

# Formation of the Groundwork for the Training of Project Managers in Engineering Bachelor

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**Abstract** — The author's technology of interdisciplinary open-ended engineering is considered in the article. This technology provides a comprehensive formation of design and project-organizational competencies. It creates a basis for the development of managerial abilities of a design engineer and increases the practical orientation of the educational process. The author's understanding and definition of the developed technology of education are formulated in the article. The stages, methodological tools and procedures that form the basis of the developed technology in the educational process of engineering bachelor's degree are shown. An organizational model of technology of open-ended engineering is presented, from which its integrating functions in the construction and implementation of the entire educational program are visible. The analysis of the characteristics of students' learning activities is carried out, as well as the intermediate results of its application in the educational process.

**Keywords** — *open-ended engineering; technology of interdisciplinary open-ended engineering; engineer-designer; head of engineering project; full life cycle of the product; project management.*

## I. INTRODUCTION

Graduates of engineering faculties of universities often become managers of engineering projects in various industries. However, this is preceded by a long period of accumulation of professional and organizational experience.

Rich experience is always a plus in any activity, but its slow acquisition reduces professional motivation and creative innovative abilities. Reduce the period of formation of the manager of the engineering project can be due to changes in the requirements for the training of graduates of engineering bachelor's and master's degrees, as well as through the application of appropriate methodology for their training.

Graduates of the university should have a wide range of engineering, applied and economic competences, including interdisciplinary and managerial knowledge for the accelerated formation of readiness to lead an engineering project. This knowledge and skills are necessary for the graduate to use them in the design and implementation of innovative technical systems. Such knowledge and abilities in graduates are not actually formed with the traditional approach to engineering training. As part of this study, it was found that many young engineers in the field of design and engineering have interesting ideas, but they cannot clearly articulate them,

convincingly substantiate and attractively present the process of their implementation in the form of a project with concrete results. This is hampered by the following shortcomings in their qualifications:

- low level of interdisciplinary knowledge;
- lack of understanding of the full life cycle of the technical system, as well as project management and the concept of the engineering project;
- superficial knowledge about the development of the technical task for the product and on the functional and cost analysis in the design process;
- poor understanding of the organization of team work on the project, organization of the project completion process and a number of other.

To form these knowledge and competences, it is necessary to change the methodology of the educational process without changing the educational program substantially. The use of the open-ended engineering method in the training of engineers and a slight correction of the content of the training program make it possible to eliminate the majority of the indicated shortcomings and increase the ability of graduates to become the head of an engineering project in a short time.

## II. THE APPLICATION OF OPEN-ENDED ENGINEERING IN HIGHER EDUCATION

The method of open-ended engineering is actively used in Russian universities, which carry out the preparation of bachelors and masters in engineering and technical profiles. Most often it is used in the educational process in the following areas: construction [1]; machine building [2-4]; instrument making and electronics [5-7].

In these publications, the implementation of open-ended engineering is usually the implementation of a complex project task by students over several semesters (two to five). The complex task contains several interrelated local assignments, which students carry out within the framework of course design in separate disciplines. In the last semester, students combine the results and protect them as their final qualifying work. In this regard, a number of authors note the need to adjust the curriculum to optimize the consistent implementation of course projects and the joint work of several departments to develop a comprehensive project

assignment. [3, 8, 9]. In addition, open-ended engineering methodology is used not only in the main educational process of higher education institutions, but it is also used in student clubs [10, 11].

Thus, open-ended engineering in the widespread practice of its application is a method of training, which is built on the basis of an integrated project assignment. It is used as a means of creating a link between course projects and creates the basis for final qualification work on a narrow technical topic.

### III. CONCEPTUAL FOUNDATIONS OF THE TECHNOLOGY OF INTERDISCIPLINARY OPEN-ENDED ENGINEERING

Not all the possibilities of open-ended engineering are realized in the considered experience. According to the authors, the main idea of open-ended engineering in the educational process of the university is to make the project activity the main method of teaching, and its content is the core of the practical interrelationship of different disciplines of the educational program with the provision of interdisciplinary content of vocational training.

The maximum effect in the realization of this understanding of open-ended engineering is achieved only with the creation of an appropriate educational technology. The technology of open-ended engineering is proposed to be considered as a set of methods and tools for organizing the educational and project activities of students and, at the same time, optimizing the structure and content of the educational program. All this in a relationship ensures the mastery of the contents of the academic disciplines and the interdisciplinary process of designing technical systems corresponding to the profile of preparation. This set of methods and tools for organizing the educational and project activities of students is united by a common logic and has a certain sequence that allows you to achieve the specified learning outcomes.

