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Project Model in The Engineering Universities: Perspectives and Problems

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ABSTRACT

The purpose of this article is to analyze ways to integrate the project approach into educational programs, taking into account the experience of Russian and foreign universities. An analysis of the research problem field has shown that over the past 10 years higher education institutions have significantly changed the traditional educational programs moving to open curricula, as well as project and problem-based approaches. In general, the modification of educational programs is aimed at strengthening their practice orientation to real industrial cases.

The novelty of the work can be expressed by systematic analysis of various approaches to integrate project method into the educational models of the following universities: Singapore University of Technology and Design (SUTD); Olin College of Engineering; Aalborg University; TU Delft Iron Range Engineering; Singapore Polytechnic University.

Over the past few years, the concept of the traditional implementation of project activities has been modified to the direction of the company-formulated projects, as well as interdisciplinary projects, where the education is student-centered.

Methodology and research methods. When writing this article, the scientific basic method of theoretical and empirical research was used: methods of monographic research, questionnaire survey, methods of working with specialized software products, Internet sources, methods of analysis, synthesis, comparison, induction, and deduction.

Keywords: digital technologies, interdisciplinarity, problem approach, project method, startup.

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I. Introduction

Global changes in the industry, such as digitalization and autonomation of the technological lines, lead to changes in the requirements for specialists, and therefore to the formats of education. Modern graduates should have not only fundamental knowledge, but also a high level of the development of universal and professional competences. Many universities are currently testing various ways of integrating the competence approach, but all approaches require additional methodological elaboration, especially in terms of quantitative assessment of the level of competence development, as well as standardization of the assessment system. In order to ensure that level of graduates' professional competence development meets the requirements of companies, it is necessary for students to take part in solving technological cases from companies, as well as performing design and research works in laboratories of universities and

On the basis of enterprises during the training process. These problems are especially relevant for engineering education.

There are well recognized leaders, such as Massachusetts Institute of Technology (MIT), Stanford University, and new appeared strong universities: Singapore University of Technology and Design; Olin College of Engineering; University College London; the Pontifical Catholic University of Chile and Iron Range Engineering (Pontifical Catholic University), (Pister, 1995). The universities which are considered to be recognized leaders are well-known educational organizations in Europe and USA with a large enrollment, well-established pedagogical technologies such as: person-centered approach, development of educational programs in cooperation with industrial partners, project approach, problem-based learning. The universities, which are conditionally referred to "new" leaders, implement educational programs, which have been developed relatively recently and their necessity was pre-determined by regional needs or specific requirements of the labor market in the region. At the same time, the common characteristic features of these educational programs are practice-oriented learning, emphasis on interdisciplinarity, as well as the model focused on the development of design thinking and the ability of students to conduct self-reflection.

The purpose of this article is to analyze the ways and formats of integrating the project method in higher education institutions, which allows making education more practice-

oriented and developing professional competences. Both of these approaches aim to develop such universal competencies as collaboration and communication competences, analytical and critical thinking. Analysis of the research problem field is aimed at systematizing stages of the integration of the project model. In the history of modernization of the project approach several stages can be distinguished:

1) Standardization of the terminological concepts such as "project": and "research activity,"
2) Increasing number of the projects,
3) Focus on the interdisciplinarity,
4) Including creative projects in curricula and organizing presentation of the obtained data during project weeks-periods when students not only presenting data but also participating in different masterclasses which are focused on the development of the universal competences,
5) Decreasing number of lectures and seminars; integration of the innovative pedagogical technologies: for example, flipped classroom model.

Research Methodology and Methods. In order to assess the relevance of the experience of integrating project and problem-based approaches in universities, a comparative analysis of literature and educational programs was conducted, and the trends that were typical for several universities in the periods of their modernization were taken into account. Such methods were used as: comparative analysis of the problem, methods of survey and pedagogical observation.

II. Results and Discussion

As it has been described in (Pister, 1995), that modern industrial companies expect high level of the development of both professional and universal competences. Modernization of the educational process in universities is aimed at integrating project and case-methods, as well as person-oriented and practice-oriented approaches. The project method can be successfully applied both for developing universal competencies and for organizing research group activities. In both cases, the use of the project method leads to an increase in participants' motivation (Graham, 2018). A number of works are devoted to the analysis of aspects of coordination and management of project activities in higher education institutions, including those based on soft methodologies (Nagorny *et al*., 2021; Safonova *et al*., 2017; Omelchenko *et al*., 2019).

