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Analysis of the Characteristics of the Implementation of Scientific and Educational Programs of Primary Engineering Education on the Basis of Various Types of Children's Camps

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***Abstract*—Since 2016, the employees of Bauman Moscow State Technical University have implemented a large number of scientific and educational programs of various orientations, duration and complexity level, including for groups with an international composition of participants, on the basis of various children's camps. In the process of their implementation, they revealed a number of peculiarities of organizing and conducting classes in children's camps not peculiar of school or university teaching groups. The presented work examines the measures taken by the university staff and the solutions proposed by them, which made it possible to increase the effectiveness of program implementation, as well as plans of their development.**

Keyword—STEM, supplementary education, children's camp, vocational guidance, engineering environment, prevocational training

I. Introduction

In the modern world, the activities of most enterprises in the real sector of the economy are associated with high-tech manufacturing, which requires highly skilled engineering personnel. Moreover, in many cases, it is not just employees who have good general and specialized training, but specialists with "innovative" thinking, i.e. able to propose, invent and implement new ideas and approaches. Thus, the quality of engineering personnel becomes one of the key factors of state competitiveness and, which is fundamentally important, the basis for its technological and economic independence. Therefore, the issues of selection and training of new personnel in different countries of the world are paid more and more attention [1]. As experience shows, the early involvement of schoolchildren in youth technical creativity contributes to their sustained interest in engineering and technology, the development of rationalization and inventive abilities, technical thinking, and contributes to the improvement of scientific education [2]. All this leads the student to the conscious choice of the future specialty and, accordingly, to his formation as a high-class specialist [1].

In the last decade, there has been a general decrease in the interest of young people in technical creativity. This is caused, on the one hand, by the absence in recent decades of visual (understandable to all, not just specialists) revolutionary achievements or breakthroughs in science and technology. Such, for example, were the launch of the first satellite, the flight of the first cosmonaut, the landing on the Moon or the introduction of nuclear energy. That is, such events that have pushed several generations of young people into science and engineering. On the other hand, the development and wide distribution of the gaming computer industry and the virtual space complicates the involvement of young people in various educational technical projects, as it is often more interesting for them to play colorful and dynamic games and communicate in various forums and social networks than something extra study and try to do it yourself. In addition, it is worth noting one of the trends of the current post-industrial period, which is characterized by the displacement of large-scale production from megacities to the periphery, or even to developing countries, and the growing prestige of employment in the non-productive sector of the economy.

The above features of modern development of youth scientific and technical creativity lead to the fact that at present there is a global problem of finding new approaches to identifying young people's abilities and inclinations for technical creativity, attracting young people to the fields of science, technology, engineering and exact sciences, and also to increase the level of its preparation. At the same time, the full implementation of vocational or pre-vocational engineering training programs within the framework of general basic secondary education is very problematic. This is related to, primarily, a significant academic load on students. In addition, schools, mostly do not have a sufficient material base for proper organization of engineering practice, and school teachers can often provide high-quality substantive training in mathematics, computer science and physics, which is very important, but does not affect the technical engineering component. related to meta subject knowledge and competencies. Therefore, such

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training is possible either in the framework of specialized sites, for example, specialized schools or classes [3], or in the framework of additional education.

As an example of the implementation of the first approach, the Engineering class project launched recently in a number of regions of Russia, in which students learn about the activities of leading industrial enterprises, attend special engineering classes at engineering universities and, after mastering specialized programs, pass a special pre-professional exam, which is a form of an independent final assessment of a graduate of engineering class with the participation of representatives of the university. Such initial engineering or preprofessional training enables the formation of a scientific and technical approach to the study of the surrounding world, the optimal development of the individual abilities of schoolchildren, allows them to better determine their future profession, get ideas about engineering, solving applied problems of physics and mathematics, where the leading direction is polytechnism, modeling and design, widespread use of information technology.

Besides, currently there are many options for the implementation of additional education programs [4-6]. These are various sections and circles of technical creativity, competitive programs, open lectures, seminars, master classes, and much more.

II. Scientific and Educational Programs in the Field of Primary Engineering Education on the Basis of Children's Camps

In principle, all children's camps can be conditionally divided into two categories: country camps and city camps.

- Country camps are classical children's recreation camps, where children are usually come for one shift of about 7 to 24 days. Camps are located in recreational zones like in forests, on river banks, near lakes and seas, etc. They may operate only in summer or throughout the year as well. During the shift, the children are at full board. Various health, cultural, educational and entertainment programs are organized for them.
- City camps are usually highly specialized short-term activities (up to 7 days) aimed at organizing daytime leisure for children during school holidays. Camps are most often located in the city. The children often live (stay overnight) in a hotel or at home. Cultural and educational events are organized for them during the day.

