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STEAM as an Innovative Educational Technology

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Abstract

The purpose of this work is to develop a model for the construction of STEAM-education, which is based on project training in the so-called "creative spaces". "Creative spaces" are integration areas of schoolchildren, students and graduate students working in the format of joint work on projects initiated by various structures of a society and business. The authors of the article analyzed the experience of different countries in the implementation of STEM and STEAM-education and identified the effective ways of structuring technical disciplines, art and creative activity into a single integration program. During 2017-2018 years within the framework of informal and nonformal education, an experimental work was carried out with 32 schoolchildren and 34 students, aimed at determining the level of the development of such competences as: the ability to manage projects and processes, system thinking, the ability to art creativity, the ability to work within the teams, groups and individuals, the ability to work in a regime of high uncertainty and a rapid change in the conditions of tasks. Analysis of the results of experimental work has shown that the use of "creative spaces" for the implementation of project activities of schoolchildren and students, the inclusion of the category "art" in its content allows students to form skills and competencies necessary for the Industry 4.0.

Key words: *STEM, STEAM, art, creative abilities, informal and nonformal, training, project training, Industry 4.0.*

Introduction

Throughout the world, the process of training for the Industry 4.0 is an urgent problem, as today the pace of technology development is several times ahead of the pace of changes in the education system. Many jobs, that are being taught now will become unnecessary tomorrow, so new educational models are needed to correspond to the changing paradigm of industrial production. The following systemic changes should be the basis of such models (Aleksankov, 2017):

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1. Digitalization of education. In essence, this means the expansion, with the help of digital solutions and informational systems, of students' access to the educational resources of the best universities in the world, to remote data from the results of scientific experiments and research, to the library of engineering tasks and problems, and to the creation of distributed labor, research and educational teams.
2. Personalization of training. This means deepening and developing the existing practice of creating an individual educational trajectory with the possibility of returning to the branch points and acquiring additional skills throughout the life. Another aspect of personalization is the consideration of the requirements and requests of not only students, but also direct employers.
3. The project approach. It is an integral component of in-depth education, which allows to significantly increase the effectiveness of the educational process - from the first stage of understanding and identification of problems to the final stage of practical work. The project approach is inextricably linked with adaptive education, the main component of which is training through practical activities in the subjects of the market, industry and science.
4. Integration of formal and non-formal education, which actually means blurring the physical boundaries of the university and shifting the focus from the process of gaining knowledge to its recognition and assessment, regardless of the actual place of obtaining knowledge and skills.
5. Making of creative spaces that actually act as integration areas for students of various specialties, real business sector and industry, academic and professional education. A prerequisite for the work of such sites is a joint work on projects initiated by the real sector of the economy.
6. Making of inter-university courses (universityhubs) - in contrast to the usual network interaction of universities means the creation of real sites in the form of scientific and educational centers created with the participation and under the auspices of various universities.

In many advanced countries, such as Australia, Great Britain, Israel, Canada, China, Singapore, the United States, the so-called STEAM-education is developing, the idea of which has become a continuation of the STEM-education concept (science, technology, engineering, mathematics). For example, in the US, STEM-education is recognized by the National Council for Research (National Research Council) and the National Science Foundation (NSF) as the technological basis of a developed society. The degree of training in the field of STEM is an indicator of the nation's ability to support its development (Frolov, 2010).