The articles (Safonova, 2017) provide an analysis of the current problems existing in project-based learning, and formulate the main requirements for organizing project activities in higher education institutions:

1) Project should be problem-based and should represent understanding the significance/relevance/urgency
2) The purpose of the project, as well as the results, should have an applied character
3) The full life cycle should be performed during making the project: from conception to operation and utilization (for an innovative project), from hypothesis to the application of the results (for a research project).
4) Complexity of the project must correlate with the level of the development of students' universal and professional competences as well as with the knowledge level acquired by the time of project realization
5) When organizing project activities, it is possible to consider options not only for individuals but also for group project work. In this case it is important to develop such universal competences as: self-management, collaboration, leadership skills, and discipline.
6) Separate elective courses devoted to the basis of the project work can be included in the curriculum.
7) Project work should be carried out with the integration of practice-oriented and problem-oriented approaches under the coordination of the university or company staff.

As it was noted in (Blomquist *et al*., 2010), there are logical correlations describing project life cycle and innovation life cycle (Fig. 1).

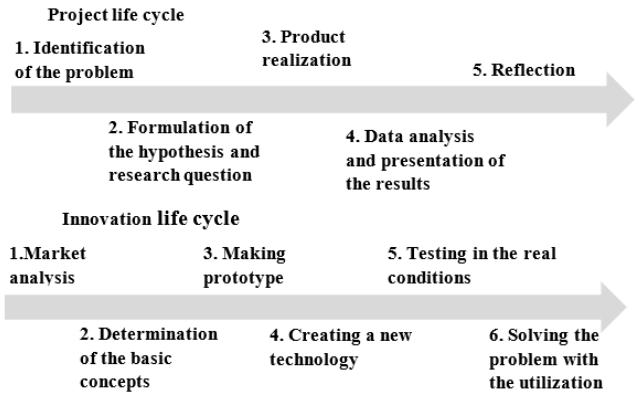

Fig. 1. Schemes of the project life cycle and innovation life cycle.

At the same time, when selecting and approving project topics, it is important to develop a standardized system of requirements and the universal procedure for projects' evaluation. As a possible option, the following scheme is proposed in the literature (Orr *et al*., 2020).

Principles of projects' selection in universities:

1) Correlation between the topic of the project and content of the knowledge obtained during lectures and seminars,
2) Focus on the development of the universal and professional competencies specified in the educational standard,
3) Applied character of the project, as well as the possibility of further commercialization of the product,
4) Comprehensive and standardized evaluation system of the project results,
5) Consideration of the motivation, as well as knowledge level of the participants, who will carry out the project.

The aim of integration of the project model into the educational process has been formulated by many universities in the program "Priority 2030." For example, Voronezh State Technical University (VSTU) has included in its curricula disciplines related to the basics of social design. The course "Project-based learning in technological entrepreneurship" has been implemented at Ufa State Petroleum Technological

University (USPTU) since 2017.

If we focus on the algorithms of organizing project activities in Bachelor's and Master's programs, usually the first two courses are devoted to teaching basics of project activities, as well as related universal competencies. At Tomsk Polytechnic University in the course "Creative Project" such issues as methodology of scientific cognition, research methods, art of presentation, basic approaches to organize work in the scientific group are considered. The discipline "Creative project" is aimed at forming the students' ability to understand and use the methods of creative thinking, the main trends in the development of scientific research, presentation of their own projects and developments in the course of presentations. The format of work on the project involves the formation of mini groups of 3–4 people who perform the project for a semester and subsequently present it during the conference week (Plotnikova *et al.*, 2015).

Each university has its own database of project topics completed by students of different undergraduate and graduate courses. The categories of projects can refer to different areas of application: for example, the development of mobile apps for developing of digital competencies; professional development in specialized and professional areas, as well as the development of business plans and startup projects in the organization of technological production. In (Fedoseev *et al.*, 2018) all projects are specified depending on the leading activities (Table I).

