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STEM-EDUCATION AS A RESOURCE OF INNOVATIVE DEVELOPMENT OF MODERN SCHOOL

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Abstract

Modern education has a strong need for innovative development. World technological progress is a reason for modernization of engineering education in Russia. There is a lack of qualified specialists in high-tech industries. The search for new methods of personnel training with engineering thinking allowed the authors of the article to turn to the phenomenon of STEM-education. The article examines the introduction of STEM-education in Russia and other countries and analyzes the term "STEM". The authors of the article propose a model for the realization of STEM-education in the educational space of school. STEM-education is characterized as the methodological orientation of the pedagogical collective, which assures the association of the physics, mathematics and natural sciences in teaching students with the application of the acquired knowledge in practice to form the student's engineering thinking. The article presents the principles of effective implementation of the model. Based on the developed model of STEM-education, the article presents the features of the STEM-center functioning in Togliatti. Particular attention was paid to robotics and 3D-modeling. In the laboratories of the STEM-center, students learn the basics of engineering, create robotic mechanisms. The students learn the technique of 3D-pen drawing and the basics of working on a 3D-printer.

The authors conclude that STEM-education as a new model of the organization of the educational process in the additional education of the school is a necessary source of innovative development of Russian educational space. It can be successfully used in the practical activities of educational institutions.

Keywords: STEM-education, STEM-project, robotics, 3D-modeling.

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1. Introduction

In the 21st century there is a rapid development of high-tech industries. World technological progress is accelerating. The leading countries recognize the acute shortage of highly qualified specialists, which should provide innovative development of high-tech industries. They should carry out scientific and engineering support. One of the trends in the development of modern education is the search for new models and technologies for the implementation of engineering, technology and information technology education. The involvement of young people in the study and practical development of engineering specialties in Russia began to be actively implemented on the basis of the developed federal and regional programs (Zasedanie Soveta po nauke i obrazovaniyu, 2014). The attention of specialists is drawn to the renewal of forms, methods, technologies that stimulate the creative activity of students from the preschool age and their involvement in technical creativity. In this regard, the phenomenon of STEM-education is of interest in the educational space.

The abbreviation "STEM" is formed by the initial letters of the following terms: Science, Technology, Engineering, Math (Rodger, 2010; Sanders, 2009). The term "Science" in the context of the concept of STEM means the section of the natural sciences (biology, astronomy, physics, chemistry, geography). The acronym STEM was proposed in the 90s of the 20th century by P. Faletra in the USA at the meeting of the National Science Foundation (NSF) on the issues of scientific education (Davis, 2014). P. Faletra sought a solution to the acute shortage of qualified specialists in engineering. The idea of "STEM" as an association of various fields of science was to become, in his opinion, the basis of the concept of future engineers training. The Director of the NSF R. Colwell supported P. Faletra's idea, and the abbreviation “STEM” was accepted by the scientific community and subsequently spread widely around the world. There were some variations. Over time, many scientists, studying the phenomenon of STEM, tried to expand and refine this concept. Some researchers use the concept of STEAM in their scientific works. They added capital letter A, which means the term "Art". These scientists emphasize the importance of creativity for the development of innovative technologies. Another variation is the abbreviation STREM, where the capital letter R represents “Robotics”, as some researchers attach special importance to modeling and design in the development of modern science.

The most effective results of the introduction of STEM-education in educational institutions have been reached in the United States of America, where the idea of STEM originated, and in Finland. The USA is the only country that supports STEM-education at the federal level: in 2009 the law "On coordination of actions in the field of STEM-education" was adopted (Nogajbaeva & Zhumazhanova, 2016; Tofel-Grehl & Callahan, 2017). According to this law, state and commercial organizations and associations working with the direction of STEM education are established throughout the country. Even the USA immigration policy is aimed at attracting foreign students to study subjects of STEM-disciplines. Already more than 40% of students in the USA have chosen to study the sciences from the field of STEM.

