Functional model of an engineering class at a university

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Abstract. The relevance of the study is based on the fact that the program of socio-economic development focuses on the expansion of science-intensive production focused on information and digital technologies. Therefore, the demand in engineers for modern production becomes the social order of society. The purpose of the study was to develop a functional model of the engineering class at the university. This will create conditions for the training of school graduates aimed at obtaining technical education with a high level of natural science and technological training. The paper is devoted to the problem: what is the functional model of the engineering class at the university? The functional model of the engineering class for high school students includes functional and structural components that ensure the formation of competencies among schoolchildren necessary for a future student mastering an engineering educational program. The following abilities of high school students serve as indicators of the efficiency of the developed model: ability to formulate and argue their point of view; work individually and as part of a team; master information and communication technologies; readiness for continuing education at the university and self-education; possession of the fundamentals of systemic thinking.

Keywords: engineering class, functional model, network interaction, functional component of the engineering class, engineering competence of high school students.

1 Introduction

The engineering class is an innovative educational model, the results of the implementation of which are aimed at forming the competencies of schoolchildren necessary for a future student mastering an engineering educational program. It should be assumed that the learning process is a purposeful interaction of a teacher, students, and the content of education, aimed at mastering the content of education by students. Obviously, the development of learning materials takes place at different educational levels. Pedagogical and methodological aspects of engineering classes were studied and described by many scientists. For example, I.I. Baïneva notes that the strategic task at present is the development of engineering education. Based on the analysis of the engineering competence model, the author writes about the need to develop “school programs of engineering education” [1]. P. Kutnick, B. Pok-Yee Lee, R. Yuen-Yan Chan, C. Ka Yuk Chan [2] show the growing need of the society for engineering specialties, simultaneously with this stating that only a limited number of schoolchildren have a desire to study in technical specialties. X. Zhang, R. Liu, W. Yan, Y. Wang, Z. Jiang, and Z. Feng [3] analyze the efficiency of engineering education through online and offline cognitive internships. A. Asfaw, A. Blais, K.R. Brown, J.H. Shapiro and C. Singh consider the main substantive aspects of the original roadmap for engineering schools and faculties to promote quantum engineering education [4]. According to the results of studying the works of these and other scientists, the following provisions were identified.

The purpose of creating engineering classes involves the formation of universal, general and pre-professional competencies and skills of the research work of schoolchildren, familiarizing them with the variety of engineering specialties, creating a contingent of applicants.

The fundamental difference between the traditional physics and mathematics class and engineering class is that in the first case, high school students receive knowledge in a larger volume than in an ordinary class, and in the second, in parallel, they familiarize themselves with engineering specialties in which this knowledge must be used to master the relevant technologies. In addition to an in-depth study of mathematics, computer science and physics, within the framework of elective courses, students study computer drawing, alternative electric power industry, the basics of nanotechnologies, 3D modeling, practice-oriented programming, etc. Besides studying subjects, high school students are included in practice-oriented research activities by participating in scientific conferences, in design and research competitions. Victories in these events provide an opportunity to get additional points when entering a specialized university. At the end of their studies in the engineering class, high school

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students are invited to pass a profile exam, the results of which can also be taken into account when entering a university.

A separate question is software and technical equipment of engineering classes. In accordance with the fact that the study in such classes is aimed at engineering training and at training programmers, there is a need for modern equipment in the form of robotics and constructors, 3D printers, carpentry and turning equipment. By acquiring skills in working on engineering and software equipment, high school students form a system of preferences for the personnel development of the engineering sphere, motivation for a conscious choice of profession. Having studied and analyzed the work of A.V. Yartsev that pre-professional training ensures the formation of specialized skills and abilities in design and research activities, and universities have all the conditions for organizing design and research activities [5] S. Jose, J. Rajan A. V.H.Wilson revealed that in order to develop the technological skills and talents of students, there is a need for environment satisfying their educational needs [6]. Instead of a single approach for all, it is proposed to use a flexible course system in which an interdisciplinary approach is implemented. Based on these and other works, it can be concluded that an engineering class can have one of three types of organization:

- at school (the creation of specialized classes for the in-depth study of natural sciences, information, mathematical and technological training), lessons are taught by school teachers of specialized subjects who have passed special advanced training courses;
- network interaction involves the organization of an engineering class for high school students at schools, but university teachers are invited to teach specialized disciplines, who, in addition to specialized career guidance, will ensure the continuity of school and university education, and also allow using the material and technical support of the university;
- at the university – this method involves additional education in the form of elective courses in natural science school subjects: mathematics, physics, computer science and technology. The material and technical equipment of the university is used.

