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Research paper

Virtual Environment as a Tool for Increasing Students' Natural Science Literacy

Zhaidary Abeldina[1*], Gulmira Makysh[1], Zhibek Moldumarova[1], Rauza Abeldina[1], Zhuldyz Moldumarova[1]

[1]S. Seifullin Kazakh AgroTechnical University, Kazakhstan, 010000, Astana, Pobeda Street, 62
**Corresponding author E-mail: abel-09@yandex.kz*

Abstract

The article is devoted to the quality of natural science education at universities. Moreover, this article reveals the causes and consequences of the decline in the level of mastery of these disciplines. The modernization of education efficiency aimed at improving the quality and accessibility of education itself largely depends on the way of using the objective information. This information can be received in the framework of studies of various types of education results such as monitoring studies of the republican level and international comparative studies. All these studies provide the information on the state of education; they allow correlating the planned and achieved results and based on that identifying the most significant education problems that need to be solved. The monitoring of the education quality implies the development of criteria for the assessments of knowledge for any stage of education. The calculation of students' progress rating can be one of the approaches to this problem. The assessment of the output knowledge of the students' progress rating can be done by using the electronic journal, which is the part of a university's automated information system. The standardization of the final rating on a scale of 0 to 100 creates an optimal opportunity to compare the results of educational progress at all stages of training. The use of virtual tools and software products is one of the essential interactive elements of the e-learning course in the virtual educational environment, which is particularly important in the study of natural sciences. These tools combine methodological and pedagogical technologies, information resources and modern software and help to monitor the educational process and find the solution to the issues of its quality.

Keywords: *monitoring of the educational process, students' progress rating, virtual educational space, electronic journal*.

1. Introduction

Global changes of the 21st-century world economy have created the need to adapt to a competitive economic environment and aggravated the issues of education quality since education and science are recognized as the fundamental priorities of the national strategy for the development of countries. However, society does not allocate sufficient resources for higher education funding, which could solve the social issues. According to UNESCO's experts, this situation is connected with the traditional approach to this problem as if educational institutions were economic entities that produce educational services for sale [10]. This approach is connected with applying to education the market principles based on freedom of choice and competition. It is not directly applicable to higher education since the education is not a branch of the economy, its products are not identical with similar financial categories, and the education itself is the essential element of the existence and development of society. In Kazakhstan, commercialization in the educational and scientific sphere is caused by the changing role of the state in these areas. Knowledge becomes a specific commodity in the current circumstances that play a mutually beneficial role in the system of expenditure and consumption of society.

According to the World Bank, Kazakhstan's education expenditures relative to GDP (Gross Domestic Product) are 2.8%. It less than in Iran (2.9%) or Russia (3.8%), but more than in Afghanistan (2.5%). In the general rating of the level of education expenditures, Kazakhstan ranked 127th out of 153 countries, maybe that is why local students occupy the places corresponding to the educational expenses.

The modernization of education efficiency aimed at improving the quality and accessibility of education itself largely depends on the way of using the objective information. This information can be received in the framework of studies of the results of education of various types such as monitoring studies of the republican level, analysis of the results of UNT (Unified National Testing) and international comparative studies. All these studies provide the information on the state of education; they allow correlating the planned and achieved results and based on that identifying the most significant education problems that need to be solved.

Kazakhstan participated in The Programme for International Student Assessment (PISA) twice: in 2009 and 2012. According to the official report of the Ministry of Education and Science of the Republic of Kazakhstan, over 40% of 15-year-old students were not able to complete second-level assignments in PISA's tests, while in countries of the Organization for Economic Cooperation and Development (OECD) this figure fluctuates around 20% [4].



Fig. 1: The results of Kazakhstan according to the Programme for International Student Assessment (PISA)

Kazakhstan took part in the PISA's research for the first time in 2009, which involved over 5,500 people from 184 organizations

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of general secondary education and 17 organizations of technical and vocational education. Kazakh schoolchildren took 59th place out of 65 in reading proficiency, in natural science they took 58th place, in mathematics, they were 53rd.

In the study of 2012, 5,808 15-year-old students from 218 educational organizations took part, including secondary schools – 200 (89 – urban, 111 – rural). The total number of students was 5,381. Along with schoolchildren, the study involved 427 training organizations of technical and vocational education.