The scientific and educational program can be the core of the camp's general program. The whole program would then be built around it. At the same time, it can also be treated as the only integral part of the camp's program. In such a case, it should fit as logically and organically as possible into the general framework.

Since 2016, the staff of Bauman Moscow State Technical University (BMSTU) has implemented a large number of scientific and educational programs focusing on a variety of different fields as well as the duration and level of complexity on the basis of children's camps. The following objectives have been set in the development of all programs:

- motivation of school students to deeper learning of mathematics, physics and computer science and to the subsequent choice of engineering education;
- acquisition of the initial theoretical knowledge and practical skills in the relevant knowledge area program by school students.

In order to achieve these objectives, it was necessary to ensure that the program is aimed at solving the following tasks:

- popularization of engineering disciplines;
- formation of students' conscious effort in engineering education;
- formation of an accessible environment allowing the study of the science (primarily mathematics and physics), as well as engineering and information technology, that can be taken to a qualitatively new level;
- use of modern information technologies and robotic solutions;
- formation of engineering thinking skills based on relevant settings and through solving engineering challenges.

The following presents a brief description of several programs implemented by the university staff.

A. *The scientific and educational program of the BMSTU Summer Engineering School*

The program has been implemented on the basis of the city camp (summer engineering school). It is held on the territory of the university (Fig. 1). Participants live at their homes. The camp shift lasts 5 days.

Fig. 1. Module Designing a robot rover for the surface exploration of a studied planet

The scientific and educational program is a set of individual modules:

- Designing a robot rover for the surface exploration of a studied planet.

- Automotive engineering.
- Computer-aided design of components for underwater robotics.
- Development of a portable gas analyzer.
- Ion-plasma technologies in engineering.

B. The scientific and educational program of the camp-seminar "Step into the Future"

The program has been implemented on the basis of one of Russia's leading international children's summer vacation centers. The camp has good infrastructure. It is located on the seashore and operates throughout the year. One shift lasts 21 days [7, 8].

The science education program is a set of integrated training modules:

- Club of young radio amateurs.
- Computer-aided design.
- Measurements carried out in nature and in engineering.
- Arduino for beginners using the example of design of a planetary rover model.
- Composite materials.

Each module has a duration of 24 hours (12 days) and includes a small introductory theoretical part, the main practical part in which students solve various small engineering tasks, and team projects and competitions in the end.

The program involves schoolchildren (8-18 years old) with different levels of training; each group consists of about 15 people.

As inferred from above, the camp-seminar program is the most intensive program, therefore, for a better understanding of the module structure of this camp as well as that of the others (which are compressed and shorter in time), we give a brief description of several modules: engineering module "Arduino" for beginners on the basis of the development of a robot rover model" and academic module "Measurements in nature and engineering". The first has been implemented in different modifications in all programs.

C. Arduino for Beginners Using the Example of Design of a Planetary Rover Model

Contrary to classical analogues, aimed at studying the Arduino electronic platform, the presented module made it possible to combine in a balanced complex the study of history of cosmonautics, theoretical foundations of robotics, microelectronics, mechanics, electrical engineering, mathematical modeling and programming with the implementation of various applied problems, it contributes to formation and development of students' engineering thinking [9].

After a short introductory lecture or theoretical part, a two-step practical part follows. At the first stage participants individually do small engineering projects, it helps them to learn more about the hardware and features of microcontrollers programming.

Fig. 2. Development of the planetary rover model

At the second stage, having split into teams, participants develop models of planetary rovers (Fig. 2). The constructed models made it possible to learn and work out a large number of algorithms for interaction with various electromechanical devices, laws of motion and the principles of controlling similar systems.

Fig. 3. Final test and team competition

Moreover, a wide variety of possible alternative solutions helps to show schoolchildren not only the best solution, as it is often done in traditional educational programs, but also the disadvantages or even, possible, local advantages of alternative solutions. This allows students to learn how to choose the optimal design criteria in general, i.e. to see the whole picture, and not just a private task.

At the end of the module, competitions are held between teams, which consist in passing the speed obstacle course (Fig. 3), both in direct distance control mode and in automatic mode with carrying out the required measurements. The introduction of a competitive component in the module contributes to students' intensive retention of the acquired knowledge, as well as to the development of teamwork skills. And the volume of the tasks is such that without distributing local tasks, i.e. without team work, participants simply do not have time to do them.

