators and improving the quality of student–teacher interaction (Chen et al., 2017; O'Flaherty and Phillips, 2015). Research further indicates that the model improves student preparedness for practical sessions and facilitates the integration of digital tools into the learning process (Chen et al., 2017; O'Flaherty and Phillips, 2015).

Studies focusing on natural science teacher education highlight that the flipped model deepens students' understanding of complex biological concepts by combining independent pre-class study with hands-on practical activities (McLaughlin et al., 2014; Seery, 2015). As biology is inherently practice-oriented and research-driven, the implementation of interactive learning formats such as the flipped classroom supports the acquisition of laboratory techniques, data analysis skills, research competencies, and collaborative practices (McLaughlin et al., 2014; Seery, 2015). From the standpoint of professional teacher competence formation, the flipped classroom fosters methodological flexibility, digital literacy, communication skills, readiness to apply modern educational technologies, and the ability to organize collaborative learning (Lo and Hew, 2017; Missildine et al., 2013). These outcomes are also linked to the development of the 21st-century skills (Lo and Hew, 2017; Missildine et al., 2013).

Domestic researchers likewise emphasize the pedagogical potential of the flipped classroom, noting increased independent cognitive activity, enhanced learning motivation, improved content mastery, and strengthened student research skills (Abdullina, 2021; Sarsekeeva, 2022; Toleubekova, 2020). Particular emphasis is placed on the role of digital platforms and multimedia resources that ensure accessibility and variability of learning materials (Abdullina, 2021; Sarsekeeva, 2022; Toleubekova, 2020). In the context of preparing future biology teachers, the literature underscores the need to shift from traditional lecture-based and reproductive teaching methods toward interactive instructional models, which

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is especially important for developing competencies related to laboratory work, field research, and the use of digital technologies (Klymkiv et al., 2022; Savinainen et al., 2018). Empirical findings indicate that the flipped classroom can enhance students' readiness for practical professional activity and strengthen their ability to apply biological knowledge in real educational settings (Klymkiv et al., 2022; Savinainen et al., 2018).

Overall, the literature suggests that the flipped classroom is an effective pedagogical model with substantial potential for fostering the professional competence of future biology teachers, contributing to learner autonomy, critical and research thinking, digital literacy, pedagogical flexibility, and the organization of interactive learning environments (Bergmann and Sams, 2012; Lo and Hew, 2017; Tucker, 2016). At the same time, the methodological conditions and success factors for implementing the flipped classroom in Kazakhstani higher pedagogical education remain insufficiently explored and require further scientific analysis and practical validation (Abdullina, 2021; Toleubekova, 2020).

Research Methodology. The methodological foundation of the study is based on the integration of the competency-based, systemic, activity-oriented, and digital approaches, which together ensure a holistic examination of the process of developing the professional competence of future biology teachers within the implementation of the flipped classroom model. The competency-based approach makes it possible to determine the structure and content of the professional skills required of a future educator, while the activity-oriented and constructivist approaches conceptualize learning as an active process of knowledge construction grounded in students' independent work. The systemic approach provides the framework for modeling the educational process, in which goals, digital learning tools, forms of interaction, and assessment mechanisms are interconnected, and the principles of digital pedagogy justify the selection of interactive and multimedia resources.

The study employed a combination of theoretical and empirical methods aimed at analyzing the pedagogical conditions that ensure the effectiveness of the flipped classroom model in preparing future biology teachers. The theoretical component included an analysis of scientific literature and contemporary models of digital and blended learning, which allowed for the identification of key criteria of professional competence. The empirical component consisted of student questionnaires, observations of learning activities, diagnostics of subject-specific, methodological, and digital competencies, as well as expert evaluation of instructional materials and the developed model of flipped classroom implementation.

The pedagogical experiment was conducted under natural university learning conditions and consisted of three stages: the diagnostic (pre-experimental), formative, and control stages. At the diagnostic stage, the initial level of student preparedness and their attitudes toward digital learning were identified. The formative stage involved the direct implementation of the flipped classroom model, in which out-of-class independent study of video lectures, digital interactive materials, and virtual laboratories was combined with in-class activities focused

on solving biological problems, performing practical and research tasks, and developing analytical and argumentative skills. The control stage aimed to assess the dynamics of professional competence development and determine the overall effectiveness of the methodology.