When determining the level of the formation of natural science literacy of students, the ability to apply natural science knowledge in situations close to the reality was assessed. The international examination participants had to demonstrate the ability to formulate conclusions and find evidence to approve or disapprove them. The average score for natural science literacy was 501 points, for Kazakhstan it was 425 points (Figure 1). In Kazakhstan, the average achievement percentage of the international test for natural science was 40% among schoolchildren. This indicator was 1% lower than the results in mathematics.

The results of PISA and Trends in Mathematics and Science Study (TIMSS) for 2009-2012 indicate that the Kazakh system of secondary education is sufficiently effective in providing theoretical knowledge and ensure the learning, recognition, and collection of information processes among students. However, in practice, the educational system is relatively inefficient in ensuring the acquisition and use of higher-level thinking skills by students, such as logical thinking in mathematics, and the analysis and evaluation of the text in the reading process [8]. In general, the analysis of the results of Kazakhstan's participation in international programs for assessing the educational achievements of students has revealed the following significant problems:

− Students can formulate a problem, but they cannot interpret it correctly. In contrast, at the same time, 9 out of 10 OECD countries have the opposite tendency.

− Teachers of the republic's general schools provide strong subject knowledge but do not teach students how to use it in real life situations.

According to data from 2009 to 2012, Kazakhstan improved its results along with countries such as Qatar and Malaysia, but they are below the OECD average. At the same time, the results of Kazakhstan for 2015 were not recognized, as they raised some doubts on the part of the organizers of the Program for the International Assessment of Educational Achievements of Students in Natural Sciences, Mathematics, and Reading.

Thus, there is a need for a reorientation to solve the primary task of modern education – the training of people who can adapt quickly and successfully in difficult circumstances and make the right decisions in any, even the most extraordinary situations.

According to modern studies conducted both in Kazakhstan and abroad, the intellectual level of students is decreasing partly because of computer technologies. They simplify the search for necessary information, and at the same time lead to specific degradation of mental activity. It mainly affects the study of mathematical and natural-educational disciplines [6], [11]. The general level of students' physical and mathematical literacy has declined, both in the secondary school and in the higher one. Thereby, teachers have to find ways to improve the training of specialists in the field of natural science disciplines.

The study of natural science disciplines is a necessary part of educational attainment for almost all areas of secondary and higher education in the world. As one of the constituent parts of the education system, with some delay in time, university education is experiencing difficulties, the origins of which are laid down in the process of teaching children in high school. Due to this, the significant part of the physical, mathematical and natural science disciplines are studied in the first two years. Teachers of this profile mainly work with yesterday's schoolchildren, who initially have to learn new rules for conducting classes, new requirements, realize the need to work at classes and learn how to use the scientific literature. Therefore, there is a need to introduce new modern teaching methods that take advantage of commutative computer technologies, avoiding their shortcomings, enriching traditional ways of obtaining knowledge and actively using them.

2. Methods

The use of information and communication technologies in the system of education not only affects educational technologies but also introduces new ones into the learning process. It is due to the use of computers and telecommunications, specialized equipment, software products and hardware, network technologies and automated data-processing systems [9]. New learning tools, means of transferring and storing knowledge are intensively developing, which include electronic educational multimedia publications; digital educational resources (DER), electronic libraries and archives, global and local educational networks; educational platforms, information-reference, and automated search systems.

Modeling a mobile virtual educational system based on virtual reality technologies is a complicated dynamic process in which all the secondary processes are cut off. The final essential components characterize the educational processes and reveal the connections among them, which allow their full representation [5], 7]. The trend of the modern stage of informatization and automation of the educational process is the desire to unify scientific and methodological approaches to the development and use of various digital educational resources [7], [13].

3. Results and discussion

According to the state program, by 2020 it is planned to connect 90% of Kazakhstan schools to the e-learning system. Experts note the strengths and weaknesses of this form of training [14], but one of the major limitations is the lack of materials and textbooks in electronic libraries. Therefore, one of the most important tasks is to develop a high-quality and useful content as an integral part of the virtual educational space. Creation of interactive materials, implementation of learning activities scenarios, methods of using virtual instruments in the educational system requires sufficient time.

