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# STEAM TECHNOLOGY AS A TOOL FOR DEVELOPING CREATIVITY OF STUDENTS: ON THE EXAMPLE OF A SCHOOL PHYSICS COURSE

**Abstract.** Physics as a discipline has a great influence on the development of science and technology, engineering. A student who has worked in physics lessons with equipment and conducted experimental observations of phenomena with physical laws will be ready to perform any practical actions. The lack of demonstration rooms or equipment failure in schools create many obstacles. As a result, the graduate of the school becomes less interested in choosing technical and engineering specialties. One of the urgent problems in the school physics course is the preparation of students who are able to clearly search for physical laws and phenomena, conclusions, questions and reasons, assimilate information through the right choice of scientific literature and achieve new results, inclined to work with advanced technical equipment. The aim and the leading idea of our research is to develop the training of students in the field of physics based on STEAM education, to identify problems of weakening of natural-technical and engineering components in secondary school. In the course of the study, the world practice of STEAM was studied, a literature review based on articles in academic databases was conducted. The results of the study showed a lack of knowledge in the academic literature in this area. The article presents didactic conditions for the development of advanced technology for teaching a school physics course based on STEAM, the possibility of increasing the number of creative students who are able to work on various projects leading to new ideas. The results of the study allow us to create high-tech products based on STEAM at school bases.

**Keywords:** STEAM technology, creativity, school physics, student, didactic condition.

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## STEAM технологиясы білімгерлердің креативтілігін дамыту құралы ретінде: мектеп физика курсы мысалында

**Аңдатпа.** Физика пән ретінде, ғылым мен техниканың, инженерлік салалардың дамуына зор ықпал етеді. Физика сабақтарында құрал жабдықтармен жұмыс жасап, физикалық заңдармен құбылыстарды эксперименттік бақылаулардан өткізкен білімгер кез-келген практикалық іс-әрекеттерді орындауға дайын болады. Мектептерде демонстрациялық кабинеттердің жетіспеушілігі немесе құрал жабдықтардың істен шығуы көптеген кедергілерді туындатады. Соның салдарынан мектеп бітіруші түлек техникалық - инженерлік мамандықтарды таңдау қызығушылығы төмен болады. Мектеп физика курсында физикалық заңдар мен құбылыстарды, тұжырымдарды, сұрақтар мен себептерді нақты іздей алатын, ғылыми әдебиеттерді дұрыс таңдау арқылы ақпаратты меңгеретін және жаңа нәтижелерге қол жеткізе алатын, озық техникалық құрал – жабдықтармен жұмыс жасай алуға бейімді оқушыларды даярлау өзекті мәселелердің бірі болып табылады. STEAM білім беру негізінде оқушылардың физика саласындағы даярлығын дамыту, орта мектептеде жаратылыстану-техникалық және инженерлік құрамдас бөліктерінің әлсіреуі мәселелерін айқындау біздің зерттеуіміздің мақсаты және жетекші идеясы болып табылады. Зерттеу барысында STEAM-нің әлемдік практикасы зерделенді, академиялық мәліметтер базасындағы мақалаларға негізделген әдебиеттерге шолу жасалынды. Зерттеу нәтижелері осы саладағы академиялық әдебиеттерде білімнің жеткіліксіздігін көрсетті. Мақалада мектеп физика курсын STEAM негізінде оқытудың озық технологиясын жасаудың дидактикалық шарттары, жаңа идеяларға жетелейтін әр-түрлі жобалармен жұмыс жасауға қабілетті креативті білімгерлердің санын ұлғайтудың мүмкіндіктері келтірілді. Зерттеу нәтижелері мектеп базаларында STEAM негізінде жоғары технологиялық өнімді құруға мүкіндік береді.