For the organization of highly effective educational and project activities it is necessary that the open-ended project becomes the backbone of the educational program. At the same time, some stages and components of open-ended project should include design tasks for most disciplines, as well as course projects and interdisciplinary projects for training modules. In addition, the logic and content of open-ended engineering should determine the structure and content of the educational program, as well as the curriculum and timetable for its implementation. This task is the most difficult in the creation of this technology, because it requires changing the traditional approaches to the development of higher educational programs at various levels (bachelor and master).

The technology of interdisciplinary open-ended engineering was developed for the original educational program of engineering bachelor's degree in "System analysis and management" in the field of design and engineering activities at the Higher Engineering School of the Ural Federal University. The development of the technology of interdisciplinary open-ended engineering is the integration of two opposing processes: 1) the formation of a plan for project activities of students, including project management, the results of which correspond to the necessary abilities (competency model) of the graduate; 2) the formation of an

educational program, including its curriculum and implementation schedule, which allow for an open-ended engineering with maximum results of project activities and training.

The interdisciplinarity of technology of interdisciplinary open-ended engineering is expressed in the organization of student work aimed at analyzing and identifying the various interrelationships in the content of different disciplines of the curriculum that are used to develop an open-ended project. This work is carried out in the form of separate project assignments, as well as in the development of interdisciplinary projects for training modules. Students analyze and identify the interrelationships between the content of different disciplines for developing effective design solutions at different stages of interdisciplinary open-ended engineering. Therefore, in the educational process, students consider the interrelationships between technical, natural-science and technological training courses, as well as their interrelations with economic, managerial, psychological, ergonomic and other disciplines.

### IV. STRUCTURE OF THE TECHNOLOGY OF INTERDISCIPLINARY OPEN-ENDED ENGINEERING

The basis of the developed technology of interdisciplinary open-ended engineering is a set of the following methodological tools and procedures that regulate the project and educational activities of students.

1. Statement of the task of open-ended engineering and requirements for its result.
2. The technical specification for the development of technology of interdisciplinary open-ended engineering. It is developed and adjusted in the joint work of the student and the teacher during the entire period of its implementation. The technical specification includes the stages of the development of an open-ended engineering with a set of design tasks and assignments for work with academic disciplines, the content of which is necessary for their implementation.
3. Requirements for the protection of intermediate results of open-ended engineering, including course projects and interdisciplinary projects for training modules that are part of the open-ended engineering project.
4. Guidelines for the management of engineering projects and implementation of results of individual stages of the design in the form of prototypes from prototyping and engineering materials.
5. Consultation of qualified design engineers and managers of engineering projects working in production at all stages of the development of an open-ended project.
6. Final presentation of the complex of the main results of the open-ended engineering, obtained at its main stages, which includes the full life cycle of the technical system.
7. Adaptation of the open-ended project to the requirements of the final qualifying work and its public protection.

The structure and integrating functions of the technology of interdisciplinary open-ended engineering in the educational program are shown in the Fig. 1.

