The Effectiveness of Using Mobile Technologies in the Formation of Professional Competencies of Biology Teachers

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Manuscript received April 15, 2025; revised May 9, 2025; accepted June 23, 2025; published October 21, 2025

***Abstract*—Today, the problem of improving the methodology for using mobile technologies in the educational process is relevant. The article outlines the methodological possibilities of using mobile technologies to form the professional competencies of future teachers and provides practical evidence of their effectiveness. The training process of future biology teachers has been chosen as the research object. The research aims to identify the potential applications of mobile technologies in the professional training of biology specialists within the framework of integrating the national education system into the global educational environment. This integration will enhance the mobility and competitiveness of future specialists. The article examines research on implementing mobile technologies in education. Based on mobile technology applications, a structural and content model for forming the professional competencies of future biology teachers is developed, describing its content, procedural, and diagnostic components. To comprehensively assess the role of mobile technology in education, a questionnaire survey was conducted, followed by mathematical processing of the results among biology students.**

***Keywords*—higher education, learning process, future teacher, professional competence, competence components, mobile technologies, professional activity**

I. Introduction

In the context of the rapid development of digital technologies and the transformation of the educational environment, the issue of improving the professional competence of teachers, including biology teachers, is becoming especially relevant. Modern requirements for the educational process of pedagogy provide not only subject training but also the development of a wide range of digital tools that facilitate their effective operation. In this context, mobile technologies are considered one of the key means of ensuring continuous professional growth, improving the quality of education and creating individualized development trajectories for teachers.

Despite the high potential value of mobile technologies, their integration into teacher education practices remains fragmented. Research shows that the level of use of mobile resources in teaching activities is often superficial: they are used primarily as auxiliary tools, rather than as full-fledged components of professional development. One of the reasons for this situation is the lack of clearly formulated methodological approaches aimed at the systematic implementation of mobile technologies in the processes of developing professional competencies. In addition, problems of digital inequality, differences in technical equipment and access to resources persist, which are especially acute in schools located in rural or remote areas.

At the same time, existing studies pay insufficient attention to the pedagogical potential of mobile technologies in the context of the professional development of biology teachers, a subject that requires the use of visual, laboratory and modeling tools. While digital platforms, mobile applications, and online laboratories have the potential to significantly expand the possibilities of teaching biology, there is a lack of empirical evidence of their effectiveness in developing teachers' subject-methodological and digital competencies.

Thus, there is a need for scientific analysis and evaluation of the effectiveness of using mobile technologies in the professional development of biology teachers, considering the specifics of the subject, the requirements of educational standards and the conditions of the modern school. This study aims to fill this gap, substantiate the feasibility, and develop recommendations for the effective use of mobile tools in the system of improving the professional competence of teachers of the biological profile.

II. Literature Review

Modern society places new demands on the training of teaching staff, including biology teachers, placing emphasis on the development of their quantitative and professional competencies. In this regard, the role of mobile technologies as a tool for increasing the effectiveness of the learning process is growing.

The theoretical basis of the study is a set of scientific approaches that explain the mechanisms of influence of digital and mobile technologies on the professional development of teachers. Let us consider the main scientific theories underlying this study.

- Constructivist Approach to Learning

The foundations of constructivist pedagogy were laid by Piaget [1], Vygotsky [2], and Bruner [3]. The essence of constructivism is that knowledge is not transferred passively but is actively formed in the process of interaction with the environment.

In the context of mobile learning, biology teachers can use technologies such as interactive applications, augmented reality elements and digital modeling to create problem

situations and organize independent search for solutions. This contributes to the development of critical thinking and practice-oriented competencies.

- Sociocultural Theory of L. S. Vygotsky [4]

Vygotsky [4] emphasized the importance of the social environment in the learning process and introduced the concept of the zone of proximal development. Mobile technologies, such as collaborative learning platforms and educational communities, expand the possibilities of social interaction and mentoring.

This is especially relevant when organizing methodological support and continuous professional development of teachers.

- The Concept of Pedagogical Content Knowledge

According to him, the effectiveness of teaching depends on the teacher's ability to combine subject knowledge with teaching methods and technological tools.

Mobile technologies serve as a connecting element of this integration. A biology teacher with skills in working with mobile digital resources can adapt the learning process to meet the specific needs of students and the modern digital context.

- Mobile Learning Theory (H. Crompton) [5]

According to mobile learnin g theory, the effective use of mobile technologies depends on the interaction of three components: technological (devices), pedagogical (the user), and contextual (the learning environment and conditions).

In the training of biology teachers, mobile learning technologies enable them to be flexible, quickly adapt to changes, use micro-lessons, conduct mobile testing, access virtual laboratories and, use interactive maps.

- Cognitive Load Theory (J. Sweller) [6]

According to the cognitive load theory, the efficiency of information acquisition depends on the structure and method of its presentation.

Mobile technologies allow you to optimize cognitive load through visualization, multimedia, step-by-step instructions, and feedback. This is especially important when studying complex biological processes such as cell division, photosynthesis, or genetic mechanisms.

When analyzing the experience of using mobile technologies in modern education, consider first the work aimed at the formation and development of professional competencies of future teachers. Since a competent approach to determining the content and results of professional training of modern teachers requires revision of the established approaches to both the content and organisation of the educational process, its scientific and methodological support. The development of professional competencies of future teachers is a multifaceted process widely covered in the scientific literature.

Nowadays, a certain base of scientific practices has been accumulated in understanding the meaning of this category. One of the prominent experts in the field, Kulheimer [7] investigates the importance of teachers' professional competence in rationally explaining complex concepts during instruction. This study contributes to a better understanding of the strategies and knowledge needed to develop the professional competencies of future educators. Marushko [8] considers ways of developing and determining the effectiveness of the model of development of professional competencies of future teachers.

