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STEM EDUCATION AS A TOOL FOR THE EFFECTIVE IMPLEMENTATION OF THE APPLIED ORIENTATION OF PHYSICS TEACHING

Abstract. Given the High role of future physics teachers in the development of Natural Science and technology, it is undoubtedly relevant to promote them to become competitive specialists in their professional activities. Therefore, there is a need to create an opportunity for future physics teachers to take a place in the world competition in the field of Science and technology by identifying advanced technologies for mastering professional competencies, introducing them into the educational process. As one of the advanced technologies – STEM education allows future physics teachers to develop as a person who can meet the requirements of the labor market, business and high-tech industries. Therefore, in the article, we considered effective methods of teaching, such as deep and comprehensive acquisition of knowledge through the wide use of Information Communication and STEM technologies in the teaching of the subject "Electricity and Magnetism", as well as the problems of mastering the scientific foundations of the subject. He not only acquired knowledge from the subject "Electricity and magnetism", but also applied the knowledge gained in everyday life, equipment, technology, etc. we showed the ways of developing the student's ability to think and creative activity.

Keywords: STEM, Electricity and magnetism subject, technology, teaching physics, students.

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STEM білім беру – физиканы оқытудың қолданбалы бағыттылығын тиімді жүзеге асыру құралы

Аңдатпа. Жаратылыстану мен технологияны дамытудағы болашақ физика мұғалімдерінің рөлі жоғары екенін ескере отырып, олардың кәсіби қызметінде бәсекеге қабілетті маман болып қалыптасуына ықпал ету өзекті мәселе екені сөзсіз. Физиканы оқыту үдерісінде STEM тәсілі білім алушылардың белсендірек болуы және ғылым мен

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технологияны қолдануға негізделген идеяны іске асыру құралы ретінде қызмет етеді. Сондықтан болашақ физика пәні мұғалімдеріне кәсіби құзыреттілікті меңгерудің тиімді технологияларын таңдап, оларды білім беру барысында қолданып, ғылым мен техникадағы бәсекелестікте орын алуына жағдай жасау қажеттілігі туындайды. Озық технологиялардың бірі ретінде – STEM білім беру болашақ физика мұғалімдеріне еңбек нарығының, бизнестің және жоғары технологиялық өндірістердің талаптарына жауап бере алатын тұлға ретінде қалыптасуына мүмкіндік береді. Сондықтан авторлар зерттеу жұмысында физиканы оқытуда STEM технологияларын кеңінен қолдану арқылы білімді терең және жан-жақты меңгеру сияқты оқытудың тиімді әдістерін қарастырған, сонымен қатар физиканың қолданбалы бағыттарын меңгеру арқылы студенттердің физиканы оқу мотивациясының артатынын анықтады. Студенттердің физиканың қолданбалы бағыттарын оқу мотивациясы SMTSL сауалнамасы көмегімен анықтаған. Берілген зерттеу нәтижесінде физиканы оқытудың қолданбалы бағыттылығын тиімді жүзеге асыру құралы ретінде STEM білім беруді пайдалану студенттердің оқу мотивациясын арттыратыны көрсетілді.

Кілт сөздер: STEM, технология, физиканы оқыту, білім алушылар, оқу мотивациясы.

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STEM образование – как инструмент эффективной реализации прикладной направленности преподавания физики

Аннотация. Учитывая высокую роль будущих учителей физики в развитии естествознания и техники, несомненно, актуальным является вопрос оказания влияния на их профессиональное развитие в конкурентоспособных специалистов. Поэтому существует необходимость создания условий для того, чтобы будущие учителя физики заняли место в мировой конкуренции в области науки и техники путем выявления передовых технологий приобретения профессиональной компетентности и внедрения их в учебный процесс. Являясь одной из передовых технологий, образование STEM позволяет будущим учителям физики стать личностями, способными удовлетворить запросы рынка труда, бизнеса и высокотехнологичных отраслей. Поэтому авторы в исследовательской работе рассмотрели эффективные методы обучения, такие как глубокое и всестороннее усвоение знаний за счет широкого использования STEM-технологий в преподавании физики, а также обнаружили, что мотивация студентов к изучению физики повышается за счет освоения прикладных направлений физики. Мотивация студентов к изучению прикладных направлений физики определялась с помощью анкеты SMTSL. В результате данного исследования было показано, что использование STEM-образования как средства эффективной реализации прикладной направленности обучения физике повышает учебную мотивацию студентов.