In addition to it, the automated information systems used in Kazakhstan do not always have convenient communication interfaces. Thus, it is often a difficult task for teachers to add educational and monitoring materials to the programs. Also, there are no affordable (low-cost) mobile devices, tablets, and other gadgets, that could allow teachers to work in real time. During the transitional period of the introduction of e-learning, teachers will have an increased workload which implies paper and electronic workflow, log books, technological and Internet adaptation.

The purchase of expensive laboratories, with the use of technologies of augmented and virtual reality, may become a thing of the past. It will be enough to open a mobile application and conduct laboratory experiments. With the use of virtual and augmented reality technologies, students of secondary and higher education institutions will be able to interact with objects in virtual space or participate in important historical events. However, it is no secret that modern schoolchildren have lost interest in learning the general scientific disciplines, such as physics, chemistry, and mathematics. The use of play-based learning in the education process, which allows understanding these complex disciplines, can be easily realized with the help of modern IT-technologies.

Virtual and Augmented Reality (VR and AR) technologies should be primarily applied in the educational sphere because the educational system must adapt to more complex processes, models, and theories, so students need to handle with a considerable amount of information and new ways of its presenting. With distance learning, a student can be anywhere in the world, as well as a teacher. Each of them will have their own avatar and personally attend a virtual classroom: listen to lectures, interact and even perform

group assignments. This will introduce a sense of presence and remove the boundaries that exist in video learning. According to the report of the research company SuperData, the virtual reality market will grow by more than 20 times in 2020 compared to 2016 – from $1.8 billion to $37.7 billion. By the end of 2017, the market value will be $4.9 billion; that implies growing by 168% compared to the previous year [15].

Under these circumstances, it is clear that at this stage the research and development of software products, using the technology of augmented and virtual reality for the study of natural science disciplines in a multilingual environment are relevant and promising. Multilingual education has been elevated to the level of state policy, within the framework of which it is planned to study such complex disciplines as mathematics and physics in English [17]. However, one should take into consideration the fact that the study of these disciplines, even in a native language, is a difficult task. Therefore, to implement multilingual education, it is necessary to prepare appropriate education facilities as well as to develop methodological and training normative documents [16].

Millennials or Generation Y, people born from 1980 to 2000, showed a special propensity to use VR/AR products at work. Moreover, 77% of the surveyed organizations said they would try to implement such devices. The Kazakh users have a certain interest in this project. As mentioned above, there are 3.3 million active users of social networks in Kazakhstan, which is one-fifth of the country's population.

The virtualization of the learning environment led to the creation of scientific, methodological and normative documents, such as course curriculum, electronic teaching materials and multimedia presentations for lectures and practical classes. In addition to it, a multimedia laboratory in physics, which included more than 40 laboratory works in all branches of physics, was added to the virtual environment of the Saken Seifullin Kazakh AgroTechnical University (KATU). Classes can be held in three languages: Russian, Kazakh, and English for multilingual groups [2].

The laboratory is a computer class, with software and methodological support, imitating real physical phenomena. For several years in KATU, studies were conducted on student groups to examine the influence of the virtual environment on students [16]. This research showed in particular how the computerization of cognitive activity affected the level of mastering the Physical Science. The experiments were carried out within the framework of training and research work and during the laboratory and practical classes. Students were divided into a "control group" in which the work was performed in a traditional laboratory, and an "experimental group," or a "mixed group" in which students did part of the work traditionally, and part of it – In a virtual environment.

Based on the study results, it was concluded that the virtual environment made it possible to individualize the learning process not only in terms of the pace of studying the material but also in terms of the students' logic and type of perception. Also, it allows the organization of distance learning for students who miss classes due to illness or other acceptable excuses (Figure 2).

Every year, applicants show a lower level of initial knowledge in physical and mathematical disciplines, even despite the use of innovative and progressive teaching methods that develop intelligence and critical thinking, instill independence, the ability to analyze, generalize and draw conclusions, and develop logical thinking.





Fig. 2: Online lectures for distance learning students

The monitoring of the education quality implies the development of criteria for the assessments of knowledge for any stage of education. The calculation of students' progress rating can be one of the approaches to this problem. The assessment of the output knowledge of the students' progress rating can be done by using the electronic journal, which is the part of KATU's automated information system since 2009.