One of the directions of reforming the modern education system in the process of transformation is to improve the level of teachers' professional competencies, their knowledge, qualifications, and skills. Chernysh *et al.* [9] studied the methods of forming professional competencies of future teachers in the conditions of transformation processes in education and applied the following scientific methods. In particular,theoretical and methodological aspects of developing professional competencies of teachers by methods of theoretical analysis and description;and the development of professional competencies of teachers in Canada and Ukraine using methods of grouping, comparison and synthesis. Mareike *et al.* [10] explores pedagogical knowledge, professional confidence, work motivation and self-improvement as aspects of the professional competences of future educators. Specifically, it analyses how these aspects influence learning and in turn student outcomes. The specifics of the formation of key competencies for teachers of labor education and technology were clarified by Debre *et al.* [11] and recommendations were provided for their implementation based on a competency approach. The study by Moreira *et al.* [12] aims to identify high-quality learning experiences at the transnational level and develop professional development programs aimed at the most valuable competencies and indicators. Zharmenova *et al.* [13] analyze the methods and means of integrating ecological and pedagogical skills into the educational process of students studying in higher educational institutions in Kazakhstan under the program for advanced training of biology teachers. The influence of factors such as management and leadership, institutional culture, resource availability, technical and pedagogical support, and teaching load on the development of professional digital competencies of novice teachers has been studied by Masoumi and Noroozi [14]. Marfuga *et al.* [15] analyze the works of scholars engaged in the formation of professional competencies of individuals and consider the possibilities of improving these competencies. Scientists point out that the concept of 'competence' by its structure is multidimensional and complex, the holistic professional competence of future teachers as a result of professional education is based on such key competences as social, professional, communicative, cognitive, educational. Omarov *et al.* [16] analyzed the problem of professional competence, creating methodological foundations for the formation of professional competencies of students of pedagogical colleges in Kazakhstan as future teachers. The study also identifies the essence of professional competence, describes its structure and content, criteria and levels.

After analyzing the above works, we concluded that "professional competence provides a close relationship of individual human qualities, professional theoretical knowledge, qualifications, skills, experience of a specialist". The above scientific articles consider the development of professional competencies of future teachers in various aspects, the works of subsequent scholars outline the issues of mobile technology applications in education, which are the basis for our research topic. Camilleri *et al.* [17] study teachers' attitudes towards mobile applications and analyze the indicators' pace of innovative technologies" and

"perception of innovative technologies". Luna-Nevarez and McGovern [18] evaluates the trends in the use of mobile technologies in education and the availability of new smart devices, digital applications. Oliveira *et al*. [19] describes the experience of undergraduate students' use of communication technology mobile applications during classes. Dahri *et al*. [20] proposes a framework for mobile learning certification in his study, which includes mobile phone support, curriculum and training assessment, peer support, and continuous professional development assessment. Fojtik [21] indicated the possibilities of mobile technologies in teaching computer science and programming, noting that according to the results of conducted surveys and experiments, mobile devices are effective in teaching computer science, programming, and algorithms. The paper also describes the experience of teaching and developing mobile applications, applications for users with special educational needs. As a resultof previous research, we also stated to biology students the effectiveness of using a mind map with the help of the Mindomo mobile application [22].

Goundar and Kumar [23] explores the ways of using mobile learning applications in higher education institutions. The systematic mapping method of research is applied here, and a systematic mapping study was conducted using 103 documents obtained from 6 different databases. Almayee *et al*. [24] developed a new model to study the influence of various factors on the development of mobile learning applications. Mirzakhmedova *et al*. [25] discussed the impact of mobile applications on the learning process of students with different educational needs and abilities, as well as the ability to use mobile applications in inclusive education. In foreign and national literature, the term "mobile learning" has many definitions. In the MoLeNet project (www.molenet.org.uk), mobile learning" is understood as a method of learning implemented to optimize learning using portable, wireless technologies, allowing learners to communicate to receive or receive information through convenient and accessible cellular devices in the field of education. A researcher in this field, Traxle [26] states that "mobile learning is completely changing the learning process, modifying the delivery of and access to materials, and creating new forms of knowledge and thinking". Mobile learning is seen as "a process that is justintime, justenough and justforme".

According to Paskova [27], mobile learning (m-learning) is learning that takes place using mobile handheld devices such as mobile phones, laptops, and tablets. Viberg [28] noted that mobile learning is "part of e-learning activities".

This literature, devoted to the topic of the study, examines the features of using mobile technologies in various aspects. In this article, we will consider the formation of professional competencies using mobile technologies in the training of biology teachers.

Mobile learning is the process of implementing learning using mobile devices anytime, anywhere, regardless of time and place (address), i.e., access to the Internet.

III. Method

Based on the results of theoretical analysis, a structural and content model of professional competencies formation using mobile technologies in biology teacher training was developed (Fig. 1). When creating the model, first of all, the content of training material, criteria, indicators of competences formation were described.

The primary objective of the developed model is to scientifically substantiate the theory and methodology of mobile technology applications in teaching and to determine their effectiveness in the formation of professional competencies of future biology teachers. In this regard, content, procedural, diagnostic components were obtained as the main components of the model.

Fig. 1 illustrates the conceptual model of the study, which shows the relationships between mobile technology use, competency development, and learning outcomes. This model serves as a basis for developing an experimental intervention and interpreting the data obtained.

During the process of training biology specialists, a need has for a set of regulatory norms has arisen to form professional competencies based on the use of mobile technologies. This set of norms includes specific criteria for developing the professional competencies of biology teachers, namely motivational, cognitive, and activity-based criteria. The motivational criterion in the proposed model for developing the professional competencies of biology teachers is characterized by students' enthusiasm and interest in using mobile technologies.

The motivational criterion characterizes motives aimed at personal development, self-activation and educational and cognitive stimulation of the future biology teacher. Motivational criteria for the formation of professional competencies reflect its motivational and incentive function.

The cognitive criterion describes the general scientific, gnostic and developmental functions that organize and implement the cognitive process in the search for, and acquisition of any theoretical and practical knowledge related to the methods of cognition. That is, the cognitive criterion in the model we propose forms the system of scientific knowledge of future biology teachers, determines their readiness and readiness to acquire, search for and process new knowledge, the scientific, cognitive and research nature of their professional activities.

The cognitive criterion, or the knowledge acquisition criterion, encompasses the theoretical knowledge that students must acquire to solve educational tasks. The activity-based criterion determines the level at which students can apply the acquired knowledge in practice. This criterion focuses on developing students' creative skills. The motivational, cognitive, and activity-based criteria for developing the professional competencies of biology teachers enable the achievement of the following outcomes:

- ensuring motivation and interest that enhance cognitive activity;
- understanding the content of competency formation;
- recognizing the importance of using internet resources and electronic textbooks in competency development;
- comprehending the significance of mobile technologies in education;
- implementing mobile technologies based on interdisciplinary connections;
- performing creative tasks;
- executing intellectual operations (analysis, synthesis, comparison, generalization, evaluation, observation,

etc.).

- monitoring and making adjustments to independent learning and cognitive activities;
- enhancing the quality of the learning process by utilizing the potential of mobile technologies.