D. Measurements in Nature and Technology

The research module "Measurements in Nature and Technology" is based on the work with the laboratory automated measuring system "Vernier" [10], which allows to use a number of sensors to measure a large number of quantities and dependencies between them. Particular attention in the module is given to the measurement errors handling while using the non-standard approach of modeling physical measurement by throwing up dice and using the statistical regularities of this random process [11].

A teacher designates the area of research, and guys, working in groups, independently set tasks for themselves, select measurement conditions, quantity and nature of the measured quantities, analyze the obtained results, determine the area of their practical application (Fig. 4 & 5).

At the final stage, competitions are held in the form of a scientific tournament, which is a model of defense of a scientific thesis. The participating in the competition teams alternately act as a rapporteur, an opponent and a reviewer. During the preparation and conduction of the tournament participants acquire important for their future professional skills: the ability to work in a team, ability to present the results of the research in the accessible and at the same time scientific language, the ability to objectively evaluate and constructively criticize the interlocutor’s position. The fascination of the game aspect of the competition creates a powerful charge of positive emotions for children, which is an additional motivational incentive for the future choice of engineering or scientific professions.

Fig. 4. Measurement of the conductivity of soil by Van der Pauw method

Fig. 5. Measurement of the conductivity of ground by Van der Pauw method

III. Implementation Features of Programs on the Basis of Children's Camps

The first few years of the program implementation were a success in regard to the approaches adopted in their development. They revealed a number of features associated with organizing and conducting classes in children's camps that are not common for school or university training groups. Few features that can be highlighted are:

- difference of children’s age in the same group;
- significant differences in the basic training of students of the same group;
- training of schoolchildren from different countries with different levels of language training and culture of learning in the same group.
- complexity of ensuring the safety of certain technological processes;
- the need for scientific and technical guidance on one hand, and on the other, the development of skills associated with solving the engineering tasks independently by schoolchildren;
- Individual differences of children in terms of the level of involvement in engineering activities.

Let’s consider these features in details and describe the proposed measures and decisions taken to improve the effectiveness of the programs being implemented.

A. Different age and level of preparation

The main peculiarity revealed in the first year of the program implementation, is a considerable scatter in the age structure of the participants due to specifics of the formation of groups (teams) in children's countryside camps. The same group may have children who are between the age of 8 and 18. In addition, the level of training is often markedly different among students of the same age. Moreover, the more intense and longer the program, the more the differences appear and greater the corrections to the program may be required.

Based on the results of the first few years of the implementation of the scientific and educational program of the camp-seminar “Step into the Future”, it was decided to implement programs of two levels: a full course (24 academic hours) and a short course (12 academic hours). These courses differ not only in the number of hours, but also in their methods, objectives and tasks.

The full course is aimed at schoolchildren, approximately of one age group, with good basic training and interest in technical creativity. In the process of learning, students acquire certain technical skills (design, modeling, programming, assembly, etc.). At the final stage, participants receive a final functioning product or a completed research project of applied engineering.

The short course, conducted in the format of children's studios, enables students to try their hand at one of the types of engineering activities, to find their strengths and weaknesses and to get the result of the small practical area the student is interested in. The course is made quite flexible, i.e. is designed to ensure that each child will solve a technical problem of different levels in accordance with their interests and capabilities. In addition, working in groups allows the distribution of the different stages of solving the problem among the participants in a way that it is within the everyone's reach.

The programs of city camps were not changed, as the groups formed in city camps are more homogeneous by age, and have short-term programs. These programs allow students to get acquainted with various types of engineering activities, to understand how much they are interested in this technical direction. Unlike the full course, where students are given freedom of creativity, and even unlike the shortened course, where the freedom of creativity exists even while being severely narrowed, here, due to time limitations, everything is strictly carried out according to the instructions and methodological recommendations. This allows participants with different levels of training to successfully complete all the basic tasks. Moreover, the ones who are specially prepared have the opportunity to do additional tasks.

B. *Level of involvement*

Before the beginning of classes, the trainees, as a rule, are given the opportunity to get acquainted with a brief description of all the implemented fields and programs. Having become acquainted with them, they can choose the one that they like most. However, since the number of participants in each field is limited, not everyone may get into what they desire. Experience has shown that in order increase the involvement of participants, it is better to give them the opportunity to choose a program when filing the documents, allowing them to focus on those programs where there are places available at the time of registration of the application.

In the first year of the implementation of the camp-seminar program ‘Step into the Future”, as an experiment, participants were given the opportunity to move from module to module during the shift, which was used by some to search and find a more interesting field for themselves. But as practice has shown, such transitions did not allow participants to fully enter the curriculum of subsequent lessons as they often missed the theoretical part and basic examples of new modules, which, accordingly, worsened their results. Therefore, in the future, the transfer of the participant was allowed only after the first introductory lesson, with a clear explanation why he considered this necessary: for example, from a brief description, the participant had an erroneous idea of the field of the module.