**Кілт сөздер:** STEAM технология, креативтілік, мектеп физикасы, білімгер, дидактикалық шарт.

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## Технология STEAM как средство развития креативности обучающихся: на примере школьного курса физики

**Аннотация.** Физика как дисциплина оказывает большое влияние на развитие науки и техники, инженерной сферы. Обучающийся, работавший на уроках физики с оборудованием и проводивший экспериментальные наблюдения явлений с физическими законами, будет готов к выполнению любых практических действий. Нехватка демонстрационных кабинетов или отказ оборудования в школах создают множество препятствий. Как следствие, выпускник школы становится менее заинтересованным в выборе технико-инженерных специальностей. Одной из актуальных проблем в школьном курсе физики является подготовка учащихся, способных четко искать физические законы и явления, выводы, вопросы и причины, усваивать информацию через правильный выбор научной литературы и добиваться новых результатов, склонных к работе с передовым техническим оборудованием. Целью и ведущей идеей нашего исследования является развитие подготовки учащихся в

области физики на основе STEAM-образования, выявление проблем ослабления естественно-технической и инженерной составляющих в средней школе. В ходе исследования была изучена мировая практика STEAM, проведен обзор литературы на основе статей в академических базах данных. Результаты исследования показали недостаток знаний в академической литературе в этой области. В статье приведены дидактические условия разработки передовой технологии обучения школьного курса физики на основе STEAM, возможности увеличения числа креативных обучающихся, способных работать над различными проектами, ведущими к новым идеям. Результаты исследования позволяют создать высокотехнологичную продукцию на базе STEAM на школьных базах.

**Ключевые слова:** STEAM технология, креативность, школьная физика, обучающийся, дидактическое условие.

**Introduction**

The formation of a young generation with developed creativity, capable of meeting the requirements of the labor market in a dynamically developing society of science and technology, is a vivid manifestation of solving important problems.

Taking into account the high correlation of the latest achievements of technical and engineering areas with physics, we are convinced of the relevance of teaching physics based on STEAM. One of the basic principles of STEAM education is the assimilation of students' experience and research methods, which are methodologically complex. Researchers have shown that the knowledge gained as a result of mastering the STEAM approach and such experience is more important than any other experience. The second important point is the development of the engineering business, that is, the achievement of new ideas in response to production tasks. Within this position, the student masters the search for solutions to specific problems and their construction.

The joint work of the Physics Department of Khoja Akhmet Yassawi International Kazakh-Turkish University and the Sakarya University of the Republic of Turkey continues in this direction. Two doctoral students and four undergraduates have completed dissertation research at the departments in this area of research. As a result, the «Physics Handbook» applications were launched, some elements of robotics were developed using 3D printing, some equipment of STEAM classrooms was developed. Other digital resources and teaching materials have gone out of print, most of the faulty physical equipment has been updated and launched using 3D printers. This contributes to the development of students' creativity indicators [1–2].

Creativity and its characteristics, according to many authors, are associated with a set of personality qualities manifested in real professional activity [3-4].

When teaching physics, it is necessary to create conditions for the effective inclusion of self-taught students in the creative process. This is due to the fact that the creative potential of the individual develops in cognitive activity. The difficulty here lies in the organization and regulation of the creative process, which forms ideas about the creative independence of the individual.

Studying the scientific literature on creativity, one can point out two main directions that have historically developed in modern science. The first direction is associated with the consideration of creativity from the side of the general psychological and conceptual direction:

- The methodological foundations of the psychology of creativity are studied;
- Methods for diagnosing creativity are developed;
- Methods of forming a general psychological theory are implemented;
- The mechanisms of the laws of creative activity are determined.

The second direction of the study of creativity will be aimed at identifying and characterizing the abilities of a person in creative activity. Creativity and its characteristics, according to many authors, are associated with a set of personality traits that are reflected in specific professional

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activities. In modern research, there is a pace of considering creativity as a complex of intellectual characteristics inherent in each individual.

However, according to the research topic, there is not enough research on the methodology for using STEAM opportunities in developing students ' creativity.

Especially in the teaching of disciplines in the technical and Natural Sciences, Engineering, in particular physics, there is no clear didactic systems in the field of development of creativity of students, the absence of a combination of STEAM educational technology with creativity in teaching.