Overall, the proposed model for developing the professional competencies of biology teachers fully reveals the possibilities of using mobile technologies in education. Thus, applying mobile learning technologies in the training of future biology specialists expands the educational resources of higher education institutions and highlights the necessity of considering them in conjunction with traditional education methods, reinforcing the importance of this research.

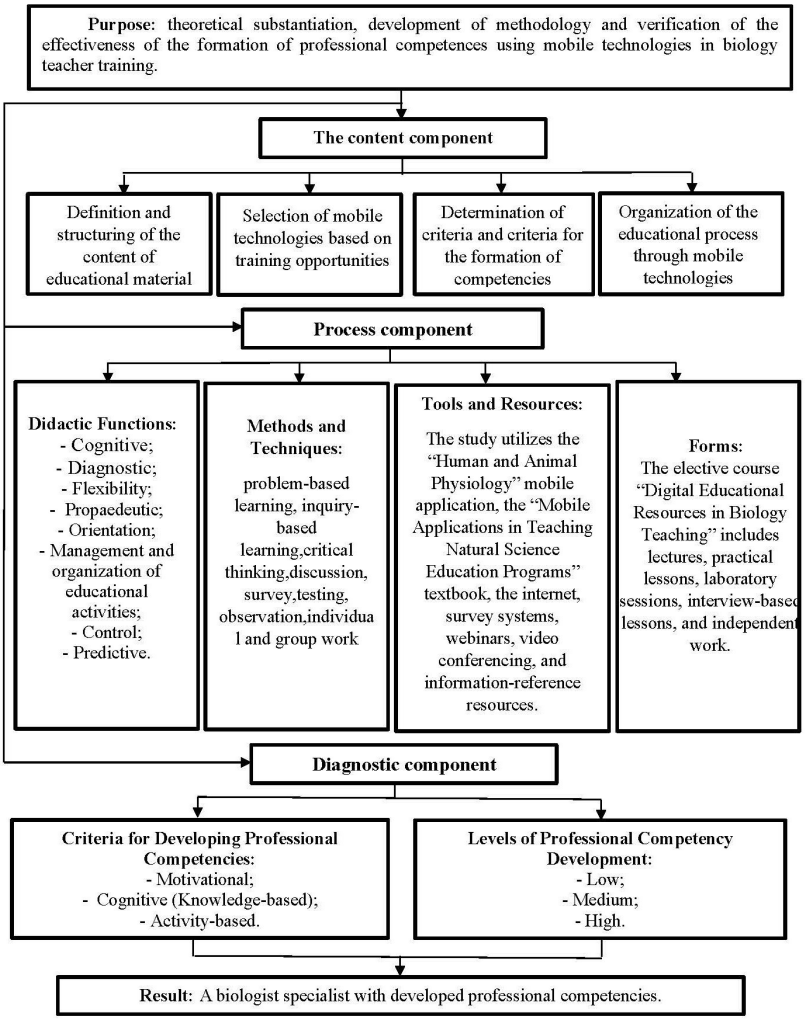

Fig. 1. Structural-content model for developing professional competencies based on the use of mobile technologies.

IV. Results and Discussion

To comprehensively examine the application of mobile technologies in education, an extensive review of scientific and pedagogical literature was conducted. In our research, theoretical methods included the analysis of educational and methodological literature, formalization, axiomatization, and the hypothetical-deductive method, among others. Empirical methods widely utilized in the study included observation, experimentation, and surveys. The experiment consisted of three main stages (Table 1).

A total of 117 students from the Biology education program at Korkyt Ata Kyzylorda University, aged 19 to 21, participated in the survey.

All participants gave informed consent to participate in the study, which complies with ethical standards for working with people and legal requirements.

During the survey, students were asked the following questions:

- what do they know about mobile technologies and applications.
- for what purposes do they most often use their mobile devices.
- use of mobile applications in the process of studying at the university.
- the importance of using mobile applications in the educational activities of students.
- the importance of using mobile applications in the professional activities of biology teachers at school.
- questions were asked to determine the level of work with mobile applications.When asked, *"What do you know about mobile technologies and applications?"*, responses from the first stage of the survey revealed: 52% of respondents stated they had limited knowledge ("I know a little about it"); 30% responded with good knowledge ("I know it well"); 18% admitted they did not know much about mobile technologies and applications;

Table 1. Stages of the experiment

Stage Number	Stage Name	Description of Work Conducted
I	Diagnostic	A two-stage survey was conducted to determine the impact of mobile technologies on the formation of professional competencies of biology teachers. Survey questions were developed. The results of the survey, aimed at analyzing the impact of mobile technologies on the professional competencies of future biology teachers, were analyzed.
II	Formative	A survey was conducted to analyze the impact of mobile technologies on the formation of professional competencies of future biology teachers. Additionally, classroom observations were carried out.
III	Final	The results of the formative and control experiments, as well as the experimental data from testing, were analyzed and compared. The key findings and recommendations were summarized.

Respondents who indicated some level of knowledge about mobile technologies emphasized that these tools meet a wide range of user needs, primarily through smartphones. Mobile technologies were described as encompassing a variety of devices, including computers, smartphones, tablets, and laptops, as well as digital learning resources such as e-textbooks, presentations, and videos. They also include platforms, software, and specialized applications developed for use on various gadgets. Mobile applications, in particular, were defined as platform-based programs developed for tablets and smartphones with specific functions. Respondents noted that the use of mobile applications is becoming an increasingly prominent trend. These applications are usually downloaded from digital marketplaces such as the App Store and Google Play. Overall, mobile technology is seen as one of the most advanced and rapidly developing areas of the 21st century.

However, 18% of respondents admitted that they did not have a clear understanding of mobile technologies and applications (Fig. 2).