Ключевые слова: STEM, дисциплина «Электричество и магнетизм», технология, преподавание физики, обучающиеся, учебная мотивация.

Introduction

One of the main goals of teaching physics, the organization of the educational process in the discipline in the context of spiritual education.

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The general education system occupies an important place in the development of the economy and public relations of each country. This is because, in the theory of scientific knowledge, the educational system is the main condition for building research from the point of view of the main problems of philosophy. The most important feature of the theory of scientific knowledge is that it creates general principles of being.

Today, for the successful assimilation of knowledge of physics, it is not enough to describe phenomena and laws. Significant changes in the modern labor market of the world require that students, that is, future specialists, be able to skillfully work with various data, master innovative technologies and apply the acquired skills in real life. High school graduates should be able to compete with students of leading foreign universities, effectively applying the skills acquired in the field of studying general physics, studying at a higher educational institution and forming their profession.

Currently, many countries of the world are updating the content of Education. One of the areas of new educational content involves the idea of maximum integration into real life through the effective use of STEM integrated interdisciplinary programs [1].

STEM (S – science, T – technology, E - engineering, M – mathematics) means the relationship between science and technology with natural sciences, as well as access to new engineering ideas and solutions using mathematics. In 1989, the United States first introduced STEM education, and in 2011 it was fully included in the K-12 Section. With the rapid development and deepening of learning research through the STEM course, the STEM curriculum faces many difficult challenges in practical learning.

The concept of STEM programs reflects the construction of a diagram or model within the framework of a particular physical problem after students have mastered theoretical information in Physics in advance. In this activity, students need to use the basics of mathematical knowledge, creative abilities, the ability to come up with new ideas and control forecasts, work out in accordance with the requirements for the properties and quality of a new product [2].

In January 2019, at the World Economic Forum “Industry 4.0: targets for the development of industrial technologies and innovations” in Geneva, Switzerland, the possibility of solving problems in today's industrial sphere and creating a future workplace through the introduction of innovations in the context of training future specialists and improving the skills of workers was announced [3]. This circumstance demonstrates the relevance of the problems of determining what needs employers expect from graduates in technical, including in the field of physics, on the way to the Industrial Revolution 4.0.

The determining factor in the effective and high – quality development of the education system is the use of STEM technology in improving the training of future teachers. Improving the readiness of the future teacher to use STEM technology is one of the pressing problems of modern requirements in higher education [4–5]. Ways to form future teacher training on the basis of STEM technology are considered in the research of many scientists and are becoming an urgent problem.

Among them, it is important to use physics as a tool for the effective implementation of applied learning. In this study, in order to determine the effectiveness of the implementation of training in the applied direction, students of the “Young radio engineer” circle are engaged in electrical generator-mechanical energy, conversion into electrical energy, etc. Based on the topics, the measurement of learning motivation in studying physics is considered. Education in this circle is based on STEM technology. During the study, students' motivation to study physics was determined using the SMTSL (students' motivation toward science learning) questionnaire. The questionnaire consists of 35 statements covering six aspects of motivation. Based on a survey of students, they pointed out that many physical theories are explained without mentioning their practical applications. Therefore, the purpose of the study is to analyze the influence of the use of STEM

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educational technology as an effective tool for implementing the applied orientation of physics education on students' learning motivation.

The rapid development of STEM technology and the expansion of its functional capabilities allow them to be widely used at all stages of the educational process. The possibilities of using STEM technology in physics training are high.

Research methods and materials

The study of the effective implementation of the applied orientation of teaching physics using STEM education included various methods to obtain a comprehensive understanding of the problem. Here are the research methods that we used to study this topic: literature analysis - conducting a literature review and analysis of scientific publications, articles, books and documents related to teaching applied aspects of physics through STEM education; observation, analysis of personal experience, Students Motivation Toward Science Learning (SMTSL) testing; pedagogical experiment with mathematical processing of the results obtained and analysis of the data obtained.

In this study, the experiment was conducted by getting a group of students to take a test before and after the experiment. That is, one group of students is tested before and after using the same teaching method. Using this method, the influence of only one group of students on the motivation to study applied fields of physics using STEM educational technologies is studied.