According to the authors of the article, and according to the results of studying the problem of organizing an engineering class at the university, the most promising, rational and effective is the type of network interaction between the school and the university. It is such interaction that will make it possible to qualitatively implement the functions of engineering education, namely polytechnic, scientific-theoretical, social-positive, design, creative.

2 Problem Statement

The relevance of creating an engineering class for high school students is caused by the social request, where there is an acute shortage of qualified engineers. This problem generates a demand for natural science specialized education, extracurricular activities and additional engineering education. Thus, the paper is devoted to the problem: what is the functional model of the engineering class at the university?

3 Research Questions

The subject of the study described in the paper is a functional model of the engineering class at the university implemented on the basis of the network interaction of the school and the university.

3.1. Network interaction between the school and the university as an innovative form of education for schoolchildren

The network interaction between the school and the university is a joint educational activity of two or more educational institutions to fulfill the public request to improve the quality of education. Scientists such as J.I. Bainevea [1] studied the methodological issues of network interaction, which confirms the need to use network interaction between a school, university and enterprise in order to be able to pass internship in modern laboratories. A Tokarev, I. Skobelin, M. Tolstov, A. Tsyganov, M. Pak show that virtual reality tools should be used in school pre-professional education [7]. This makes it possible to formulate the main tasks of network interaction.

1. Adapt engineering forms and technologies to the psychological and pedagogical features of school education.
2. Create conditions for the development of the research and creative career guidance component of school education.
3. Determine the direction of career guidance for the purpose of professional self-determination of high school students.
4. Identify and create conditions for the formation of engineering competencies necessary for training at a technical university.
5. Introduce high school students to the system of general cultural, scientific and professional development and self-education.
6. Motivate school teachers and university teachers to find optimal and effective technologies for teaching, developing and educating schoolchildren.

In addition to general ideological the specific principles of network interaction between the school and the university were identified: innovation in the use of modern information technologies; continuity of innovative and career-oriented educational programs; integrity to the results of the specialized development of schoolchildren, their adaptation to external changes in the professional sphere; voluntariness, freedom to choose the network interaction.

The success of organizing network interaction depends on a number of conditions that must be observed for the success of its organization. The study describes the following: current training of teachers; justified use of distance technologies in the education of schoolchildren; availability of a modern material and
The purpose of the study is to analyze and determine the functional component within the structural components of the engineering class model implemented on the basis of the network interaction of the school and the university aimed at forming the competencies among schoolchildren necessary for future mastering the engineering educational program.

5 Research Methods

The study applied a methodology of pedagogical modeling. The results of studies on the identification of functional components of the engineering class model at the university are summarized. Forms, methods of its implementation are described. The experience of foreign and Russian scientists on the problems of organizing engineering classes for schoolchildren and on the network interaction of the school and the university was carried out, analyzed, and summarized.

6 Findings

Based on the analysis of different approaches to specialized training, the study developed a functional model of the engineering class at the university. I.M. Osmolovskaya notes that the classical didactics addresses the following educational components in the process of learning: purpose, content of education, forms, methods, means and result [8]. The authors of the paper supplemented the classical educational model with a functional component, since its content affects the formation of competencies among high school students necessary for a future student mastering an engineering educational program. The functional apparatus of engineering education, the identified structural components of network interaction, made it possible to develop a material functional model of the engineering class (Fig. 1).

Functional component. Let us list the interaction between the functions of the engineering class and the indicators of engineering competence: the polytechnic function contributes to the development of the indicator of engineering competence of schoolchildren; master information and communication technologies, readiness to continue education at the university and self-education; scientific and theoretical – to formulate and argue students’ point of view; socially positive – work individually and as part of a team; design and creative – knowledge of the basics of systematic thinking.

The motivation-target block is the purpose and determines the promotion of motivation for students to master engineering competencies, namely: ability to formulate and argue their point of view; work individually and as part of a team; use ICT; readiness for continuing education at the university and self-education; know the fundamentals of systematic thinking.

3 Purpose of the Study

The purpose of the study is to analyze and determine the functional component within the structural components of the engineering class model implemented on the basis of the network interaction of the school and the university aimed at forming the competencies among schoolchildren necessary for future mastering the engineering educational program.
The **content block** is the integration of the content of general education subjects and the research work of the natural science disciplines of the university. This approach focuses on the formation of basic knowledge about modern industries among high school students, which makes it possible to demonstrate the unity of the world of technology and digital technologies, and in the future make the choice of profession. Therefore, the basic substantive directions are: computer technologies (drawing, modeling, graphics, CAD/CAM systems, etc.); fundamentals of industrial robotics, electronics and electrical engineering; electrical installation. The curriculum of the engineering class contains both traditional specialized subjects (mathematics, physics, computer science and ICT, technology, etc.), as well as additional subjects on the choice of students (for example, robotics, programming, project work, etc.).