Inclusion in the STEM-education of creative disciplines, which can be designated by the term Arts - art, expands this direction and enriches its creative component. Today there is an active movement from STEM to STEAM education (Tarnoff, 2011; Sousa & Pilecki, 2013). The unity of the scientific-technical and Arts-directions in education is also explained from the physiological point of view. The so-called "left" side of the brain is responsible for logic: it helps to memorize the facts and draw logical conclusions. The "right" side of the brain is responsible for thinking through direct perception and provides creative, instinctive-intuitive thinking. The work of both hemispheres is important: if one of them does not work, then it, like any muscle of the body, will become atrophied, unclaimed. Therefore, it is wrong to make a choice between technical and humanitarian sciences, they should harmoniously combine in the content of education, which fully meets the needs of the economy of the Industry 4.0. Members of the bipartisan commission for the development of STEAM education, established in 2013 in the US Congress, announced that "only activation of both hemispheres of the brain will teach people to think creatively and innovatively, which will be crucial for the growth of the economy in the 21st century and the creation of high-performance jobs ". According to the head of the personnel service of the medical company Rally Health Tom Perrot in the near future, the IT-business will be especially acute in STEAM-specialists, since the robots are about to start coping with the duties for which STEM-education is needed, better than people. But machines are unlikely to master the humanities (for example, psychology or art) yet in the foreseeable future. In the nearest future the development of the product design, its aesthetics and philosophy will help IT specialists to create new competitive solutions and therefore humanitarian disciplines will be needed here that teach students to understand the human essence and think creatively (Perrault, 2016).

The idea of using the methods of all-round development in the sphere of education does not have any know-how. For example, there is the concept of SEL, which implies the development of social and emotional skills in children, which are placed on a big stake in the education of "people of the future". Alternatively, the method of phenomenologically-oriented teaching and teaching of PBL, similar to STEM in the sense that here and there attempts are made to combine different disciplines in the study or workup of a topic (Estapa & Tank, 2017). This PBL methodology and the STEM concept largely provide for the reinforcement of technical disciplines by humanitarian ones. Therefore, a logical step was an attempt to "legitimize" such an association, to connect the creative aspect of personal development to the purely technical concept of STEM. So there were systems where along with science, technology, engineering and mathematics are present Art (from English "art") - this is the concept of STEAM, Music (English "music") - STEMM, Reading ("reading" along with art) STREAM. The STEAM method was the most widely used as a full-fledged, self-sufficient phenomenon (Maeda, 2012).

In general, if we evaluate the prospects of these two concepts - "pure" STEM and STEM with a creative component, the first of them was more in demand at the end of the last century. At the same time, STEAM can respond adequately and effectively to the challenges not only of today, but also of the future. Here we are talking about the fact that a significant part of the work processes are now being automated, and in the future, as analysts predict, more and more professions will fall into the risk zone, disappearing one after another - they will be replaced by artificial intelligence. And so far, among the few skills that in the foreseeable future will not succumb to the pressure of artificial intelligence, there remain empathy and emotional intelligence.

Theoretical Background

Studies on the implementation of elements of STEAM education are conducted in many countries: The United States, Australia, South Korea, Canada, Thailand, etc. The possibility of including the element "ART", used in the abbreviation STEAM, as shown by the study of experience in the implementation of STEAM-education, quite diverse, and they Expand as the students' progress through the basic levels of education.

For example, in kindergartens and junior classes, such an area of physical knowledge as acoustics can serve as an element linking STEM and STEAM. According to the researchers, acoustics is ideal for STEAM, since it is closely related to one of the areas of art - music (Goates, et al., 2017). It is clear that this requires the pedagogical staff training, and there is such an experience of cooperation (training) Acoustics Research Group at Brigham Young University (BYU) with primary school teachers who subsequently successfully integrated art into teaching activities (Goates, et al, 2017). A set of activities on increasing of younger schoolchildren's interest in physical phenomena can be integrated into the system of STEAM-education (Sabirova & Deryagin, 2018; Mullins, 2019).

Researchers at the University of Ghent argue that by incorporating art into STEM programs, educational activities can become more attractive to a wider audience. As a model of such educational activity they represent the international week of robotics and art for secondary school students (Wyffels, et al., 2016).

Scientists from Finland (Thuneberg, et al., 2017) point to the need to improve creativity in mathematical education in school. They offer mobile interactive mathematical exhibitions "The Art of Mathematics." In Australia, an educational program has been developed, according to which teachers include in STEM programs on the history and culture of Aboriginal and Torres Strait Islander peoples, economic and cultural influences of Australia and Asia (Taylor, 2018).