Currently, the system of didactic tools used by the teacher during the lesson and outside the lesson can be considered sufficient for the implementation of teaching physics in the applied direction. A physics teacher can teach solving problems of practical importance in physics based on the necessary materials without special training.

Let's name the main conditions necessary for the development of students ' scientific knowledge in the applied direction:

- increase the scientific degree of teaching the discipline, strengthen the focus on the study of physical theories, and widely use it to understand the properties of physical phenomena and bodies;

- constant mixing of elements of research into the educational process of physics, various types of educational activities of students (including solving problems), the implementation of a research approach to the study of certain topics and problems of physics.

The most important tool for the development of students in the applied direction is the solution of problems related to the research element. When solving problems, students find rational methods of calculations and measurements, determine in what conditions the work of technical installations will be most effective, the importance of the problems is especially great.

Currently, we have identified the reasons for the inability of students to apply physical knowledge to solving problems of practical importance, in our opinion, we believe that the reason for this is the teacher's inability to organize the student's activities.

Thus, one of the tasks of improving the professional training of future physics teachers is the formation of the organization of students ' activities to teach them to solve qualitatively applied problems.

Solving qualitative problems in the process of performing laboratory work in physics is of great educational and educational importance. When conducting physical experiments, students are convinced of the reality of physical laws, as well as get acquainted with the methods used in the course of scientific research work. In the course of laboratory work, students have a deeper understanding of the laws of physics and a desire to further study these laws in depth. In addition, skills are formed to be able to work with measuring devices and learn to consciously apply the knowledge gained in everyday life. Laboratory work ensures the applied orientation of training, playing an important role in education. A successfully completed laboratory lesson increases the educational activity of students and activates cognitive activity.

In laboratory classes, the following qualitative problems can be solved:

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- demonstration of the studied laws (justification of correctness), for example, a condition for checking the balance of the lever, an indication of the Ohm law for the part of the chain;
- master the methods of measuring physical quantities, such as determining conductor resistance, for example, determining the current strength of an electric lamp;
- to study the relationship between physical quantities and determine the physical laws of phenomena, for example, the dependence of the current on the resistance in the circuit and the number of consumers connected in parallel;
- formation of skills in working with measuring instruments: dynamometer, scales, various types of pressure gauges, ammeters, voltmeters;
- practice drawings;
- development of students ' skills and technical knowledge;
- knowledge of the rules for repairing and operating defects of physical equipment.

Results and discussion

As a result of the analysis of the works of domestic and foreign psychologists and teachers, we came to the idea that it is necessary to consider the methodology for the formation of professional competence of future specialists at a high level based on STEM technology.

The word “STEM” has many perspectives. Bybee (2013) described several STEM perspectives in his research (Figure 1) [6].

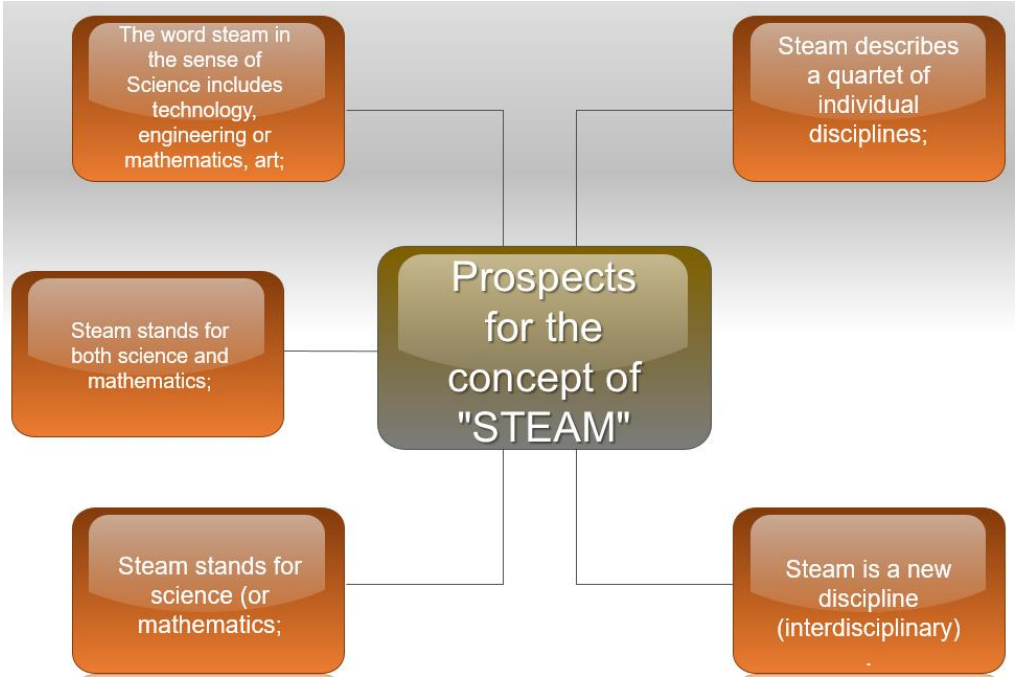

Figure 1 – Prospects for the concept of “STEM”