In the direction of considering the joint integrative multilingual practice of STEAM in educational institutions of Japan, D. Oyama M. Moor conducted a study by D. Kitano Y. Fujita [5]. The physical phenomena and patterns are explored by Rico na, Arevalo N. [6], organizing entertainment fairs using LEGO educational maps and STEAM elements.

However, in the conditions of today's rapid pace of Science and technology, the methodology of teaching students on the basis of the development of creativity through the use of STEAM education does not fall into a single system, but is formed at the level of individual recommendations.

In the resolution of the Government of the Republic of Kazakhstan dated December 27, 2019 No. 988 on approval of the state program for the development of education and Science for 2020–2025:

-it was noted that schools will be equipped with classrooms for:

Chemistry,

Biology,

Physics,

STEAM classrooms.

There are contradictions between the need to use STEAM educational technology in order to develop students ' creativity and the lack of a methodological system for realizing this need and research on the organization and conduct of the educational process on the basis of effective methods and Means.

The search for a solution to these contradictions is the goal and the main feature of our research.

To determine the theoretical foundations for the development of students 'creativity on the basis of STEAM education, to determine the didactic system of teaching on the basis of the development of students' creativity on the basis of the school physics course. In addition, STEAM influences the development of learning tools based on educational technology and the development of their application conditions.

**Research methods**

In order to identify the problems associated with the use of STEAM technology in teaching the school physics course and better understand the concept of creativity, a 2-step review of the literature was conducted. Reliable peer-reviewed articles from the Scopus and ScienceDirect databases were selected as bibliographic sources, and stages related to the special coverage of the study were implemented.

The key words selected to search for materials are as follows:

1-keyword: «STEAM technology»;

2-keyword: «STEAM education and physics»;

3-keyword: «Creativity»;

4-keyword: «School physics course».

During the study, articles from magazines were analyzed using these keywords. The topics and theses of the collected articles were carefully studied, the filtered articles were used in writing the descriptive concepts presented in the discussion section (table 1).

**Table 1 – Stage of activities in the course of the study**

| Stages | Actions |
|---|---|
| Stage 1 | - Search for articles by keywords and evaluate the content;<br>- working with websites scopus.com, sciencedirect.com (Scopus ScienceDirect);<br>- Analysis of annotations of individual articles on the above four keywords.<br>- Search for articles by linking keywords. «STEAM technology» AND «STEAM education and physics» AND «Creativity» |
| Stage 2 | - Analysis of articles collected from databases and evaluation of conclusions |
| Stage 3 | - Conclusion on the analyzed articles |

During the study, a total of 30 articles were collected, of which 18 were selected. Of the 18 articles, an analysis of the annotations of 14 articles was carried out, and the remaining 4 articles were studied in full. The analysis of philosophical, psychological, pedagogical and methodological literature on the basis of theoretical research methods was aimed at determining the indicators of creativity of students, determining the didactic conditions for the development of creativity on the basis of STEAM.

**Results and discussion**

Creativity and its characteristics, according to many researchers, are associated with a set of personality traits that are reflected in specific professional activities. In modern research, there is a pace of considering creativity as a complex of intellectual characteristics inherent in each individual.

From the analysis of scientific papers, among the most common definitions of understanding creativity, one can select the most effective ones for use by students in teaching a school physics course (Figure 1).