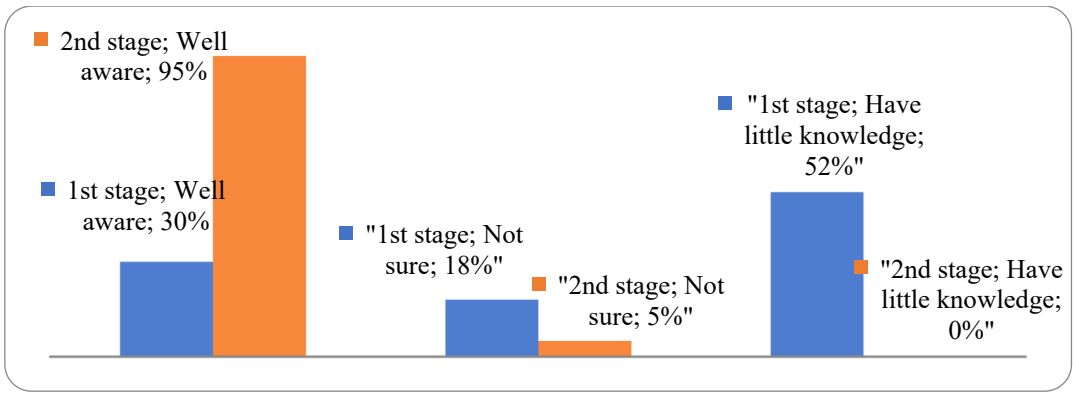

Fig. 2. Indicators of respondents' knowledge about mobile technologies and mobile applications.

In the second stage of the survey, the majority of respondents (95%) answered "I know well". The following reasons were provided:

- Mobile technologies are highly developed now, allowing us to access everything electronically without leaving home;
- Mobile technologies are used for viewing news, engaging in social interactions in a market-driven society, exchanging photos and videos, and creating personal content;
- Mobile applications are programs designed to perform specific functions;
- Mobile technologies refer to internet-enabled devices;
- Mobile applications are platform-based programs developed for tablets and smartphones (iOS, Android, Windows Phone, etc.) with specific functionalities;
- Mobile applications are software solutions installed on mobile phones according to their intended functions;
- Other responses included web applications or mobile websites.

However, 5% of the surveyed respondents stated that they "do not know exactly" about mobile technologies and mobile applications. Analyzing the definitions of the concept of "Mobile Technology" provided by students during the survey, the responses obtained in the first phase were as follows:

- Interactive whiteboards, working with the internet;
- Phone, internet, mobile applications;
- Digital technologies accelerate work;
- New library services, practical skills, future;
- A set of mobile technologies;
- Working with sources of information;
- A set of organizational and administrative measures and documents.

In the second phase, after completing the course, no respondents stated that they "do not know" the concept of "Mobile Technology". Regarding the survey question *"For what purposes do you most often use your mobile device?"* the responses from students in the first phase were as follows:

- Accessing social media;
- Mostly for watching English learning videos and acquiring new information;
- Obtaining information needed for studies;
- Creating various videos and presentations on a laptop;
- Using E-gov to obtain certificates and paying phone bills;
- Communicating, browsing social media, playing games, scanning, and taking photos;
- Watching and uploading videos on YouTube, among other uses.

During the survey, respondents were asked, *"Are mobile applications used in the university's educational process?"* In the first phase of the survey, the majority of respondents 40% stated that mobile applications "are used", while 30% indicated that they are "partially used" (Fig. 3).

In response to the question, *"If used, in which subjects are they applied?"*, the following opinions were expressed:

- Mobile computers are used, but we only use them for taking tests;
- Mostly used in English language classes;
- Accessing lessons via phone, making them available anywhere;
- Used in all subjects for general information searching;
- Used for communication in chats during online learning, among other purposes.

However, 30% of respondents stated that mobile applications "are not used in the university's educational process. In the second phase of the survey, 70% of respondents stated that mobile applications "are used", while 20% indicated they are "partially used". In response to the question, "*If used, in which subjects are they applied?*", the following opinions were expressed:

- Used based on our field of study and for online learning;
- We use Zoom and WhatsApp for all subjects related to distance learning;
- Used in all subjects due to the current situation;
- Used for slides, internet browsing, video, and audio materials;
- Applied in the university's educational process;
- Specifically used in the subject "Digital Educational Resources in Biology Teaching".

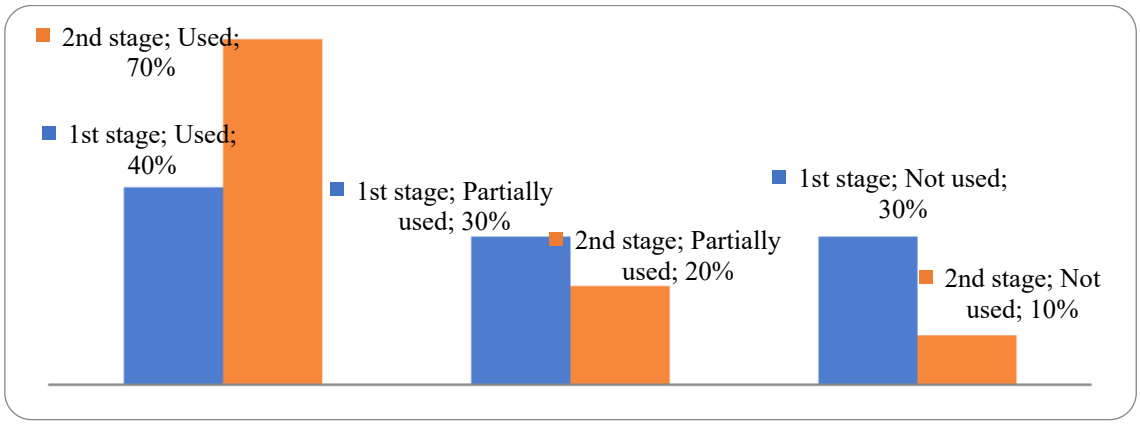

Fig. 3. Indicators of mobile application usage in the university's educational process.

However, 10% of respondents stated that mobile applications "are not used" in the university's educational process. In response to the survey question, "*Do you use mobile applications for independent work in the classroom?*", the first phase of the survey showed that 60% of respondents answered "yes" (Fig. 4). In the second phase, 90% of respondents stated "yes". When asked, *If you use them, which ones?* ", the following responses were given:

- Snapchat, Kahoot, Duolingo;
- Social media apps: Facebook, Telegram, Instagram, WhatsApp;
- Tele2, Kaspi.kz, Biology theory, tests, terminology, etc.;
- Reading e-books on Wikipedia, anatomy, cytology;
- Google Translate, Zoom, Classroom, Platonus, 3D Anatomy, Microsoft PowerPoint;
- Biology-related apps: Biology Tutor;
- XRecorder, Prezi were also mentioned.