Another country, that effectively implements and develops STEM-education, is Finland (Nogajbaeva & Zhumazhanova, 2016). Since 2003, STEM-centers have been functioning in Finland - organizations that provide interaction between schools, universities, industry and business, as well as scientific and technical camps and other activities for students. An important contribution of STEM-centers in Finland is the development and dissemination among teachers of methodological materials in the field

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of STEM-education. Such active work in the field of STEM-education has already yielded results: by 2011, the largest number of highly qualified specialists in engineering was trained in Finland (among European countries).

The ideas of STEM-education were supported by Great Britain, Austria, Germany, Spain, Italy and other European countries. A notable step in its development was the creation of the K-12 STEM curriculum, which takes into account the principle of continuity (Honey, Pearson & Schweingruber, 2014). The term "K-12" stands for "kindergarden-12", which implies the introduction of STEM-education at various stages of study, from preschool age to the 12th grade of the school. The idea of STEM-education has been implemented in Australia, where in 2015 they adopted the National Strategy for the Development of STEM-education in schools for 2016-2026 (Nogajbaeva & Zhumazhanova, 2016).

Of course, the phenomenon of STEM-education could not bypass the CIS countries. The scientific community at the world level notices the results achieved in Kazakhstan. There, the learning process includes elements of the STEM-program, which involve project activities.

In Russia at the moment there are several STEM-centers, mainly financed by commercial organizations. With their participation, technoparks are being created - research and development complexes on the basis of which students implement various innovative projects. Different Olympiads, competitions, festivals and tournaments on robotics and 3D-modeling (STEM disciplines), are held (Apolskih & Lobancova, 2014). Nevertheless, there is a lack of theoretical development of the idea of STEM-education not only in Russia, but also in the world scientific community.

2. Problem Statement

It should be recognized that STEM-education is being introduced in countries striving for scientific and technical leadership, and is gaining increasing popularity. However, it is still unclear what this phenomenon is from the point of view of its essential characteristics. The term itself in scientific works and popular scientific articles is treated differently (Averin & Markova, 2017; Dotsenko, 2016; Kit & Kit, 2014; Strizhak, Slipuhina, Polihun & Cherneckij, 2017). Researchers A. Tserkovnaya, S. Averin, V. Markova say that STEM-education is a technology (Averin & Markova, 2017; Cerkovnaya, 2013). J. Breiner, S. Harkness, C. Johnson, Koehler C., A. Strizhak, I. Slipukhina. and others define STEM as an approach (Breiner, Harkness, Johnson & Koehler, 2012; Strizhak, Slipuhina, Polihum & Cherneckij, 2017). V. Chemekov, D. Krylov (Chemekov & Krylov, 2015; Kuzmina & Yashina, 2017) explore the advantages of its implementation. Uncertainty, incompleteness of knowledge about the essence of the STEM-education concept makes it difficult to introduce it into the educational space of educational institutions. All this leads us to the statement of the key question of this study: how to characterize the essence of STEM-education from a pedagogical point of view and ensure its introduction into the educational process of a modern school?

3. Research Questions

Comprehension of the phenomenon and the concept of "STEM-education" can contribute to the creation of perspective models of its implementation in the modern school, in the system of additional education for the realization of engineering, technological and information technology education.

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Involvement of students in the design and experimental research activities will create a condition for conscious choice by students of the future engineering profession.

4. Purpose of the Study

The purpose of this study is to comprehend and substantiate the phenomenon of "STEM-education" and to develop its model as a practice-oriented educational environment for the implementation of engineering, technological and information-technological education of students.

5. Research Methods

Analysis, generalization, systematization, pedagogical experiment.

6. Findings

The conceptual idea of the educational model, built on the ideas of STEM-education, is that STEM-education is the methodological orientation of the pedagogical collective, which assures the association of the physics, mathematics and natural sciences in the educational practice-oriented activity of students for the implementation of engineering, technological and information technology education.

Creating a model of the educational environment based on STEM-education suggests clarifying the concepts:

Engineering thinking is a kind of thinking that is formed and manifested when solving engineering problems, allows to quickly, accurately and originally solve any problem in a specific subject area.

STEM is a union of the natural sciences (biology, chemistry, and astronomy), physics, mathematics, computer science, etc.

STEM-center is a design laboratory on the basis of an educational institution that allows students to conduct scientific research and create scientific projects.