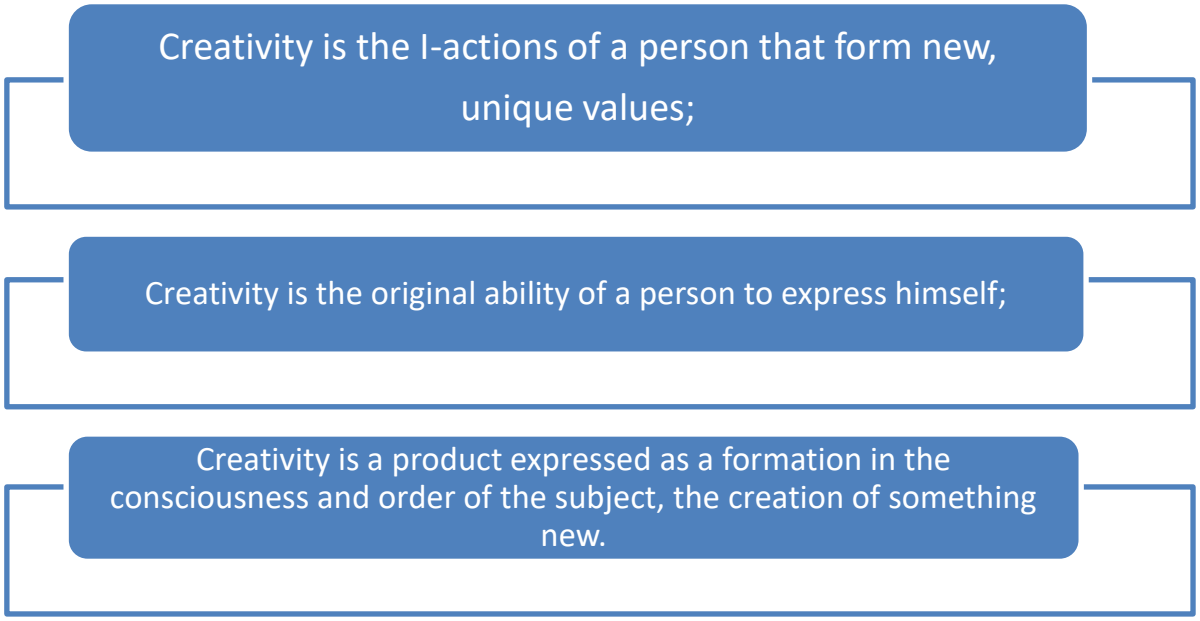


**Figure 1 – Definitions characterizing the need to develop students' creativity in teaching physics**

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In our research, the concepts of «creativity» and «creativity» are two separate worlds. The creative process is based on the inspiration of the author, his abilities and traditions. And since the main component of the creative process is the pragmatic element, the question arises of why, for whom and how to make a novelty.

Studying rreative learning, along with the psychologo-pedagogical basis for the construction of Education, consider its psychological connection with the teacher and form two main psychological conditions that contribute to cognitive creativity:

1) What is necessary to achieve psychological security:

a) recognition of the unconditional value of the person;

b) the result of his labor;

c) sharing the understanding and feeling of the inner world of a person.

2) psychological freedom, achieved through the full expression of feelings and situations, thoughts through symbols.

From the above features of the formation of creativity, we have identified in our research the forms of STEAM training aimed at the formation of creativity (Figure 2).