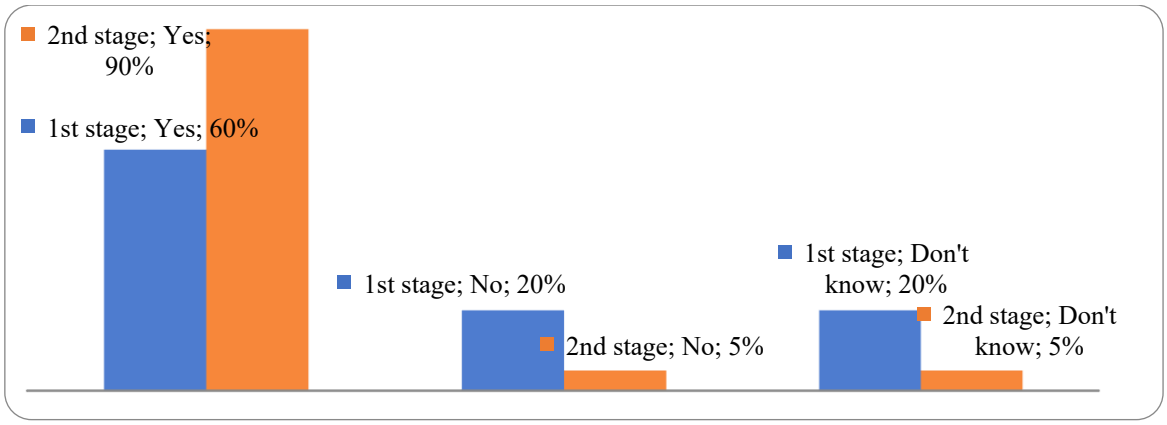

Fig. 4. Indicators of mobile application usage in independent classroom work.

However, 5% of respondents stated that they "do not use" mobile applications for independent work in the classroom, and another 5% responded with "don't know". Regarding the importance of using mobile applications in students' learning activities, 22% rated it as "low", while 18% stated "don't know". In the second phase, 82% of respondents considered their importance as "very high", while 10% rated it as "moderate". The following reasons were provided to support these responses:

- A necessity of modern times—videos, audio, photos, and dialogues can all be accessed;
- Using various programs such as Zoom, Bandicam, XRecorder, Prezi.com, etc., helps students learn electronic work and understand lessons better;
- Mobile applications provide people with many opportunities today;

- Mobile applications help save time.

In response to the question, "*In your opinion, what is the significance of using mobile applications in students' learning activities?*", the first phase of the survey showed that 38% of respondents rated their importance as "very high", while 22% considered it "moderate" (Fig. 5). The following reasons were provided to support these responses:

- Using mobile applications for solving problems;
- Contributing to overall development and gaining knowledge;
- Assisting with translations in English;
- Being effective for saving time;
- Enhancing students' knowledge by integrating mobile applications into lessons.

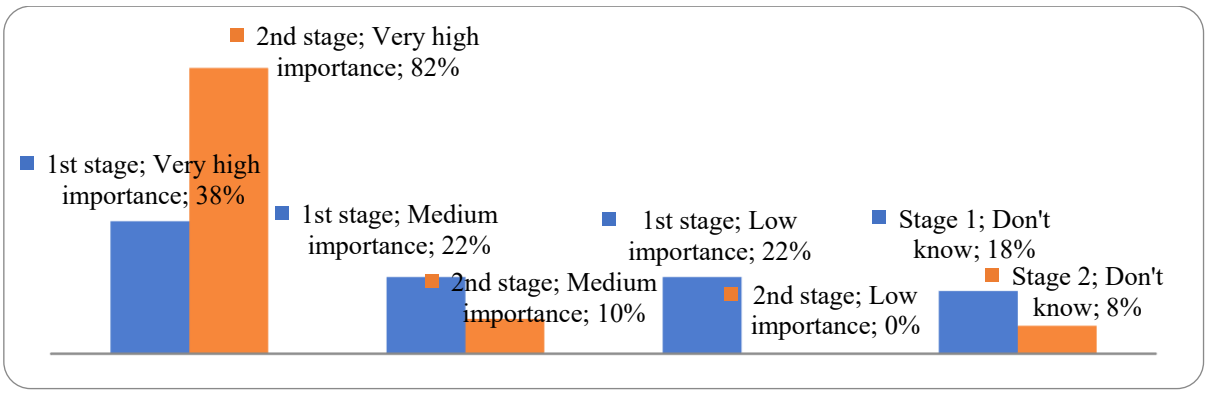

Fig. 5. The importance of using mobile applications in students' learning activities.

During the survey, in response to the question, *In your opinion, what is the significance of biology teachers using mobile applications in their professional activities at school?*" 74% of respondents in Stage I stated that it is "significant" (Fig. 6). The following reasons were given as the basis for these responses:

- For explaining new topics to students;
- When obtaining necessary information;
- Important for working in a virtual laboratory;
- For explaining lessons using video clips and presentations.
- For laboratory research;
- It would be great if all life growth processes in biology could be marked;
- If applications help highlight the importance of the subject, then their significance is indeed high;
- Teachers can make lessons more engaging, as mobile sites provide access to creating presentations;
- Considered important for biology teachers as well.

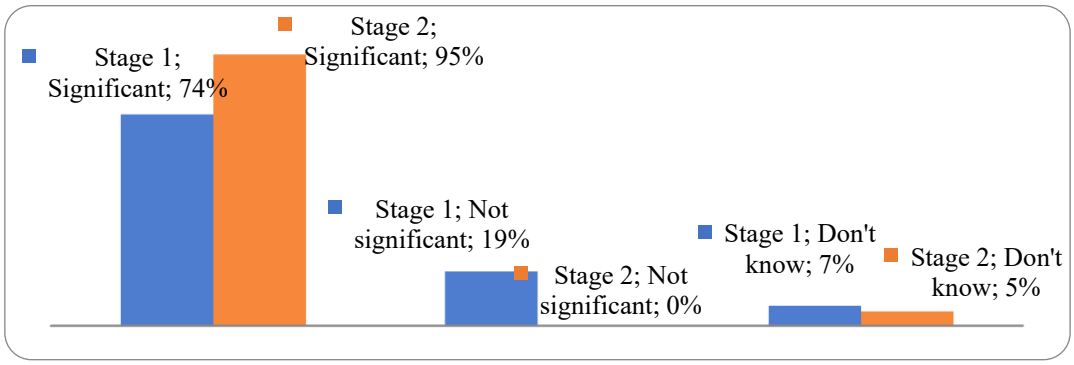

Fig. 6. The importance of using mobile applications in the professional activities of biology teachers in schools.