STEM-project is a project aimed at creating models and real products of construction, programming, modeling, prototyping.

In the course of this study, the following principles of effective STEM-education in the educational space of the school were formulated:

the principle of mandatory effectiveness, which means the creation of models and real products of design, programming, modeling, prototyping in the process of experimental research;

the principle of cooperation, aimed at motivating students to in-depth study of natural sciences, physics and mathematics; organization of joint activities on the basis of intersubject communications and dialogue interaction;

the principle of creativity and success, allowing to reveal the creative potential of students in classes organized both in individual and in group form; creation of conditions for personal and professional development of youth.

A technology of project training achieves effective results when the STEM-education models are implemented. It helps students to develop interest in technical creativity, independence, creativity, creative thinking, communication skills and research skills. The pedagogical concept of the STEM-project is the creation of prototypes of the modern scientific and technical industry, based on the application of

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knowledge from different scientific fields and subject disciplines. The algorithm for implementing the STEM project is the following: updating the knowledge from different fields of science, which is necessary for the project; instructing, explaining the order of implementation of any actions during the work on the project; development, creation and testing of prototypes of real products of modern industry. STEM project as a technology can be reproduced by any trained teacher and can guarantee the achievement of a result - a modeled or constructed product of the real world.

Let us dwell on the developed and implemented model of STEM-education in the supplementary education of MBI "Gymnasium № 77" in Tolyatti. Since 2014, the STEM-education center has been functioning in the gymnasium, on the basis of which students are successfully engaged in technical creativity. The development of STEM-education goes in two main directions - robotics and 3D-modeling (Apolskih & Lobankova, 2014; Havronina, 2015). The STEM-center has laboratories in which students of different ages are engaged in elective courses. Programs of elective courses are created taking into account the theoretical knowledge of students in natural sciences, physics and mathematics, which is necessary for work in laboratories. In total there are seven of such laboratories: "Pre-school robotics", "Elementary modeling", "Elementary robotics", "Educational robotics", "3D-modeling", "Technical modeling", "Multimedia technologies". The laboratories are equipped with modern educational hardware devices: computers, tablets based on interactive textbooks, 3D-printers, 3D-scanners, and constructors: LegoWeDo, TIKO, HUNAROBO, Technolab, Arduino, Fischertechnik etc. With the help of this equipment students master advanced technologies. Taking into account age features allows to successfully introduce elective courses already in primary school. So, students of primary classes in robotics classes get acquainted with the basics of design. At the initial stage, children learn the types of parts, their attachment, try to create their first models. Later, students design their first robotic mechanisms, the simplest kinds of robots with moving parts. At an advanced level, students collect complicated robot models and are engaged in their programming.

3D-modeling allows students to design three-dimensional models of real or fictional objects, usually using the developed sketch. The study of this discipline begins with the development of a 3D-pen - a tool that allows to draw in space. At first, children learn to use the 3D-pen confidently: to control the thickness of the plastic and the speed of drawing, to draw smooth and accurate lines. Drawing techniques with a 3D-pen are used by students to create flat shapes and objects. At the next stage, the children using sketches, create three-dimensional models from a variety of individual parts. Later students begin to learn the basics of working on a 3D-printer and create graphic models using special software.

STEM-education as an approach carries a lot of opportunities for modernization of the educational process. The elements of STEM-education can be included in the content of such subjects as physics, mathematics and natural sciences. A variant of STEM-approach implementation is the creation of a new STEM-discipline as a subject, which combines the disciplines of the STEM-cycle.

Proceeding from the foregoing, we can conclude that STEM-education is a resource of innovative development of the educational space. It allows upgrading not only the technical creativity of students, but also the organization of the educational process, introducing experimental and research activities of students.

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7. Conclusion

STEM-education as a methodological orientation of the pedagogical collective of the modern school, which assures the association of physics, mathematics and natural sciences in the educational activity of students with the application of the acquired knowledge in practice, will contribute to the formation of the student's engineering thinking. STEM-education is a necessary source of innovative development of the Russian educational space. Models of STEM-education implementation, outlined in this article, allow us to better understand its essence and successfully implement it in the practical activities of educational institutions.

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