Data analysis included both quantitative and qualitative methods. Statistical processing of the results made it possible to determine the significance of differences between the experimental and control groups, while qualitative analysis of observations and expert evaluations provided deeper insights into changes in students' learning behaviors. The study was conducted at the South Kazakhstan Pedagogical University named after Özbekali Zhanibekov and Abai Kazakh National Pedagogical University, which ensured sample representativeness and comparability of the obtained data. The reliability and validity of the findings were confirmed through methodological triangulation, the use of validated diagnostic tools, and expert verification of the study's content.

Results. The results of the study demonstrate that the flipped classroom model has a statistically significant impact on the formation of professional competence among future biology teachers. At different stages of the experiment, notable changes were identified in students' subject preparation, methodological skills, digital literacy, and research abilities. A comparative analysis of the control and experimental groups revealed a stable positive dynamic, confirming the effectiveness of blended and interactive learning technologies.

To evaluate the outcomes, a system of competence indicators was used, comprising four components: subject competence (SC), methodological competence (MC), digital competence (DC), and research competence (RC). The results of the formative stage of the experiment are presented below.

To assess the effectiveness of the implemented flipped classroom technology, a comparative diagnostic evaluation of the professional competence levels of students in the control and experimental groups was conducted. Measurements were carried out across four key components - subject, methodological, digital, and research competence - which represent the fundamental indicators of the readiness of future biology teachers for professional activity. Initial measurements were taken before the start of the pedagogical experiment, and repeated assessments were conducted after the completion of the instructional cycle. The collected data made it possible to trace the dynamics of competence development and to identify differences in educational outcomes between students taught using traditional methods and those instructed through the flipped classroom model. The summary of results is presented in Table 1.

Table 1 – Average Competence Indicators of Students in the Control and Experimental Groups (0–100 points)

Indicator	Control Group (before)	Experimental Group (before)	Control Group (after)	Experimental Group (after)
Subject Competence (SC)	56	55	59	74
Methodological Competence (MC)	48	47	52	79

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Digital Competence (DC)	41	42	50	83
Research Competence (RC)	45	44	53	77

The data presented in Table 1 reflect the dynamics of the formation of key professional competencies among future biology teachers in the control and experimental groups before and after the implementation of the flipped classroom technology. The indicators demonstrate substantial differences between the groups, allowing us to assert the high effectiveness of the chosen instructional model.

1. Subject Competence (SC). Before the experiment, the levels of subject competence in both groups were nearly identical: 56 points in the control group and 55 points in the experimental group. After completing the course that employed the flipped classroom model, the increase in the control group was minimal-only 3 points (from 56 to 59).

In contrast, the experimental group showed a significant improvement-from 55 to 74 points, an increase of 19 points. This indicates that preliminary independent study combined with interactive in-class work enhanced the depth of students' understanding of biological processes and terminology.

2. Methodological Competence (MC). Methodological competence is one of the key indicators for future teachers, as it reflects their mastery of teaching methods, instructional strategies, and pedagogical technologies.

In the control group, the indicator increased from 48 to 52 points (+4), which corresponds to a typical progression under traditional instruction. The experimental group, however, demonstrated a dramatic increase-from 47 to 79 points (+32). This represents the highest gain among all competencies. The result is explained by the fact that the flipped classroom creates conditions for the practical application of methodological techniques: working in small groups, analyzing video fragments of lessons, solving pedagogical tasks, and developing reflection skills.

3. Digital Competence (DC). Digital skills improved in both groups; however, the dynamics differ fundamentally.

The control group showed an increase from 41 to 50 points (+9), which reflects students' general rise in digital activity throughout the course.

The experimental group demonstrated a gain of +41 points-from 42 to 83. This is the most striking result. The flipped classroom model requires constant use of online platforms, digital simulations, virtual laboratories, and interactive assessments, which fosters strong digital competence among future biology teachers.

4. Research Competence (RC). Before the experiment, the levels were nearly the same - 45 and 44 points. The control group demonstrated a moderate improvement to 53 points (+8).

In the experimental group, the increase reached +33 points-from 44 to 77. This is explained by the inclusion of mini-research projects, data collection and analysis, preparation of presentations, and analytical reports within the flipped classroom model, all of which promote the development of research thinking, planning skills, and the interpretation of biological data.

Summary of Findings Across the Four Competence Components:

− The control group demonstrates moderate gains in competence within the range of 3–9 points, which corresponds to typical learning dynamics under the traditional model.

− The experimental group shows remarkable results: gains range from +23 to +41 points, with the highest values recorded for digital and methodological competence.