Since 2011, the initiative "Scientist for the Future" (SfT) has been supported in Chicago. The SfT initiative is intended to use a training program based on STEAM, and is a partnership between higher education institutions, out-of-school organizations and providers of non-formal education. The initiative is implemented in all communities during the academic year, within which various learning modules, such as "Alternative energies", "Physics of sound and mathematics of music", "People and plants", "Robotics" "And" Astronomy " are studied in the time free from basic studies or work (Caplan, 2017). This initiative helped to increase the level of knowledge in the areas that aroused interest and the growth of a positive attitude towards STEAM.

In Russia, this problem is also understood - the Centers for Technical Education Support (TSTPO) are being opened, where the tasks of involving students in engineering and robotics are partially being solved. Business companies are actively being involved in the implementation of projects for subject-oriented education of children and young people, which confirms the correctness of this strategy in education. "On the way of convergence of engineering, natural science and humanitarian knowledge, it is very important to acquire and develop meta-competence among students, since they determine the success of young people in a post-industrial society, and the design laboratories that unite science, technology and art should become the environment for the emergence of competencies!" , - said Sergey Kuvshinov, director of the International Institute for New Educational Technologies of the Russian State University for the Humanities and curator of the new STEAM-center project (Leading Universities, 2017).

The need for an interdisciplinary approach in STEAM education (inter-, trans- and cross-disciplinary learning), implemented with the cooperation of subject teachers, the use of creativity in the work of secondary school teachers for the development of critical thinking of students is convincingly justified by the results of an international study where secondary schools Australia, the United States, Canada and Singapore took part (Harris & Bruin, 2018). The study showed that with establishing a trusting relationship between teachers and students, favorable conditions are created for developing the creative potential of both.

In some countries, experiments are being conducted on the use of interdisciplinary strategies for university and high school teachers. The results show that using STEAM-technologies in studying physical and mathematical disciplines by high school students of colleges and university students (Segura, 2017; Chanthala et al., 2018) performance and self-esteem improve, and creative abilities are developed. The experience of research in Korea in the field of STEAM education also shows that it is preferable to conduct physical research in connection with the humanities and art (Paik et al., 2018; Moon & Kang, 2015). Thus, the implementation of STEAM-education is feasible at all levels of education, from preschool to professional, often in close cooperation and cooperation between educational and non-academic organizations.

Method of Projects as a Basis of Steam-Education

It seems to us that STEAM teachers can implement training programs based on projects. In the Russian pedagogical practice, the technological education of schoolchildren within the subject "Technology" can serve as an excellent example of STEAM-education. The purpose of studying this subject is to form ideas about the components of the techno sphere, about modern production and about the technologies that are common in it. Technology as a school subject today contributes to the professional self-determination of schoolchildren in the labor market, it focuses on the use of design, research, project and scientific and technical activities. Educational and cognitive activity of students in the subject area "Technology" is based on natural scientific, technical, technological, entrepreneurial and humanitarian knowledge. There is no other discipline in the school that would use the material of such a wide range of fundamental and applied sciences for its own purposes. However, the subject "Technology" is not taught in Russian schools for high school students, and therefore the projects are implemented in the framework of informal and informational education, which is a certain difficulty for technology teachers.

The way out of this situation can be the creation and development of interdisciplinary scientific and educational "creative spaces" in the format of scientific and educational centers that are primarily aimed at creating an environment for effective interdisciplinary project work of schoolchildren, students and graduate students on orders initiated by the real industrial sector. One of the main roles of such sites should be the role of integrators of the scientific, educational, business and industrial environment that provide on their territory a synergy of knowledge and experience from different spheres (Dagdilelis, 2018; Mallinson, 2018; Solas & Sutton, 2018).

The experience of creating such "creative spaces" is available in foreign universities (for example, Design Factory in Aalto University, Finland, FabLab network and others). This experience requires separate consideration, but one of the important issues is the degree of integration of such centers into a standardized educational process. A distinctive feature of "creative spaces" should be the free construction of the learning process on the basis of the design method of instruction, with the provision of students' access to the largest possible array of educational materials with the obligatory expertise of the teachers about the reliability and relevance of the teaching materials used. The independence of training should be a prerequisite for training in such research and educational centers (Gratchev & Jeng, 2018; Sebastianelli, 2018; Tarman, 2018).