We found that such a new pedagogical method can solve the problems of the educational process using approaches.

Understands the relevance of the acquired knowledge and the need to motivate and use the topic under study. For example, in the chapter mechanics of liquids and gases, the student is interested in studying the properties of bodies moving in a viscous medium, makes reports on ships and parachutes. Given the possibility of putting the knowledge gained into practice, the billiard report will be more interesting than calculating the course of the collision of two bodies.

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The structure and content of the physics lesson should be determined by the following prerequisites, that is, in the lessons of problem solving, the composition of qualitative problems of the applied direction is increased, regional features are taken into account. Also, the introduction of elements of qualitative problems of the applied direction in mastering the course of physics, the content of new approaches to improving the quality of the educational process, teaching knowledge [7].

Training of students in foreign countries using educational material of Applied (Technical) Content is carried out within the framework of technological disciplines.

In the UK, the physics course considers material of an applied nature as the application of physical phenomena and laws. At the end of each section, Technical Research tasks with a detailed description are given. In physics textbooks in England, students are offered many (more than a few hundred) laboratory works, experimental problems and exercises [8].

In the Polish education system there is a special discipline called “technique”. The purpose of its training is to form a technical culture of students. The most important problem in teaching the discipline is that students acquire knowledge about the types of techniques, their most important parts and functions, the principles of operation of the most common technical objects, etc. [9].

In the United States, students participate in large design projects. The relevance of this issue led to the creation of the technological Association of students in the United States. In addition, there are a lot of Applied-oriented optional subjects in the United States: “technique”, “applied physics”, “technical modeling”, etc. [10].

In the course of physics, a lot of attention is paid to studying the problems of technology. Most physics textbooks introduce modern technical objects at the beginning of each topic. The student is told about the importance of the practical application of the material being taught and the household devices known to them. Then the physical foundations of their functioning are mentioned. It should be noted here that in domestic textbooks, as a rule, the physical significance of the first phenomenon is considered, followed by its application in technology. In physics textbooks, in separate paragraphs, American students are given the task of independently assembling experimental installations and experimenting using the same simple devices. Instructions for creating these practices will be given, but the necessary tools for practice will need to be selected by students themselves. The Applied Technical material is also presented in the content of questions and tasks (explanation of the physical foundations of the functioning of the technical object, calculation of the parameters of the technical object, etc.).

Analyzing the theory and practice of physical education abroad, we came to the conclusion that their application of the problems of Applied orientation in the process of teaching physics is real. We found that the applied orientation of teaching physics is determined in the study of various objects of technology, in the independent technical activity of students, in solving problems of an applied nature, etc.

The practice of introducing applied-oriented laboratory and practical classes in the educational process is also being expanded. This process is largely due to the widespread introduction of STEM technology in the educational process, which is facilitated by the educational experiment.

The types of extracurricular activities of an applied orientation are identified (excursions, physical and technical circles, physics evenings, etc.).

At the Department of physics of Khoja Akhmet Yassawi International Kazakh-Turkish university, a physics and Technology Circle “Young radio engineer” was established. Students studying in the educational programs 6B01510, 6B05348 – Physics take part in this circle with great interest (Figure 2).

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Figure 2 – Technology Circle "Young radio engineer"

For example, students used the empirical method in practical research work and developed generators, familiarizing themselves with the functions of equipment (Figure 3).

Figure 3 – Practical work of students

In general, an electric generator is a device that converts mechanical energy into electrical energy. It is based on the principle of electromagnetic induction, discovered by Michael Faraday in 1831. A simple example of an electric generator is an AC generator. It consists of a wire that moves in a magnetic field. When a wire moves inside a magnetic field, an electromotive force is created that creates a current in the wire.