− The implementation of the flipped classroom technology had a complex positive effect on students' professional development, particularly in components related to practical activity and active engagement in the educational environment.

− The observed difference between the groups is both statistically and pedagogically significant, confirming the effectiveness of the innovative technology as a tool for developing the professional competence of future biology teachers.

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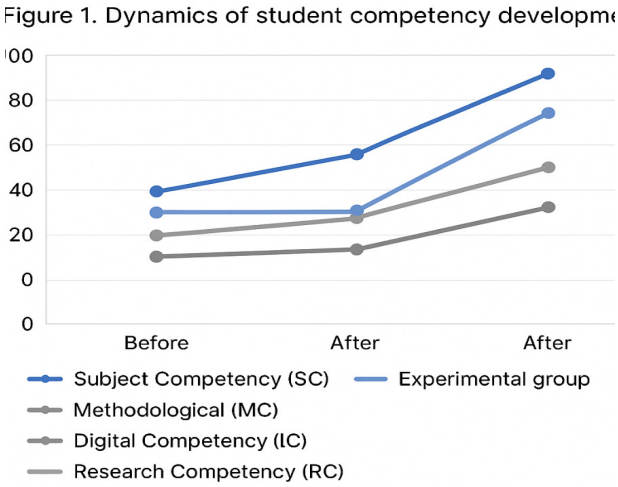

Figure 1 - (Description): Dynamics of Competency Development

The presented graph illustrates the comparative dynamics of four key professional competencies-subject-matter, methodological, digital, and research - in the control and experimental groups before and after the pedagogical intervention. The lines corresponding to the experimental group demonstrate a pronounced increase across all indicators, with the most substantial positive changes observed in digital competence (DC) and methodological competence (MC). Following the implementation of the "flipped classroom" technology, the level of digital competence increased from 42 to 83 points, and methodological competence from 47 to 79 points, indicating a significant strengthening of students' practice-oriented and technological skills.

In the control group, the growth of indicators is moderate and does not exceed 4–8 points, which confirms the limited effectiveness of traditional teaching methods in developing integrated professional competencies. A visual comparison

of the curves on the graph reveals a substantial gap between the groups after the intervention, supporting the conclusion that the "flipped classroom" approach is highly effective in the professional preparation of future biology teachers.

Beyond the quantitative changes, the experiment revealed a profound transformation in the nature of students' learning activities. Students became more active in classroom interactions, formulating questions, initiating discussions, and exploring alternative solutions to biological problems. The sessions also showed a stronger project-based and practice-oriented focus, with increased attention to laboratory work, modeling of biological processes, and analysis of biological systems. Particular attention was devoted to examining students' digital skills. The results demonstrated that students showed confident proficiency in platforms such as Moodle, Google Classroom, Kahoot, and PhET, as well as in virtual laboratory environments. This expanded their understanding of modern tools for teaching biology and increased their readiness for digital pedagogical practice.

To gain a more detailed understanding of how the "flipped classroom" approach influences not only the level of competency formation but also the nature of students' learning activities, systematic pedagogical observations were conducted in both groups. The purpose of the observation was to identify changes in cognitive engagement, independence, levels of interaction, and students' participation in practical and research-oriented tasks. The collected data made it possible to record qualitative shifts in learning activity triggered by the new instructional model. A summary of the observation results is presented in Table 2.

Table 2 – Changes in the Nature of Students' Learning Activities (Based on Observations, % of Total Number of Students)

Activity Indicator	Before the Experiment	After the Experiment
Active participation in discussions	28%	71%
Formulation of questions	22%	68%
Conducting mini-research projects	19%	64%
Use of digital tools	31%	89%
Demonstration of independence	34%	74%

Analysis of the data presented in Table 2 allows us to conclude that students' learning activity increased substantially following the implementation of the "flipped classroom" approach. Almost all indicators show more than a twofold increase in student participation, initiative, and autonomy.

First, communicative activity increased markedly: the proportion of students actively participating in discussions rose from 28% to 71%, indicating higher engagement and the development of academic discourse skills. Second, the ability to formulate questions increased from 22% to 68%, reflecting growth in critical thinking, analytical reasoning, and the capacity to pose research-oriented tasks. Third, the share of students conducting mini-research projects increased from 19% to 64%. This demonstrates that the "flipped classroom" approach effectively supports the development of research skills and practice-oriented thinking. Fourth,

a particularly significant improvement is observed in digital activity: the use of digital tools increased from 31% to 89%. This result confirms that the instructional model successfully integrates digital technologies into the educational process and enhances the digital competence of future biologists.