Method

Research Design

The experimental work involved the organization of "creative spaces" for carrying out the project work of schoolchildren and students in working groups that were formed from the number of schoolchildren and students. Working groups were formed on the basis of the free choice of students and students of the themes of projects and their interest in carrying out project activities. At the organizational training, invited students and students of the Elabuga Institute of the Kazan Federal University discussed the topics of the projects and broke up into working groups of 5-6 people. As objects of design, socially important topics were chosen, relevant both for the level of the school and the university, and for the level of the city and region. To each group was attached a mentor from among university professors, as well as a scientific consultant - a specialist in a certain field (museum worker, designer, ecologist, businessman, etc.).

Participants

During 2017-2018 years in the framework of informal and informational education, an experimental work was carried out with 32 schoolchildren and 34 students of the Kazan Federal University, aimed at determining the level of the formation of such competences as: the ability to manage projects and processes, system thinking, the ability to art creativity, the ability to work with collectives, groups and individuals, the ability to work in a regime of high uncertainty and a rapid change in the conditions of tasks. The project activity for carrying out the experimental work was not chosen by chance. For the modern world of work, the confusion of personal and professional identification and competencies becomes the norm, gradually the standard workplace is replaced by a project work with a multitude of tasks and activities.

Data Collection

Work on the projects lasted 3 months, students gathered once a week to discuss topical issues and implement the project. Then the project works were defended before the tender commission. Representatives of business and culture, city administration, teachers of the university and teachers of schools were invited to the commission. Scientific advisers and mentors who worked with groups, preliminary estimated the work of each participant on the following criteria (Savinova & Shubnyakova, 2015):

1. Achieving the result and its awareness is the predominance of the desire to get a concrete result over the tendency to unproductive participation in the process. Ability to assess the degree of completeness of the case and the adequacy of the result of the goal set earlier. Analysis of their own activities, understanding of working situations and problem-solving tools.
2. Initiative and independence - the degree of intellectual activity of the student in the process of searching and developing ways to solve the set goal. The ability to make independent decisions within the scope of their competence, to take responsibility for the results in complex situations involving uncertainty (in the absence of external guidance). Readiness to go beyond the set tasks, independent initiative. Independence in the formulation of the objectives of its activities.
3. Time planning, self-organization - the ability to rationally allocate the time allotted for the project, consistently solve the tasks in the framework of a common goal.
4. Communication and cooperation - the ability to work in collaboration with other team members, the ability to fulfill their role in the team, the ability to jointly solve the problems encountered. Ability to empathy. Level of emotional intelligence.
5. Integration - interest in various fields of activity, openness to the tools of other related areas, readiness to consult with leaders of other projects, to approach the project systematically.
6. Creativity - the rejection of the cliched mental patterns, the ability to find non-standard solutions to problems. Ability to offer an original idea, allowing to bring the project to a new level. High variability of proposed solutions.

Data Analysis

Each criterion was evaluated using a 5-point system. Based on the identified criteria and indicators, five levels of skills were determined for the industry of Industry 4.0: low (0 to 3 points), below average (3 to 3.5 points), medium (3.5 to 4 points), higher average (from 4 to 4.5 points), high (from 4.5 to 5 points).

The competitive commission evaluated the performance of the teams on the following criteria: consistency and reasoning of the presentation of the project results, speaking skills of the speakers, ability to interact with the audience, ability to conduct discussions with experts, readiness and ability to answer questions, creative approach to choosing the presentation form of the results of the project work, quality clearance explanatory note.

Findings

Analysis of the results of experimental work has shown that the use of "creative spaces" for the implementation of project activities of schoolchildren and students, the inclusion of the category "art" in its content allows students to form skills and competencies necessary for the Industry 4.0.At the organizational training, before the start of the projects, the scientific leaders of the groups exhibited scores for each criterion and determined the levels of the assessed skills and competencies. The average scores are shown in Table 1.