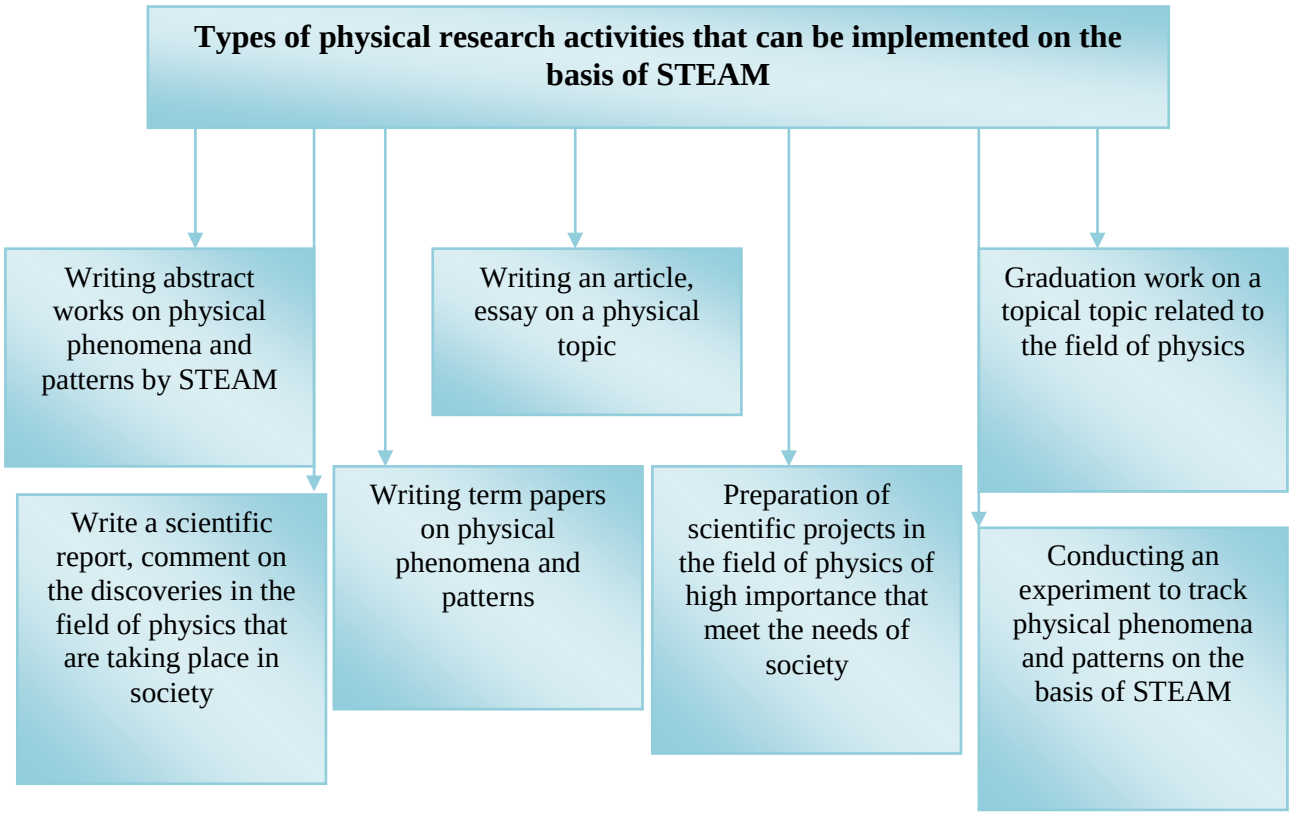


**Figure 2 – Types of physical research activities that can be implemented on the basis of STEAM**

Within the framework of our research, the content and technological (STEAM) aspects of the formation of creativity of students are identified.

Creativity is the ability to solve problems in the practical application, because the situation with decision-making requires a person to think creatively. And creativity in the field of STEAM technologies in relation to the activities of specialists in the field of physics is reflected in the search, accumulation, processing of necessary information, attracting experience for it, coordination of new structures that help determine the solutions to ten problems.

Thus, creativity allows you to solve more complex problems, the ways of solving which are considered in the sweat of the personality characteristics of the subject and are somewhat or completely unknown. according to many researchers, abilities, including creative abilities, can be developed through special training.

Markus, L., Sungkim, S., & Ishak, Mohd. Z. B. in their research, they identified the expected concerns and concerns of teachers and students in the study and simplification of quantum physics in high school when they introduced STEAM integrated learning. The difficulties of studying and simplifying quantum physics cause serious misconceptions among teachers and students. The solution to this difficulty is considered using interactive modeling and practical experiment. This article presents the theoretical basis for developing a training module with integrated STEAM elements to make quantum physics a meaningful study. The proposed theoretical framework has several advantages, including guidance on the planning of the training module applied to classroom activities and explanation of the topic using the 5e learning model [7].

However, further research is needed to test the design of the training module, ease of Use and the effectiveness of teaching and simplification in the classroom.