In city camps, such a transition is not available.

In order to further cover the training areas for each of the participants in 2018, it was decided to make an experimental 24-hour program, partially combining the two modules described above: “Measurements in Nature and Technology” and “Arduino for Beginners Using the Example of Design of a Planetary Rover Model”. The theoretical and basic practical part takes place separately in each of the modules, and the experimental (competitive) is done together and is aimed at creating an automated measuring system based on the planetary rover model.

The results of the program showed that it requires further methodical improvement for improving the interaction of children between different modules, since the role of teamwork in this case increases significantly. Some participants had set tasks for their colleagues, who in turn introduced them to possible solutions, and together they agree to implement the joint project. At the same time, we got the impact of working in a small design bureau, consisting of interacting departments (groups) responsible for the technical platform, the payload and the carrying out of the experiment. The program aroused increased interest among the participants, and contributed to a more creative approach to solving the task. In the future, it has been planned to expand this branch and attract participants of other modules. This will make it possible to implement a more integrated approach, making the task more voluminous and interesting. In particular, it is possible to attract a group of radio amateurs to assembling and manufacturing boards, rather than to give ready-made modules. Some of the parts can be made of composite materials. Computer modeling specialists will allow implementing more sophisticated control algorithms.

C. *Engineering environment*

Despite so much information about various professions, modern schoolchildren often do understand their propensity and what they really find interesting, because they do not have the practical component of this information. Therefore, their exposure to the appropriate situation or environment is an important stage in the process of involving the school students in engineering or scientific and practical activities. It is not just about interior and equipment, although this is very important, but also about the atmosphere of industry – specific scientific and engineering activities.

At the initial stage, lecture halls similar to school classrooms and portable equipment partially brought by the university staff can be used to create an appropriate space that allows implementing various creative technical ideas. Practice has shown that it might be possible to recreate the atmosphere of scientific or engineering work with good content and methodological support, but special lecture rooms are required in order to ensure an individual approach, maintain safety practices of all technological processes and form schoolchildren's capacity for emerging independence.

Thus, creating a special technological engineering environment on the basis of summer camps is a very important moment for qualitative implementation of the practical component of programs. This environment, as a form of the accessible innovative educational environment, provides the conditions for realization of the potential of schoolchildren who are creative in science, technology and engineering. Such an environment makes it possible to take the study of science (primarily physics and mathematics), as well as engineering and information technologies, to a qualitatively new level, and provides a unique opportunity for schoolchildren to "meet" with various professions and "touch" them with their hands. On one hand, work in such an educational space is fascinating for students, but at the same time high standards are formed which allow them to throw themselves earnestly into engineering activities. Examples of such an environment, from the point of view of design, can be the various scientific and educational centers (for example, at BMSTU [5, 12]) or engineering kitchens. One of the best examples of the engineering kitchens can be the Rice University Oshman Engineering Design Kitchen (USA) [13].

IV. Main differences and specificities of different categories of camps

On the basis of the above, a number of features, advantages and disadvantages of different categories of camps, reflecting the specifics of the implementation of scientific and educational programs on their basis, can be delineated.

Shifts in country camps are longer than in city camps. On one hand, this allows taking children from their habitual environment and plunging them in a new one, in particular, in engineering environment. On the other hand, there is enough time for harmonious blend of the study into the general program of the camp, and children get the opportunity to learn and relax. Longer communications, joint living and participation in various events allow participants to better organize team work. Thus, this category of camps allows the participant to cover a small number of tasks (often only one) that are analyzed in depth. It is interesting that some schoolchildren purposely try to return to countryside camps for pre-professional engineering education programs (having passed the competitive selection for this purpose) in order to be trained in a program related to another technical field next time. This indicates the formation of a steady interest in students in creative engineering activities.

City camps have short-term shifts. They do not allow going into the depths of each area of study, but do permit more participants to try themselves in different specialties having joined several programs during the holidays. Therefore, these programs are aimed primarily at general career guidance, while the programs of countryside camps are aimed more towards obtaining and developing certain skills associated with a specific technical field.

A greater number of children's countryside camps are also focused on work only in the summer, and only some camps work year-round. An additional difficult task is set for year-round camps – to fit the schooling program harmoniously into the life of a children's health camp. It is necessary that during the shift students who come there study the school curriculum.