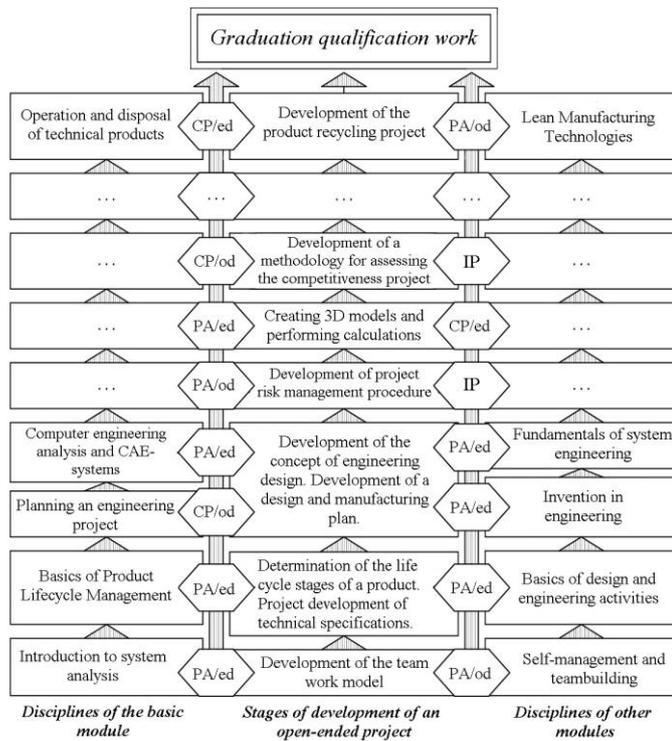


Fig. 1. Organizational model of the technology of interdisciplinary open-ended engineering: PA – project assignment; CP – course project; IP – interdisciplinary project for the training module; ed – engineering design; od – organizational design

It should be noted that, as a rule, one of the types of project activity prevails in the study assignments, which are provided for interdisciplinary open-ended engineering (not including interdisciplinary projects for the training module). Engineering design prevails at some stages of the educational process, organizational design prevails on others. This is due to the objectives of training, the logic of the educational program and the content of the subjects studied in the relevant period.

As can be seen from Fig. 1, open-ended engineering provides a two-way counter process between the design, organizational and educational activities of students at all its stages. In the work on the open-ended project, students' educational and practical activities are organized in such a way that the engineering tasks and project management that are solved in it are maximally projected onto the contents of the academic disciplines studied by students in parallel. And on the other hand, academic work in most academic disciplines is organized in such a way as to provide students with the opportunity to successfully solve the tasks of the open-ended project. Thus, mastering the educational program is a preparation for future engineering activities, as well as a key condition for solving the organizational problems of project development and implementation, which students perform in the process of open-ended engineering.

V. RESULTS OF APPLICATION OF THE TECHNOLOGY OF INTERDISCIPLINARY OPEN-ENDED ENGINEERING

Analysis of the implementation of technology of interdisciplinary open-ended engineering shows that as a result of its application, educational and project activities are organized, which:

- 1) provides the creation of a project of a real technical system relevant for any industry;
- 2) is the core of the educational process, which integrates the content of the educational program and defines the basic vector of vocational training;
- 3) organizes teamwork for the development of the concept of an engineering project and the implementation of all stages of the creation of a new technical system;
- 4) brings together the educational and professional activities of the engineer and the head of the engineering project, which constitute a complex of different types of individual and collective action;
- 5) provides training of well-educated engineers capable of organizing complex engineering projects;
- 6) determines the actual practical-oriented theme of the final qualifying work and ensures a higher quality of its performance;
- 7) forms system thinking and skills of its application in project-organizational activity.

When technology of interdisciplinary open-ended engineering is applied, the formation of both a design engineer and an engineering project manager is dynamic, as can be seen from the following learning outcomes. In the second semester, students are able to:

- organize team work on a project;
- determine the content of the stages of the product life cycle and plan the stages of the engineering project;
- interact, improving the effectiveness of group design solutions and preventing conflicts;
- create a functional model of the product from prototyping materials;
- implement solid-state and mathematical modeling in the development of design documentation.

In the 4th semester students can independently:

- prepare scientific and technical reports, reviews, feedbacks and conclusions in accordance with the requirements of the engineering task;
- manage open-ended engineering, adjusting the compiled plan for its implementation, and taking into account the risks of the project of a particular product;
- choose the basic design and technological characteristics of the product and perform the corresponding calculations;

- perform (individually and command): analysis of the requirements of the operational environment in the preparation of technical solutions; feasibility study for the product; evaluation of available technological capabilities when making design decisions.

At the end of each course, students prepare a report on the work done and protect it before a commission including teachers, design engineers and engineering project managers of industrial enterprises.

## VI. CONCLUSION

Thus, an interdisciplinary open-ended project is a real engineering project related to the field of student training. This project is systematically developed by students throughout the training period or a large part of it. At the same time, the tasks of the project activity are interrelated with the learning outcomes specified in the educational program. Accordingly, the contents of the educational program and the curriculum are adapted to the stages of the open-ended project, and their tasks and content are determined in accordance with the opportunities for the optimal implementation of the educational program. As a result, a new model of a practice-oriented educational program is formed, which determines the priority of educational and project activities. The graduate of this program, built on the basis of technology of interdisciplinary open-ended engineering, acquires the experience of designing, project management and production of the designed product. Thus, professional design and organizational competencies are formed in the graduate of this program, which are necessary for the development and implementation of an engineering project.

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