**Organizational and activity block**

*Methods*: explanatory and illustrative, research, projects.

*Forms of work*: work in laboratories and visits to specialized departments; work of schoolchildren together with students or group work of schoolchildren with a student consultant; visits (excursions) to enterprises, production facilities to familiarize students with the organization, technological process; attracting representatives of enterprises to work with schoolchildren (project defense, career guidance meetings, etc.); inclusion of university types of work (lectures, seminars, workshops) in the work with students of the engineering class; joint lectures with students, seminars (with adapted content), conferences, project defenses; industrial internships; professional hackathons [9].

*Means*: information and communication technologies, software and pedagogical, scientific and pedagogical, technical.

The control and correction block consists of three parts: control and testing (testing, creative tasks, questionnaires in accordance with the content block); assessment and result (closely interrelated with the first part of the block, allows tracking the dynamics of the formation of engineering competencies of high school students); checking the level of formation of engineering competencies among schoolchildren, which allows either continuing specialized training, or making adjustments to the model of their career guidance training.

After developing the main components of the functional model of the engineering class, the authors of the study organized an online survey of teachers of mathematics, computer science, physics and deputy head teachers of Solikamsk city district. The survey covered 52 people. The purpose of the online survey was to identify the attitude of the teaching community to the developed engineering class model and identify implementation risks. The survey contained three questions:
1. Do you consider it possible and socially overdue to organize a network interaction between a school and a university in order to form indicators of engineering competence among schoolchildren: to formulate and argue your point of view; work individually and as part of a team; know information and communication technologies; readiness for continuing education at the university and self-education; mastery of the fundamentals of systemic thinking.

2. In case of a positive answer, highlight those indicators of the engineering competence that you consider the most important.

3. What are the risks of introducing this model at schools?

The online survey revealed the following results: 85 % (44 people) of the respondents supported the possibility of implementing a functional model of the engineering class. All indicators of the engineering competence received approximately the same significance values. The risks of implementing the model were the following: large extracurricular workload in all school subjects of teachers and schoolchildren; low motivation for the additional burden of teachers and schoolchildren; small number of schoolchildren wishing to participate in network interaction, olympiads, competitions, etc., to be engaged in research work; need to make adjustments to the school curriculum.

7 Conclusion

In conclusion it is necessary to compare the results presented in the article with the results of the work of other scientists. Thus, S. Belyaevskaya, G. Grishko, G. Kozlova present the experience of attracting specialists from enterprises in engineering classes to supervise the research and design activities of students, university teachers to conduct a special additional course in advanced computer science; organization and conduct of professional hackathons [9]. The study proposes to invite university teachers to conduct special additional courses in advanced computer science, mathematics, physics, as well as to supervise the research and design activities of high school students. V.I. Belyaev, considering the organization of training in engineering classes, notes that the school faces the problem of the shortage of teaching staff able to acquaint students with the basics of the engineering profession, a small number of students who are really interested in this, lack of equipment, modern devices, etc. The author offers a 72-hour program “Fundamentals of Radio Electronics and Robotics” implemented at the school on the basis of the network interaction with the university [10]. The authors propose to solve the problem of personnel through the network interaction of the school with university teachers. S. Huda, S. Alyahya, L. Pan Al-Dossari H. characterize the process of combining innovative technologies and context-oriented approaches in software engineering training [11]. The authors used the same principle, but expanded it with a functional component. Q. He identifies the features of the design and application of an interactive training system for “Electronic Engineering” based on the ZigBee platform [12]. W. Zhu, X. Fan, N. Brake, X. Liu, X. Li, J. Zhou, D. Sisk, J. Yoo conducted research on the inclusion of engineering design and manufacturing in the high school curriculum. The purpose of the project is that every summer 12 secondary school teachers take part in engineering design and manufacturing research and then transfer the obtained expertise to the secondary school curriculum [13]. The authors agree that teachers need to improve their professional competence and adapt it to the innovative achievements of technology. Thus, the study conducted by the authors showed that school teachers are not against a network interaction between a school and a university in order to organize an engineering class, but identify the risks of such work. The authors also hope that the work on the introduction of a functional model of the engineering class must be continued and seek ways to motivate teachers, schoolchildren and their parents to cooperate.

References

3. X. Zhang, R. Liu, W. Yan, Y. Wang, Z. Jiang, Z. Feng, Effect Analysis of Online and Offline Cognitive Internships Based on the Background of Engineering Education Accreditation. Sustainability (Switzerland) 14(5), 2706 (2022)
4. A.V. Yartsev, The role of design and research activities in the pre-professional training of students in engineering classes. Phys. at Sch. S2, 190–193 (2020)