In order to solve these problems, network educational modules were represented as an interesting form of integration of basic school education and additional pre-professional engineering education.

This form of studies involves the allocation of a separate topic of the education subject (physics, mathematics, or computer science), corresponding to the school curriculum, and studying its practical engineering aspect, as well as solving problems of applied orientation after a little theoretical preparation.

For example, in the process of implementing the network educational module program related to the educational area "physics", two teachers with basic engineering and physical education conduct the classes simultaneously. This allows giving the theoretical foundations of the chosen educational field in a form adapted for schoolchildren, but different from the usual school presentation of the material, and to acquaint students in practice with the applied aspects of the acquired knowledge. During the class the children work in scientific and training mini-laboratories, use laboratory measuring instruments, and assemble the simplest electronic devices under the guidance of two teachers. It is important that the students have a direct dialogue with an engineering specialist and a representative of the scientific educational field. With such an organization of the educational process, educational environments are created in which it is necessary to use various types of intellectual activity. This makes it possible to integrate the scientific and technical training of schoolchildren with elements of engineering, design and research activities.

V. Conclusions

The scientific and educational programs presented in this work have only been implemented for the third year. Thus, it is too early to talk about any global results, but following the results of the program implementation, many students became interested in technology and exact sciences, continued, in the framework of technical creativity, implementation of projects started in the camp and, as result, entered technical universities, including, the University. We can also make the following intermediate conclusions and observations:

1) Each category of camps has its own specifics, which must be taken into account when developing programs for them.

2) The engineering environment, high intensity of activities, competitive atmosphere and teamwork contribute to the development of the students' skills in the joint work, allowing them to realistically assess their knowledge, skills and abilities in relation to other children and new conditions, and understand what they should study more thoroughly in order to achieve high results in the future.

3) Various engineering tasks with a large number of possible alternative solutions allow children to reveal themselves, never fear to try new approaches and think independently, which, in turn, leads to the development of innovative thinking. The value of an engineering approach is that an engineer himself puts questions in the given area, looks for answers, and analyzes the results. The team work of participants (trained in different areas) on one project allows solving more complex engineering tasks, finding more interesting and innovative ways to solve them, contributing to the additional development of teamwork.

4) Additional educational programs implemented on the basis of the children's camp have already shown a worthy result and can become a good form of pre-professional engineering training combining the subject, practical, developmental and motivational components.

The project is still a work in progress. New programs are being developed and existing ones are being expanded. The different ways of their improvement and stronger integration are being sought out.

References

[1] S. Beechler and I.C. Woodward, The global “war for talent”, Journal of International Management 15 (2009) 273-285.

[2] A.O. Karpov, Early engagement of schoolchildren in research activities: The human factor, J. Advances in Intelligent Systems and Computing, V. 596 (2018) 84-94.

[3] Engineering class in the Moscow school, http://profil.mos.ru/inj/o-proekte.html, (accessed 11.01.19).

[4] V.I. Mayorova, D.A. Grishko and V. Leonov, New educational tools to encourage high-school students’ activity in STEM, J. Advances in Space Research, V. 61, I. 1 (2018) 457-465.

[5] V.I. Mayorova, Concept of using innovative-educational university centers of space services as an innovation for space education, Proc. 63rd International Astronautical Congress (2012) 10045-10049.

[6] A.Yudin, A. Vozhdaev, D. Sukhotskiy, M. Salmina and [all], Intensive robotics education approach in the form of a summer camp, J. Advances in Intelligent Systems and Computing, V. 560 (2017) 246-250.

[7] Leonov V., Burkova E. Space Oriented Scientific and Educational Programme in the Field of Basic Engineering at Children’s Summer Camp // Proc. 68th International Astronautical Congress, 2017. V. 3, P. 1721-1727.

[8] International Children’s Center “Artek” http://artek.org/en/, (accessed 10.01.19).

[9] V.I. Mayorova, O.K. Bannova, T.H. Kristiansen, V.A. Igritsky, Importance of joint efforts for balanced process of designing and education, J. Acta Astronautica, V. 111 (2015) 249-256.

[10] Vernier LabQuest Hardware and Specifications, https://www.vernier.com/products/interfaces/labq/hardware, (accessed 14.01.19).

[11] E. Burkova, A. Kravtsov and G. Pogodin, Supplementary education program for school students "The measurements in nature and technology", J. of Physics: Conference Series, V. 918, I. 1 (2017).

[12] Research in the BMSTU, http://www.bmstu.ru/en/science-community/research-in-bmstu, (accessed 10.01.19).

[13] Oshman Engineering Design Kitchen, http://oedk.rice.edu, (accessed 11.01.19).