Table 1

Initial levels of the formation of skills and competencies of the participants in the experiment

Level	*low*	*below average*	*average*
Schoolchildren	*6,25 %*	*18,75 %*	*53,13 %*
Students	*2,94 %*	*20,59 %*	*44,12 %*
Level	*low*	*below average*	*average*
Schoolchildren	*6,25 %*	*18,75 %*	*53,13 %*

At the last stage of the project implementation, the team leaders conducted an expert evaluation of the levels of skills and competencies of each participant in the experiment. The data are given in Table 2.

Table 2

The final levels of the formation of skills and competencies of the participants in the experiment

Levels	*low*	*below the average*	*average*
Schoolchildren	*0 %*	*3,12 %*	*9,38 %*
Students	*0 %*	*0 %*	*8,82 %*
Levels	*low*	*below the average*	*average*
Schoolchildren	*0 %*	*3,12 %*	*9,38 %*

88% of schoolchildren and 91% showed the formation of these competencies at a level above the average. The final results are shown in Figure 1.

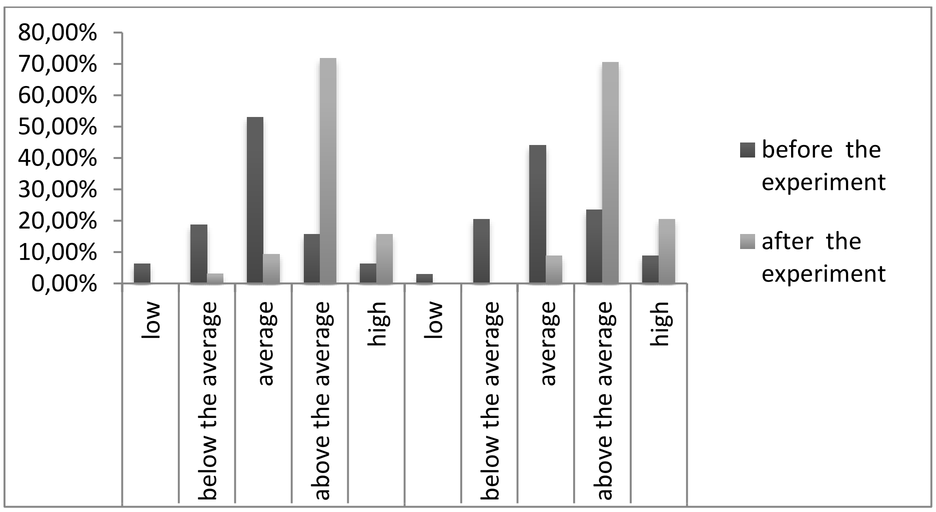

Fig. 1. Levels of formation of skills and competencies of schoolchildren and students before and after the experiment

In our opinion, the competencies viewed do not contradict, but only complement the competencies proposed by other researchers. In particular, as the main elements of project activities aimed at developing skills and competencies for the economy of Industry 4.0, we propose: design, scientific research, solving non-trivial tasks, developing non-standard thinking, flexible working hours, work experience, working with scientific literature, etc. (Formation ..., 2018, p. 642). According to the results of the World Economic Forum survey, by 2020 the following skills will become critically important: comprehensive problem solving, critical thinking, creativity, people management, coordination with others emotional intelligence, service orientation, assessment and decision making, negotiations, cognitive flexibility. They are also reflected in the proposed model.

In a number of scientific studies, the authors highlight other critical competencies necessary for successful operations in the digital economy. Their analysis was carried out in the monograph "Trends in the development of the economy and industry in the conditions of digitalization" (Aletdinova, 2017). Among them there is the collective network competence "the ability to apply knowledge based on collective intelligence in the Internet environment". The development of this competence is also ensured in project activities. Thus, the proposed model can be considered as a universal tool for the qualitative preparation of schoolchildren and students for professional activity in the context of the economy of the Industry.

Conclusion

The future of economic growth largely depends on the availability of qualified engineering personnel, the beginning of which should be established at the secondary school level and continue in colleges and universities through the support and active implementation of STEAM education. This support should be carried out through the targeted development programs, which, in their turn, should include the active involvement of trainees and their mentors in project activities. Project activities in the context of "creative spaces" within the framework of informal and informational education make it possible to form and develop in each of its participants the skills and competencies that are necessary for the person of the digital age.

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