The natural sciences curriculum has undergone many reforms to keep with scientific and technical development, the «STEAM» approach is considered one of the most important global movements and approaches to curriculum development. Enriching the content of the physics curriculum within the framework of the «STEAM» approach with activities aimed at developing science fiction among students is one of the most important goals of scientific and technological progress in the future [8].

As a result of the research of domestic scientists G. Kazbekova and Zh. Ismagulova, within the framework of the topic Formation of Innovative STEM-education, shows the main factors of reforming education in the STEM direction.

The authors also highlight the main benefits of «STEM education» in the order below:

- It allows us to show the relationship between the disciplines of the physical-mathematical and natural science cycle both in theory and in practice;
- The ability to achieve high productivity through the use of scientific and technical knowledge in practical activities. Students will be able to create and build prototypes of real products in the classroom;
- STEAM programs allow students to solve various problems, independently propose solutions necessary to overcome emerging difficulties;
- Develops communication skills, teaches to work in a team;
- The organization of STEM classes attracts students from all over the world to study mathematics, physics and other subjects [9].

In our study, we present didactic conditions, identifying the importance of STEAM technology in the development of creativity.

- offer additional topics on STEAM to the physics teaching methodology;

- in order to form the creativity of students, to organize their work on STEAM and on their own in such a way that they understand the knowledge;

- to determine the interdisciplinarity between physical disciplines and computer science disciplines, mathematics;

- flexibility of content, methods, forms, means of teaching physical subjects to STEAM;

- Organization of the use of STEAM in any form of physics training in connection with innovative methods;

- implementation of the program for the formation of creativity of future physics teachers, consisting of Digital Program products used in teaching physical subjects;

We have organized the following stages for the development of students' creativity in teaching physics in STEAM conditions:

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Stage 1: organization of the training «development of students' creativity through STEAM». Systematic work aimed at developing creativity on the topics of the training.

Stage 2: the connection of physical knowledge with life, technology, the manifestation of activity in any form of teaching physics using STEAM elements in practice, the formation of skills to interpret physical knowledge.

Stage 3: development of a methodology aimed at developing students' creativity in teaching physics in the conditions of STEAM education. Development of students' creativity using methods and techniques, means aimed at the development of creativity.

Considering that science does not stand still, and the content of modern education also changes accordingly, it becomes clear that it is not enough for the student to only passively listen and remember information. It is important that the student is able to independently create new solutions in the subject, critically rethink the available data, and reveal previously unused capabilities of the technique [10]. STEAM technologies make it possible to develop these abilities, effectively apply knowledge and implement creative ideas in educational institutions and further professional activities of school graduates [11]. In our preliminary research, we noticed that students are interested in teaching physics based on STEAM technologies (Figure 2).

**Figure 2 – the process of teaching physics based on STEAM technologies**

In addition, from the analysis of the scientific literature, we have distinguished the following indicators of STEAM literacy. Apply the knowledge gained in Physics in practice, the ability to implement mini-projects, design products according to physical laws, knowledge of mathematical methods of physics, etc. In addition, according to our research topic, the first task is the need for these services to be implemented on the basis of STEAM.

In our study, we propose to improve the content of the discipline «Techniques of physical experiment at school» in the educational program «6b01510 – training of physics teachers» on the basis of STEAM as a didactic condition in order to form the creativity of students on the basis of STEAM.

The subject «technique of physical experiment at school» teaches students to study experimental methods and techniques of teaching physical sections of the school course, the place occupied in the system of teaching methods, the structure and tasks of physical experiment in education.

Allows you to master the system and features of the educational experiment in secondary education organizations for the formulation of physical processes and phenomena, the technique and technology of demonstration, virtual laboratory work.

Therefore, taking into account these features of the discipline, it is possible to determine the importance of implementing its effective teaching. We took into account the need for students to form the following creative indicators in the course of updating the educational content of the discipline:

- mastering the skills of organizing and conducting demonstration, virtual and laboratory experiments in the field of physics on the basis of STEAM;
- The ability to demonstrate the knowledge gained by steam-based physical thinking in the formulation of processes, phenomena in nature and technology, solving problems;
- mastering modern approaches to the collection, processing, analysis of scientific and pedagogical research, achieving unique ideas in the conclusion of research works.