However, 19% of respondents stated that the use of mobile applications in the professional activities of biology teachers in schools is "not important," while 7% responded with "I don't know". In Stage II, 95% of respondents expressed the opinion that mobile applications are "important". The following reasons were provided to support these responses:

- Suitable for displaying graphs and diagrams in certain topics;
- It is easier to teach students; for example, there are various 3D programs that show internal organs and other structures in a movable, animated format with different colors and explanations;
- However, excessive use of mobile devices can be harmful to health;
- When using games or saving video lessons, mobile applications should be used in biology to keep students engaged and prevent boredom;
- School teachers use the Bilimland application;
- The importance is moderate, but mobile applications are useful for displaying graphs and diagrams in certain topics, as well as for showing plants and human anatomy in 3D format using applications like Kahoot, Xrecorder, 3D Anatomy, Biology Book, and Quiz Biology;
- For assessing students' knowledge in a short time, mobile applications are important for biology teachers in schools, including resources such as Infourok, videos, presentations, and test questions;
- Mobile applications play a significant role in increasing students' cognitive interest;
- Mobile applications are important for school biology teachers because they make lessons more engaging and

easier to understand.

However, **5%** of respondents stated **"I don't know"** regarding the use of mobile applications in the professional activities of biology teachers in schools. During the survey, the question "Evaluate your level of working with mobile applications on a 5-point scale" was asked. According to Stage I, 11% of respondents rated themselves 5 points – very high, 26% rated themselves 4 points—high, and 56% rated themselves 3 points –average, showing a generally positive evaluation (Fig. 7). On the other hand, 7% of respondents stated that their level of working with mobile applications is 2 points – low.

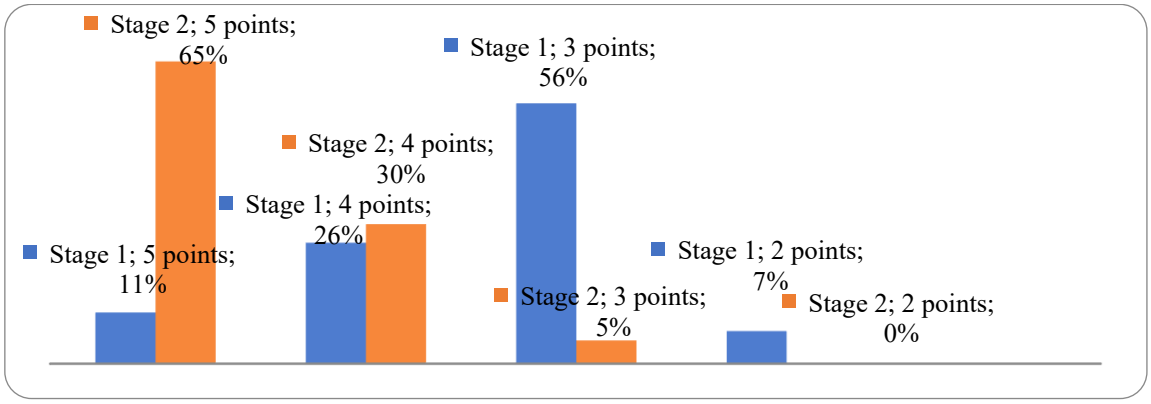

Fig. 7. Respondents' self-assessment of their proficiency in using mobile applications on a 5-point scale.

According to Phase II, after completing the course, 65% of respondents rated their proficiency as 5 points—very high, 30% as 4 points—high, and 5% as 3 points—moderate. These survey results indicate that students' outcomes improved positively after completing the course.

V. Results and Discussion

In the final stage, when evaluating lesson outcomes, the key criteria of the structural-content model for developing students' professional competencies through mobile technologies were taken as a basis. Specifically, students' interest and need for mobile technologies, the content of knowledge gained through mobile learning, and the development of skills and competencies in applying mobile technologies for creative activities were considered. Based on the model's criteria, three levels of professional competency formation were identified. Based on these levels, we used the chi-square (χ^2) measurement method from Cherepanov's expert evaluation methodology in pedagogical research to conduct a diagnostic analysis of our research results, expressed by the following Eq. (1) [29]:

$$\chi^2 = \frac{1}{N_1 \cdot N_2} \cdot \sum_{i=1}^{C} \frac{(N_1 \cdot O_{2i} - N_2 \cdot O_{1i})^2}{O_{1i} + O_{2i}} \quad (1)$$

where:
N_1—number of students in the experimental group;
N_2—number of students in the control group;
O_{1i}—number of students in the experimental group at the i-th level of competency formation;
O_{2i}—number of students in the control group at the i-th level of competency formation;
C—number of levels (i).

This formula is applied only when there are at least 5 students at each level. If the number of students at any level is less than 5, the levels are combined, and the chi-square (χ^2) measurement is calculated using the following Eq. (2):

$$\chi^2 = \frac{N(O_{11} \cdot O_{21} - O_{12} \cdot O_{22})^2}{N_1 \cdot N_2 (O_{11} + O_{21})(O_{12} + O_{22})} \quad (2)$$

where:
N—total number of students;
N_1—number of students in the experimental group;
N_2—number of students in the control group;
O_{11}, O_{21}—number of students in the experimental and control groups at the low level;
O_{12}, O_{22}—number of students in the experimental and control groups at the high level.

To study the growth dynamics of students' professional activity formation, we used the average indicator (AI), calculated using the following Eq. (3):

$$AI = \frac{(a + 2b + 3c)}{100} \quad (3)$$

where:
a—percentage of students at the low level;
b—percentage of students at the medium level;
c—percentage of students at the high level.

Next, the effectiveness coefficient (EK) of the pedagogical experiment is calculated:

$$EK = \frac{AI_{\text{exper.gr.}}}{AI_{\text{control gr.}}} \quad (4)$$

where:
$AI_{\text{exper.gr.}}$—the average indicator of the experimental group.
$AI_{\text{control gr.}}$—the average indicator of the control group.

The research results of the diagnostic stage of the pedagogical experiment are presented in Table 2. At this stage, the professional competencies of students were assessed based on motivational, cognitive, and activity-based criteria as follows:

According to the motivational criterion:

1) Low level: Experimental group—44.5%, Control group—46.3%;
2) Medium level: Experimental group—38%, Control groupb—35.2%;
3) High level: Experimental group—17.5%, Control group —18.5%.

According to the cognitive (knowledge-based) criterion:

1) Low level: Experimental group—36.5%, Control group—38.5%;
2) Medium level: Experimental group—39.7%, Control group—42.6%;
3) High level: Experimental group—23.8%, Control group—18.5%.