To conduct the research, the authors chose the specialty 5V071900 "Radio Engineering, Electronics, and Telecommunications". Students of this specialty study physics, the volume of which is only 6 credits (270 hours including lectures, laboratory and practical classes and independent work of students), for two semesters. There are table data from electronic journals of students for years 2009-2010 and 2017-2018 below. The rating policy is based on a scale of 0 to 100 and provides the following distribution of points. There are 60 points for current and two midterm tests during the semester in total, for the final control the maximum is 40 points.

Table 1 shows the initials of the students from group 18, who studied in their first year in 2009-2010 (the specialty is 5V071900 "Radio Engineering, Electronics and Telecommunications"). The columns 3 and 4 display the results of midterm tests, conducted at 7 and 15 weeks of learning. Column 5 contains the average current points of a student, based on the results of mastering the theoretical course, attending laboratory and practical classes and controlling of a student's independent work during the semester on all topics. Column 6 shows the average results of the three previous columns and column 7 presents them as 60% of a student's assessment during the semester. There are students' exam points in column 8, which in column 9 are estimated at 40% of the total assessment of students' progress. The sum of columns 7 and 9 gives the final point of students' progress. Columns 11 and 12 contain students' grades in the alphabetical and digital equivalents of points, adopted in the credit rating technology and traditional system.

In addition to the above types of control, the students held a monthly check that allowed a quick response to students' absence, helped to find the reason for it and notify the dean's office in time. Table 1 shows that only those students who scored at least 50 points in column 6 were allowed to the final test. During the exam, they could score any sum of points, but to pass the exam successfully, students needed to score at least 50 points in column 10. However, after a while, this university system of knowledge assessment was improved, and students who passed the examination were only those who scored at least 50 points.

Table 1: Electronic examination-rating report in physics for group 18 during 2009-2010

No.	Student's name	M1%	M2%	CP %	CP_{avg} M_{avg}, %	*60%	Exam points, %	*40	Exam score		
									Total score, %	Credits	Grades
1	A.T.M.	100	100	100	100	60	87	34.7	**95**	4.0	Excellent (A)
2	A.A.S.	80	90	60	77	46	61	24.4	**70**	2.33	Satisfactory (C+)
3	B.A.S.	70	80	0	50	30	27	10.7	**41**	0	Unsatisfactory (F)
4	V.M.V.	85	75	33	64	39	45	18.1	**57**	1.33	Satisfactory (D+)
5	G.V.V.	85	80	40	68	41	50	19.9	**61**	1.67	Satisfactory (C-)
6	D.A.V.	85	80	35	67	40	47	18.9	**59**	1.33	Satisfactory (D+)
7	Z.H.A.	90	100	89	93	56	79	31.7	**88**	3.33	Good (B+)
8	I.D.S.	90	100	90	93	56	80	31.9	**88**	3.33	Good (B+)
9	K.M.G.	80	85	47	71	42	53	21.3	**64**	1.67	Satisfactory (C-)
10	K.A.A.	85	100	76	87	52	72	28.7	**81**	3.0	Good (B)
11	K.E.N.	80	85	64	76	46	62	24.8	**71**	2.33	Satisfactory (C+)
12	S.A.N.	80	80	53	71	43	56	22.2	**65**	2.0	Satisfactory (C)
13	S.A.	85	100	58	81	49	63	25	**74**	2.33	Satisfactory (C+)
14	K.Y.A.	80	80	32	64	38	45	17.9	**56**	1.33	Satisfactory (D+)
	Average:	83.9	88.2	55.5	75.9	45.5	58.97	23.588	**69.29**	2.14	

For comparison, the authors present data from the electronic journal of the same specialty 5V071900 "Radio Engineering, Electronics, and Telecommunications" for the 2017-2018 academic year (Table 2, Figure 3).

Only those students whose grade point average (GPA) was at least 50 points were allowed to the final control. Those who pass the exam are those students who scored 50 or more points and overcomed the total score (TS) threshold. The last column in Figure 3 indicates GPA and TS on the average score of the group (AS – the average score of the group). In this group, only 19 out of 24 students successfully passed the exam, the rest were either not allowed to the final control or could not pass it.