Electric generators are widely used to generate electricity in power plants, wind turbines, hydroelectric power plants and other renewable energy sources. They are also used to charge batteries in cars.

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So, if we consider the physics of our STEM performed by students research project. The principles of operation of generators and transformers are based on magnetic flux. Magnetic flux uses machines that convert mechanical energy into electrical energy (generators) or convert electrical energy into mechanical energy (Electromotive forces). The operation of all powerful electric current generators is based on the phenomenon of electromagnetic induction of the movement of a conductor in a magnetic field. The phenomenon of electromagnetic induction, on the other hand, is the formation of an induction current during a change in the magnetic flux through which a closed conductor pierces the circuit.

The main parts of the generator are as follows:

1) inductor – a device that generates a magnetic field. It can be a permanent magnet or an electromagnet. In the generator we are creating, it is a device consisting of a magnet.

2) anchor – a winding on which EMF is formed. We made and installed this winding using copper wire.

One of these parts rotates, if we call it a rotor, and the other is called a stationary part – a stator. This stator is our anchor. When the rotor rotates, an electric current is generated by the magnetic flux alternately crossing each phase of the stator winding. In this way we can generate electricity through the generator.

The peculiarity of our STEM research project is that the generator is used to provide energy for the use of agricultural and industrial technologies. It should be noted that the power generator based on water pressure is highly efficient in frequency regulation, performing additional loads and providing emergency reserves of the power system. The water mill is one example of the successful application of agricultural technologies for small farms. Water mills were the first device to convert natural energy resources into mechanical energy for the use of some technique.

We made a brief review of the methods and types of implementation of the applied orientation of modern physics teaching and made sure that these concepts are being expanded and refined.

Means for the implementation of the applied orientation of teaching physics today. The means of organizing classes related to questions of Applied Physics include, first of all, material objects, models of to (devices, tools, machines) and to; equipment for demonstration experiments and laboratory work, etc. Today, new technical objects are widely used: computer hardware and some elements of robotics.

To solve the problems of preparing university students for the production of a new applied substance, combining the knowledge gained in several disciplines, it is necessary not only to re – equip industry and switch to high-efficiency technologies, but also to significantly increase the intellectual potential of the nation-the ability of people to create and assimilate knowledge, create and maintain a high technical culture of complex and scientific production. That is why the formation of students' skills in applying the results of STEM technology in their future economic activities is the main problem of socio-economic development, ensuring the economic survival of the country, its national security and sustainable development, and, of course, the education system of the Republic of Kazakhstan as a whole.

Since the problem of our research is aimed at creating a methodology and technology for increasing the applied orientation of teaching physics to future physics teachers using STEM technology, we can say that this issue is becoming especially relevant in the transition to a system for training future physics teachers. In the context of informatization of knowledge, the educational process in physics should be thought out in such a way as not to lose the best aspects of traditional forms of training, but also to show the enormous potential of modern achievements in the field of STEM technology to improve the creative process and the quality of training of a qualified specialist in general. Training of future physics teachers and ensuring their needs for quality education should be carried out in such a way as to meet the conditions of informatization of knowledge.

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In this regard, during our research, a group of students from the "Young radio engineer" club, under the guidance of a teacher, implemented this project based on STEM educational technology in five stages (Table 1).

Table 1 – Stages of project implementation based on STEM educational technology of "Young radio engineer" club

Preparation period	Using the knowledge gained by students before; Distribution of tasks by dividing students into groups; Collecting material, creating a project design	100%
The stage of execution	Creating a project based on your own design; Launch and test the product you received; Identification of problems.	100%
Presentation	Creating a project presentation; Presentation of solutions to the problem	100%
Readjustment	Identify the shortcomings of the project and send it for correction	100%
Rating	Product adjustment based on the recommendations given	100%

One of the directions of modernization of knowledge is the introduction of ICT tools into the educational process. ICT provides the conditions for the formation of a new type of knowledge necessary for the development of modern society. Therefore, in the context of informatization of the education system, the problem of developing directions, methods and types of ICT use in increasing the applied orientation of teaching physics is relevant.

In addition, in the qualification description of The Bachelor of 6B01510-Physics, the future physics teacher must be prepared to perform the following functional duties:

- to carry out pedagogical and educational activities, including through the use of modern pedagogical and information technologies;
- conducting scientific research in the chosen direction and relevant areas;
- participation in all stages of design, implementation and further continuation of the results of scientific research;
- it is said that ICT should be able to effectively use the scientific basis for the organization of its own labor and independent training.