Table 2. Indicators of the diagnostic stage of the experimental study (in %)

Criteria	Group	Number of Students	Levels						AI	EK	χ^2
			Low		Medium		High				
			No. of Students	%	No. of Students	%	No. of Students	%			
Motivational	EG	63	28	44.5	24	38.0	11	17.5	1.73	1.00	0.1
	CG	54	25	46.3	19	35.2	10	18.5	1.72		
Cognitive	EG	63	23	36.5	25	39.7	15	23.8	1.87	1.03	0.49
	CG	54	21	38.9	23	42.6	10	18.5	1.80		
Activity-Based	EG	63	23	36.5	27	42.9	13	20.6	1.84	1.07	0.84
	CG	54	23	42.6	23	42.6	8	14.8	1.72		

According to the activity-based criterion:

Low level: Experimental group—36.5%, Control group—42.6%;

Medium level: Experimental group—42.9%, Control group—42.6%;

High level: Experimental group—20.6%, Control group—14.8%.

Based on the data in the table, we calculate the average indicator (OK) of the development dynamics of the motivational criterion in students' professional activities using Eq. (3).

Average indicator of the experimental group

$$AI_{\exp er.gr} = \frac{(44.5 + 2 \cdot 38 + 3 \cdot 17.5)}{100} = 1.73$$

Average indicator of the control group

$$AI_{contr.gr.} = \frac{(46.3 + 2 \cdot 35.2 + 3 \cdot 18.5)}{100} = 1.72$$

We calculate the effectiveness coefficient *(EK)* of the experimental study using Eq. (4):

$$EK = \frac{AI_{\exp.gr.}}{AI_{contr.gr.}} = \frac{1.73}{1.72} = 1.0$$

To analyze the research results, we use the chi-square (χ^2) method based on Eq. (1), calculated as follows:

$$\chi^2 = \frac{1}{63 \cdot 54} \cdot \left(\frac{(63 \cdot 25 - 54 \cdot 28)^2}{28 + 25} + \frac{(63 \cdot 19 - 54 \cdot 24)^2}{24 + 19} + \frac{(63 \cdot 10 - 54 \cdot 11)^2}{11 + 10} \right) = 0.1$$

Thus, based on the data in the table at the diagnostic stage, we also calculated the development dynamics of students' professional competence in cognitive and activity-based criteria using the previously mentioned Eqs. (1), (3), (4). According to the data in Table 2, the average indicator of the development dynamics of motivational criteria in professional activity was 1.73 in the experimental group and 1.72 in the control group. Accordingly, based on the data in Table 2, the average indicator of the development dynamics of the cognitive criterion in professional competence was 1.87 in the experimental group and 1.80 in the control group, while the average indicator of the development dynamics of the activity-based criterion was 1.84 in the experimental group and 1.72 in the control group. The effectiveness coefficient of the experimental study was 1.0 for the motivational criterion, 1.03 for the cognitive criterion, and 1.07 for the activity-based criterion. The chi-square (χ^2) indicator was 0.1 for the motivational criterion, 0.49 for the cognitive criterion, and 0.84 for the activity-based criterion.

Based on the results of the diagnostic stage of the experimental study, we concluded that the level of students' professional competencies in using mobile technologies was at a medium and low level. This indicates that future biology specialists have insufficient knowledge about mobile technologies and show a below-average level of interest in using them. Although students demonstrated a positive attitude towards the use of mobile technologies and applications, they lacked independent experience in utilizing them effectively.

During the formative stage, students in the experimental group were taught the courses "Digital Educational Resources in Biology Teaching" and "Pedagogical Design of the Digital Educational Environment", which included a system of theoretical and practical knowledge. In contrast, the control groups were not offered any new content courses.

Mobile applications used in teaching the subjects were selected based on criteria such as pedagogical relevance, technical accessibility and empirical support. Pedagogical appropriateness—each application solves a specific educational task:

Duolingo—is used to develop language competence, effective for individualized learning.

Kahoot—used for formative assessment, promotes active student engagement.

Biology applications (for example: Human Anatomy Atlas, BioInteractive, Mindoma) were selected based on their relevance to the course topics and visual clarity.

Technical accessibility—all applications:

Are free or have a free basic version.

Are compatible with the operating systems used by students (Android/iOS).

Do not require high-speed Internet, which is especially important in conditions of limited access.

Empirical support—the selection of applications was based on the results of previous studies that demonstrated their effectiveness in the educational environment.

Thus, the selection of digital tools was not carried out arbitrarily, but based on a combination of pedagogical, technical and empirical factors, which strengthens the validity of the experimental intervention.

To summarize the practical experimental work conducted during the formative experiment, the same surveys used in the diagnostic stage were re-administered to both the experimental and control groups. The research results obtained during the formative stage of the pedagogical

experiment were calculated using Eqs. (1), (3), (4). The results are presented in Table 3.

Table 3. Indicators of the formative stage of the experimental study (in %)

Criteria	Group	Number of Students	Levels						AI	EK	χ^2
			Low		Medium		High				
			No. of Students	%	No. of Students	%	No. of Students	%			
Motivational	EG	63	13	20.6	31	49.2	19	30.2	2.15	1.20	7.43
	CG	54	22	40.7	21	38.9	11	20.4	1.79		
Cognitive	EG	63	14	22.2	28	44.4	21	33.4	2.11	1.14	3.59
	CG	54	19	35.2	24	44.4	11	20.4	1.85		
Activity-Based	EG	63	16	25.4	30	47.6	17	27.0	2.01	1.13	3.19
	CG	54	21	38.9	24	44.4	9	16.7	1.77		

According to the data in Table 3, the average indicator of the development dynamics of the motivational criterion in professional activity was 2.15 in the experimental group and 1.79 in the control group. Similarly, the average indicator of the development dynamics of the cognitive criterion in the experimental group was 2.11, while in the control group, it was 1.85. The average indicator of the development dynamics of the activity-based criterion in the experimental group was 2.01, whereas in the control group, it was 1.77. The effectiveness coefficient of the experimental study was 1.2 for the motivational criterion, 1.14 for the cognitive criterion, and 1.13 for the activity-based criterion. The chi-square (χ^2) indicator was 7.43 for the motivational criterion, 3.59 for the cognitive criterion, and 3.19 for the activity-based criterion.

The analysis of the data in Table 3 indicates that students in the experimental group showed an improvement in their professional competencies based on mobile technologies. A decrease in the number of students at the low level was observed in the experimental group. In contrast, the control group did not show significant changes in these indicators. These results confirm that the courses "Digital Educational Resources in Biology Teaching" and "Pedagogical Design of the Digital Educational Environment" had a positive impact on the formation of professional competencies among biology students.