Table 2: Electronic examination-rating report in physics for group 12 during 2017-2018

No.	Student's name	M1%	M2%	CP %	Exam points, %	Exam score		
						Total score, %	Credits	Grades
1	A.A.E.	50	50	57.62	50	52	1.0	Satisfactory (D)
2	2. A.D.M.	55	50	56.59	50	52	1.0	Satisfactory (D)
3	3. B.A.E.	80	80	70.76	74	76	2.67	Good (B-)
4	4. B.F.G.	50	40	66.43	50	40	0	Unsatisfactory (F)
5	5. B.N.G.	45	20	38.69	0	0	0	Unsatisfactory (F)
6	6. G.Z.A.	55	50	60.06	50	53	1.0	Satisfactory (D)
7	7. G.S.V.	50	60	52.92	50	53	1.0	Satisfactory (D)
8	8. D.I.R.	50	50	50.31	50	50	1.0	Satisfactory (D)
9	9. D.A.A.	75	72	79.74	70	73	2.33	Satisfactory (C+)
10	10. D.K.R.	60	80	78.54	80	76	2.67	Good (B-)
11	11. I.S.ZH	60	60	67.76	50	58	1.33	Satisfactory (D+)
12	12. I.T.R.	50	60	70	50	56	1.33	Satisfactory (D+)
13	13. K.A.A.	35	0	40.14	0	0	0	Unsatisfactory (F)
14	14. K.C.Z.	40	40	38.97	0	0	0	Unsatisfactory (F)
15	15. K.S.Z.	55	70	52.66	60	60	1.67	Satisfactory (C-)
16	16. M.M.K.	35	70	55.29	50	52	1.0	Satisfactory (D)
17	17. N.N.V.	45	57	48.81	50	50	1.0	Satisfactory (D)
18	18. S.D.M.	55	60	63.25	75	66	2.0	Satisfactory (C)
19	19. C.Z.A.	50	60	71.55	50	56	1.33	Satisfactory (D+)
20	20. T.S.G.	60	50	64.62	80	67	2.0	Satisfactory (C)
21	21. T.M.S.	75	45	68.02	50	58	1.33	Satisfactory (D+)
22	22. T.A.N.	35	40	32.38	0	0	0	Unsatisfactory (F)
23	23. T.E.K.	75	70	73.1	80	76	2.67	Good (B-)
24	24. T.M.D.	80	70	84.29	72	76	2.67	Good (B-)
	Average:	83.93	88.2	55.5	58.97	65.0	1.70	

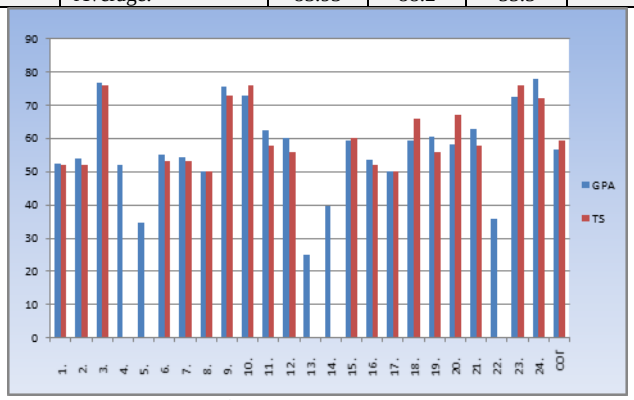


Fig. 3: The progress of the group 12 on a specialty 5V0071900 in the 2017-2018 academic year in physics. GPA – grade point average, TS – total score

The standardization of the final rating on a scale of 0 to 100 creates an optimal opportunity to compare the results of educational progress at all stages of training. It is possible to trace and compare the differentiating ability of the "mark" and the estimated equivalent in the rating form since 2009. The comparison of the "average score" and the rating (Table 3, Figure 4) by year is as follows.

Table 3 shows the data on the students' progress on the specialty 5V071900 "Radio Engineering, Electronics and Telecommunications" by years, where the grade point average for the group (GPA) is indicated in column 3, columns 4 and 5 contain the examination point (EP) and the TS on the average for the group.

Table 3: Electronic examination-rating report on specialty 5V071900 by year in physics

Group	Years	GPA	EP	TS
118 RET	2009-2010	75.9	58.97	69.29

117 RET	2010-2011	76.5	66.76	72.71
111 RET	2011-2012	71.0	61.83	67.27
112 RET	2012-2013	76.7	66.99	72.86
109 RET	2014-2015	59.7	52.96	57
111 RET	2016-2017	63.7	67.94	69.94
112 RET	2016-2017	63.0	65.4	63.9
122 RET	2016-2017	64.2	55.36	60.55
112 RET	2017-2018	56.51	59.55	60.55
113 RET	2017-2018	53.44	54.71	55.571

Figure 4 represents the especially noticeable dynamics of academic progress by year in physics. The GPA and TS decreased from 60-80 points to 55 from 2009 to 2018.