Currently, it is known that the majority of university teachers in teaching physics courses use STEM technology when considering the problems of Applied Physics. The use of STEM technology in the process of physical education makes it possible to activate the educational process in pedagogical practice, increase the system of psychological and pedagogical technologies that implement the ideas of developing learning.

The possibilities of using STEM technology as a new tool for teaching physics, gave rise to new methods of teaching and types of its organization, a new attempt to quickly integrate them into the educational process.

As we have already mentioned, the teacher needs to ensure the creation of an innovative educational environment. To do this, the teacher must use STEM technology (hardware and software), as well as traditional means of implementing the dual orientation of training. One of the software components of STEM technology is the presence of technical information in various media formats in the educational resources on Applied Physics. They are:

- symbolic objects (symbols, symbols, texts, graphs, schemes, tables, etc.);
- visual objects(photos ,images, scenes), computer graphics objects (including images, copies);
- audio information (oral reading texts, explanations of virtual objects, music, sounds of natural processes, etc.);

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- virtual reality environment (interactive models (including 3D models), trainers, interactive constructors, virtual laboratories, etc.

The variety of presentation of educational material makes it visual and accessible for assimilation, arouses interest in learning, stimulates cognitive activity and independence of students.

The SMTSL test questionnaire developed by N. Tuan was taken to students before and after the study to determine their learning motivation [11]. A total of 21 students took part in the study. Table 2 below shows the design of the study.

Table 2 – Research design for a group of students

Stage 1	Stage 2	Stage 3
Pre-test SMTSL test	Implementation of teaching applied areas of physics using STEM educational technology	Post-test SMTSL test

SMTSL testing consists of 35 statements on five motivation scales. The five scales include self-efficacy, active learning, the importance of mastering scientific and applied knowledge, the goal of achieving results, the goal of achievement, and a learning environment that motivates. This means that on a five–point scale in the questionnaire, 5 – Completely agree, 4 – agree, 3 – no answer, 2 – disagree, 1 – against (Table 3).

Table 3 – Classification of motivation by statements in SMTSL testing

Motivation scales	Statements	Total
self-efficacy	1, 2, 3, 4, 5, 6, 7	7
active learning	8, 9, 10, 11, 12, 13, 14, 15	8
the goal of achievement	16, 17, 18, 19, 20	5
the goal of achievement	21, 22, 23, 24, 25, 26, 27, 28, 29	9
motivating learning environment	30, 31, 32, 33, 34, 35	6
Total		35

Table 4 – Results of students' motivation to study physics on the basis of STEM educational technology before and after the experiment

	Number of students	Minimum Score	Average Score	Maximum Score
Before the experiment	21	55,6	70,1	90,2
After the experiment	21	68,3	75,8	87

As can be seen from the table 4, the minimum score of 21 students who participated in the experiment increased by 12.7. In addition, we note that the pre-experiment maximum score decreased by 3.2. The average score of students' motivation for learning before and after studying the process of teaching physics on the basis of STEM educational technology changed by 5.7. Therefore, the results show that students have increased motivation to study applied areas of physics.

Conclusion

And if we formulate the potential of teaching applied physics questions using STEM technology tools in the implementation of the applied orientation of teaching physics to future physics teachers at universities in our country:

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1. Practical Data on the tendency to use STEM technology tools in the process of physics education have been collected only since 2000. The university has not conducted enough research on STEM technology tools with technological devices.

2. Modern electronic textbooks are presented with information of an applied orientation in comparison with traditional textbooks. In most electronic textbooks, tasks from traditional printing textbooks are copied.

3. Although the number of teachers and methodologists engaged in STEM-based training is increasing, universities are increasingly using traditional methods and tools to study the problems of Applied Physics.

4. Applied Physics in the educational process should not be limited to reflecting the basic principles of the operation of individual technical means. The results of the study clearly show that in the process of teaching physics, it is important to raise learning motivation by performing a project using STEM technologies.

It is necessary to draw the attention of students to the fact that the main tool for performing calculations in practice is STEM technologies. Therefore, in the process of practical and laboratory work, for example, practical or manual STEM tools can be widely used. It can be concluded that the motivation of students to study the areas of applied physics based on STEM educational technology increases significantly.

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