Now, by comparing the results of the diagnostic and formative stages of the experiment (Table 4), we determine the indicators of the control stage (Table 5).

Table 4. Comparative analysis of the results in the diagnostic and formative stages

Criteria	Group	Number of Students	During the identification stage						During the formation stage					
			Low	Medium	High	AI	EK	χ^2	Low	Medium	High	AI	EK	χ^2
Motivational	EG	63	44.5	38.0	17.5	1.73	1.00	0.1	20.6	49.2	30.2	2.15	1.20	7.43
	CG	54	46.3	35.2	18.5	1.72			40.7	38.9	20.4	1.79		
Cognitive	EG	63	36.5	39.7	23.8	1.87	1.03	0.49	22.2	44.4	33.4	2.11	1.14	3.59
	CG	54	38.9	42.6	18.5	1.80			35.2	44.4	20.4	1.85		
Activity-Based	EG	63	36.5	42.9	20.6	1.84	1.07	0.84	25.4	47.6	27.0	2.01	1.13	3.19
	CG	54	42.6	42.6	14.8	1.72	1.00	0.1	38.9	44.4	16.7	1.77		

Table 5. Indicators of dynamic changes in the final stage

Criteria	Groups	Number of Students	Dynamic Changes in the Final Stage					
			Low	Medium	High	AI	EK	χ^2
Motivational	EG	63	–23.9	11.2	14.7	0.42	0.20	7.33
	CG	54	–5.6	3.7	1.9	0.07		
Cognitive	EG	63	–14.3	4.7	9.6	0.24	0.11	3.1
	CG	54	–3.7	1.8	1.9	0.05		
Activity-Based	EG	63	–11.1	4.7	6.4	0.17	0.06	2.35
	CG	54	–3.7	1.8	1.9	0.05		

According to the data in Table 4, we see that the dynamics of the development of the motivational criterion of professional activity of students in the experimental group increased from a coefficient of 1.73 to 2.15, the dynamics of the development of the cognitive criterion in the experimental group increased from a coefficient of 1.87 to 2.11, and the dynamics of the development of the activity criterion in the experimental group increased from a coefficient of 1.84 to 2.01.

The efficiency coefficient at the final stage of the experimental study increased from 1.0 to 1.2 coefficients for the motivational criterion, from 1.03 to 1.14 coefficients for the cognitive criterion, and from 1.07 to 1.13 coefficients for the action criterion.

At the same time, the indicator at the final stage increased by the motivational criterion from 0.1 to 7.43 coefficients, by the cognitive criterion from 0.49 to 3.59 coefficients, and by the action criterion from 0.84 to 3.19 coefficients. That is, the effectiveness of the experimental work was given not as a percentage, but as a coefficient using the χ, according to the formula of Cherepanov.

In order to identify statistically significant differences in the levels of development of professional competence components between the control and experimental groups, a chi-square analysis (χ^2) was conducted. The total number of students was 117 (63 in the experimental group, 54 in the control group). Statistically significant differences were found for the motivational component:

$$\chi^2(2, N = 117) = 7.33, p = 0.026$$

which indicates the influence of pedagogical intervention on the formation of sustainable academic motivation in students in the experimental group. In terms of the cognitive component, the differences between the groups are not

statistically significant:

$$\chi^2(2, N = 117) = 3.10, p = 0.21.$$

Similarly, in terms of the activity component, no significant differences were found:

$$\chi^2(2, N = 117) = 2.35, p = 0.31.$$

Thus, pedagogical influence had the greatest impact on the motivational component of professional competence, while cognitive and activity aspects require additional conditions for sustainable development.

Despite the obtained results concerning the immediate increase in the level of competence formation in the participants, the study has certain limitations. Within the framework of this work, an assessment of the sustainability of the acquired competences over time, as well as their application in real situations of educational and professional practice, was not carried out.

This limitation is due to the time frame and methodological focus of this study.

In the future, it is planned to conduct a study aimed at tracking the dynamics of the development of competencies, assessing the degree of their preservation after a certain period of time, as well as studying the practical use of these competencies in the conditions of the real educational process.

The results obtained confirm the effectiveness of using mobile technologies to develop professional competencies in future biology teachers, which is consistent with the findings of a number of studies, but some differences were also identified. In particular, unlike studies focused on the mass use of general-purpose platforms, our study focused on specialized biology applications, which allowed us to more accurately adapt the learning process to specific educational tasks.

The practical significance of the work lies in the possibility of introducing the described mobile tools into teacher training programs, which can contribute to increasing the interactivity and motivation of students, as well as the development of digital literacy—a key skill of a modern teacher.

However, the study has several limitations. First, the limited sample size reduces the generalizability of the results, requiring larger studies. Second, the use of a specific set of mobile applications and technical conditions limits the ability to directly transfer the results to other educational contexts.

Third, the analysis focused on short-term results, while the long-term sustainability of the developed competencies requires further study.

Future research opportunities include conducting longitudinal experiments, comparing the effectiveness of different mobile platforms, and studying their application in different disciplines and educational environments. This will allow for a more comprehensive understanding of the potential of mobile technologies in education and optimize methods for their integration.

VI. Conclusions

This study examined the issues of using mobile technologies in the training of future biology teachers. In this context, a methodology for using mobile applications in teaching biological subjects was developed and scientifically justified. The effectiveness of using mobile technologies in the formation of professional competencies among future biology teachers was experimentally proven.

As identified in the study, the experience and trends of using mobile technologies in the learning process demonstrate that mobile learning in education can be viewed as a transformative technology that modifies traditional teaching models, corrects shortcomings that have emerged in conventional education, and enhances its effectiveness. This implies that, regardless of time and place, mobile learning meets people's educational needs and demands, while also integrating traditional education technologies with mobile technologies. This comprehensive connection is continuously evolving, relying on pre-approved educational programs established by responsible institutions in education management. The future prospects of the study highlight the necessity of developing a specialized course on the use of mobile technologies in the formation of professional competencies of biology teachers.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Bayanali Doszhanov: Writing initial draft, review and editing, resources management, supervise, analyze. Raikhan Almenayeva: Development of a structural and content model for the formation of professional competencies of future teachers. Lazzat Zhamansarieva: Collect data and resourses, consider research methods. Gulbanu Mukeyeva: Formulation of results and conclusions, scientific and methodological recommendations. All authors had approved the final version.

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