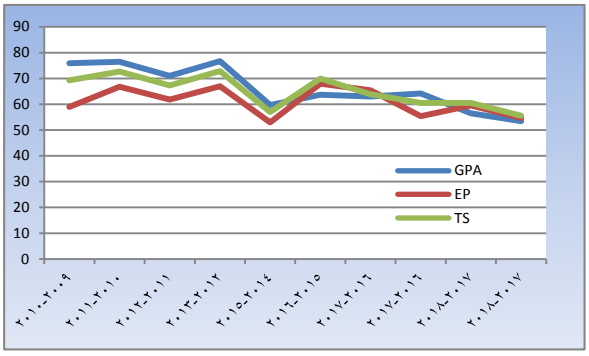


Fig. 4: The progress of students on specialty 5V0071900 in physics by year

Monitoring of the educational process shows that the initial knowledge determines the academic performance and the starting rating of applicants for the last few years has decreased, the secondary school mainly trains graduates on specific subjects to pass UNT. In recent years, there has been a situation when students who won grants did not have the elementary knowledge of mathematics, let alone the knowledge of physics or other natural science disciplines.

In order to improve academic performance, there should be additional work on general science subjects with first-year students: completion of the program of school disciplines, training on independent work, teaching how to summarize texts and write abstracts, solving logical tasks, and much more, which is the key to successful education on special subjects at senior years.

Earlier in this article [1], [3], conclusions were drawn based on the study of the educational process in groups with multilingual education. According to these conclusions, the study of natural science disciplines, such as physics, mathematics, chemistry, and biology in English, causes certain difficulties, since these disciplines are difficult for perceiving. Some experienced researchers [12] agree with the authors. They believe that education reforms in Kazakhstan are proceeding hastily, without in-depth analysis and taking into account specific conditions and with no long-term forecasts. Indeed, 2.5 million children in Kazakhstan study in 7.500 schools, 70% of which are rural (and half of them are ungraded), so there is no purpose to speak about the creation of new types of schools like Finnish or Japanese ones. Kazakhstan has other geographic, climatic, economic, social and ethnocultural conditions. Nowadays, Kazakhstan has faced consequences of the work done in the 1990s, which, most likely, was dictated by the need to restructure the education system to the requirements of the principles of a market economy and by the need to invest the money that the young country received from organizations such as the Asian Development Bank and The World Bank. That being the case, the reforms were carried out under their dictation without taking into account the specificity of the country. Moreover, the same thing is happening now. The use of English as a teaching language requires at least three conditions – an English-speaking teacher, an English-speaking student and authentic materials to study.

In order to reach at least a minimum threshold level in multilingual groups, it was necessary to give lectures in three languages, first in English and then in Russian or Kazakh, thus groups with monolingual education gave more information within the same period of time. Table 3 shows the data for two groups during 2016-2017. The TS for group 111 with monolingual education was 69.94; the group 112, where part of the students who studied at the school in the state language attended classes in Russian, scored 63.9, and the total score for group 122, where part of the disciplines was taught in English, was 60.55. Thus, monolingual group 112 showed highest academic achievement score, the lowest was in multilingual groups.

4. Conclusion

The virtual environment makes it possible to individualize the learning process not only in terms of the pace of studying the material but also in terms of the students' logic and type of perception. Also, it allows the organization to offer the distance learning for students who miss classes due to illness or other acceptable excuses. Virtualization of the educational space provides an opportunity to independently search for materials on the Internet for the preparation of reports and abstracts, and also assists in finding answers to problematic issues. The speed and accuracy of the collection and processing the information regarding the success of training are repeatedly increased. Due to computer testing and knowledge control, it is possible to carry out an operative correction of the learning process using the received analytical material. At the same time, as the general level of students' physical and mathematical literacy has declined, both in the secondary school and in the higher one, teachers have to find ways to improve the training of specialists in the field of natural science disciplines. One of the ways to solve this problem is to use the technologies of virtual educational space [18].

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