Taking into account the indicators of creativity that develop in accordance with the final results of training in the above educational program, we propose to include the following topics in the curriculum of the discipline:

- STEAM experiment in physics, its importance in teaching physics, methodological requirements for it;
- Science project tips from a teacher. Educational Robotics as an Innovative Educational Technology;
- STEAM glossary. Basic equations and definitions;
- Basic ideas in STEAM projects. STEAM theme selection criteria.
- Exploring Student Engagement in STEM Education through the Engineering Design Process;
- 3D printing for experiments in the field of physics. Assess the engagement with 3d virtual learning tools;
- Creation of stands for explaining light phenomena. STEAM and Light. Teaching Atomic Structure.

The subject «Technique of physical experiment at school» is a 5-credit subject and is given 15 hours for a lecture and a total of 30 hours for practical classes.

The purpose of teaching the discipline is: to master physical phenomena and laws with the main emphasis on STEAM literacy of students, to implement the application of physical knowledge in engineering, design activities at enterprises, mathematics through mini-projects, to familiarize with technical devices.

Objectives of the discipline: to master the methods and techniques of independent staging and demonstration of demonstration practices in the course of high school physics; to teach students to stage frontal laboratory work and school physical workshop work. Mastering the terms of the technical and engineering field by sections of physics.

The forms of teaching the discipline are lectures and practical classes. In addition, it includes independent work of the student and work performed under the guidance of the teacher. In the lessons of the lecture, students are taught theoretical knowledge, methods of organizing and performing mini-projects implemented on the basis of STEAM in English. In practical classes,

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students perform mini-projects and explain them in English. In the course of teaching the discipline, the 5e, 7E model in teaching, the case study method, the problem-based learning method, and the design method are organized in conjunction with the CLIL learning technology.

The results of training are evaluated in accordance with the criteria set in advance for the implementation of the project.

The importance of the results of the study is characterized by the need to obtain a new impetus for leadership in innovations at the state level, the need to improve the degree of educational institutions in STEAM disciplines, meet new requirements for knowledge on the part of the labor market and business, high-tech production, develop the ability of graduates to meet the requirements of future activities and business, employers by introducing a methodological system of training based on STEAM education into the educational process at the national level.

In addition, by improving access to all STEAM programs, rural or remote residents are characterized by the need to provide opportunities for promising education.

**Conclusion**

The results of the study were obtained through the development of a didactic system for teaching natural and technical disciplines, in particular, the school physics course on the basis of STEAM:

- increase opportunities to improve the quality of human capital, create high-tech products based on the introduction of innovative technologies into the educational process.

So, our research has an impact on the development of the following indicators for students:

- accelerates the assimilation of physical phenomena and laws, allows you to expand the educational material to a certain extent;
- increases motivation for learning, mastery of learning, regularity of learning problems;
- increases activity in solving problems and problems in physics;
- increases their ingenuity in solving the problem posed in connection with the new topic;
- forms the ability to effectively use certain physical experiences in New conditions;
- forms the ability to improve and change the known in accordance with new tasks;
- demonstrate the ability to work independently in new areas in physical research work.

The results of the study will further contribute to the improvement of the material and technical base of rural schools, the easy assimilation of the laws of physics by students, the emergence of competitive specialists in engineering and technical fields, and thus the development of Science and education, industry in the country.

In addition, the results of the study are recommended to be used in higher educational institutions, schools and institutes for advanced training. The importance of this study is that the results of the analysis of the current practice of teaching physics teachers clearly define STEAM elements as accessible and inaccessible. Recommendations for improving and improving the teaching of physics will be given on the basis of analysis using the integrated STEAM concept as a teaching concept. The results can be transferred to other subjects, such as chemistry and biology, if necessary. Recognizing that STEAM education research is not widespread in the school environment, this research will also contribute to STEAM educational literature at school.

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