Fifth, the proportion of students demonstrating independence increased from 34% to 74%, suggesting the formation of sustained academic motivation, self-organization skills, and responsibility for personal learning outcomes. Overall, the observational data clearly demonstrate the effectiveness of the "flipped classroom" approach: it not only strengthens students' cognitive engagement but also fosters the development of key professional competencies essential for future biology teachers in the context of educational digitalization.

In addition, instructors participating in the study noted several positive developments:

– Students became more motivated, showing increased readiness for independent preparation.

– Skills in analyzing biological data improved considerably, especially when working with virtual laboratories.

– Students demonstrated greater confidence during practical tasks, explanations, and presentations.

– Collaborative skills strengthened, as a significant portion of in-class time was devoted to group activities.

– The student cohort gradually shifted from passive listeners to active participants in the learning process, which is a key requirement of contemporary biology education.

Discussion. The obtained data allow us to consider the "flipped classroom" approach as an effective tool for modernizing biology education, enabling a shift from a traditional reproductive model of instruction toward an activity-based, learner-centered paradigm. Importantly, the effectiveness of this approach manifests not only in the growth of individual competencies but also in the transformation of the very logic of pedagogical interaction between instructors and students.

A key effect is the transformation of the student's role: learners become not objects but active subjects of the educational process. This aligns with contemporary concepts in higher education pedagogy, which emphasize autonomy, research orientation, and the ability to work with information. Within the context of preparing future biology teachers, such a transformation is particularly significant, as it develops students' ability to organize similar learning processes in their own professional practice. Furthermore, the use of the flipped classroom shifts the emphasis from transmitting ready-made knowledge to developing meta-subject skills-critical analysis, question formulation, use of digital resources, and organization of mini-research projects. These activities represent core elements of the competency-based model of the 21st-century educator. Thus, the flipped classroom serves not only as a teaching method, but also as a mechanism for shaping the modern professional identity of future teachers.

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It is also important that the approach strengthens the practice-oriented component of teacher training. Students gain opportunities to apply knowledge in situations closely approximating real pedagogical practice: analyzing biological processes, conducting mini-research projects, and interpreting data. This fosters a stable connection between theory and practice, significantly enhancing the overall quality of professional preparation. Special attention should be given to the integration of digital tools into students' learning activities. The development of digital competence reflects global trends in the digitalization of education and corresponds to the demands of contemporary instructional practice, in which biology increasingly relies on digital simulations, databases, visualizations, and multimedia laboratories.

Finally, the observed dynamics indicate that the flipped classroom approach exerts an integrative influence: it simultaneously stimulates learning activity, enhances motivation, supports the development of research-oriented approaches, and increases readiness for independent learning. Such a multifaceted effect makes this technology a promising direction in the development of teacher education and confirms the necessity of its further implementation and methodological refinement.

Conclusion. The conducted study has established that the "flipped classroom" approach serves as an effective tool for modernizing the professional preparation of future biology teachers. Its use transforms not only the organization of the educational process but also the very logic of competency formation, shifting the focus from reproductive assimilation of material to active, independent, and meaningful engagement with learning content.

One of the key outcomes of the study is the confirmation that the flipped classroom creates favorable conditions for the sustained development of professionally significant competencies. Under this approach, the learning environment becomes more flexible, variable, and student-centered, which contributes to the development of skills in analysis, interpretation, digital literacy, pedagogical reflection, and research initiative. This learning format enables students to construct individual learning trajectories and adjust their working pace according to their own capabilities.

The obtained data show that the use of the flipped classroom transforms the role of the student: they become not passive participants but active agents of the educational process, capable of independently organizing their activities, formulating questions, searching for information, and applying knowledge in practical situations. This aligns with contemporary requirements for teacher education, where not only subject knowledge but also the ability to work in a digital environment, collaborate, make decisions, and engage in scientific-pedagogical inquiry is crucial.

It is also important to note the positive influence of the approach on the pedagogical readiness of future biology teachers. Mastering instruction in the flipped format provides students with experience relevant to modern school practice, where increasing demands are placed on teacher flexibility, the integration

of in-person and distance learning formats, the use of digital resources, and the design of active learning strategies.

Thus, we may conclude that the "flipped classroom" approach has the potential to become a sustainable and integral component of biology teacher preparation, ensuring the development of key competencies necessary for successful professional activity in the context of the digital transformation of education.

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