TABLE I: MODELS OF THE INTERACTIONS BETWEEN HIGHER EDUCATION INSTITUTIONS AND INDUSTRIAL COMPANIES (Fedoseev *et al*., 2018; Nikolsky *et al*, 2018)

Innovative model of the interactions between higher education institutions and industrial companies' Standard model+Project model	
Standard model	Project model
Lectures of the experts from the companies	Identification of the project problem
Excursions	Excursions or short-time internships
Workshops	Group solution of the project tasks
Internships	Testing of the prototype
	Preparing of the documents and final presentation of the project

In the standard model, formats of the interactions are quite traditional and include discussions/lectures from company representatives, excursions to companies, masterclasses and workshops (Fedoseev *et al*., 2018; Nikolsky *et al*, 2018; Yurlovskaya, 2014; Hodgson, 2008). In the project model, all stages of the projects are made under the coordination of higher education institutions and companies. It is important to note that the topics of the proposals can be formulated by both the representatives of companies and universities, and the participants of the research group. The next stage is organization internships or excursions to companies. It is optimal if students get short-term internships with a group of researchers, which allows them to get a comprehensive and objective view of the specifics of the company's work.

At Moscow Polytechnic University organization of project-based learning was institutionalized in the form of Project Activities Center (PAC), which carries out planning, launching, monitoring, and controlling of students' project activities. To organize the management of students' project activities within the framework of mastering the relevant discipline in the Center of project activities all the projects are grouped into nine topics, including transportation, additive technologies, technologies of art modification of the materials, ChemBioTech, energy, initiative projects and various competitions, information technologies, socio-humanitarian technologies (Nikolsky *et al*., 2018).

A unique model of project activities has been developed in Singapore University of Technology and Design (SUTD) (Graham *et al*., 2018). SUTD implements an educational model taking into account 4D design technologies. The driving force in changing the educational and research programs of SUTD are the tasks of industry and companies in order to form a specialist of the future. A fundamental point in the 4D-design approach is the establishment of causal relationships between individual modules of a discipline, as well as between disciplines within a course in the curriculum. In fact, the realization occurs through the fact that in each semester (or more often) students perform an interdisciplinary project that links several disciplines which have been studied in this period. For example, in the first year, students complete the first 1-week project, which includes knowledge areas from mathematics, physics, chemistry and the social sciences. After that project activities are focused on interdisciplinary projects with different levels of complexity, in which leader roles are transferred to students.

Scheme of 4D-design can be described by the following way:

1D-design-project work related to the area of knowledge of the one discipline (with the duration from several weeks to a semester);

2D-design-interdisciplinary project that involves areas from several disciplines studied in the same semester/year.

3D-design-a comprehensive interdisciplinary project in which students work systematically on several areas of study, applying knowledge from several disciplines.

4D-design-a long and comprehensive interdisciplinary project which is coordinated by students themselves

University College London (UCL) has started modification of the educational programs since 2014 with the integration of the case method to solve real industrial problems. In the first-year students participate in two interdisciplinary projects (each of them lasts 5 weeks), then students carry out specialized projects within the activities of a single engineering center (Graham *et al*., 2018; Hodgson *et al*., 2008).

The project method is the basis of the educational model at Charles Sturt University. During the first period of the education (since passing and up to 1.5 years) students participate in making thematic projects on campus, working in teams, and communicating with coordinators. During the second period of study (from 1.5 to 5.5 years) students take part in internships outside the university. During this period students must complete 4 internships. The first internship takes place on the territory of one of the state organizations, and then 3 internships-on the territory of the private companies. The last one is devoted to students' final qualification work.

Student based learning (SBL) technology includes the opportunity to choose and study a large number of short educational modules. These modules are logically connected with each other, and the set of modules allows developing

certain professional competences in the chosen field ("topic tree" model) (Fig. 2). It is assumed that studying each module should take no more than 3 hours for a student, and the student must perform practice-oriented assignments. Although students are free to choose their own modules in the topic-tree, there are several limitations:

1) Students must complete 240 required educational modules, 80 of which are engineering-related (Graham, 2018), before they can choose additional elective courses.
2) By the time students graduate, they should have studied 600 educational modules, 80 of which are devoted to engineering topics.

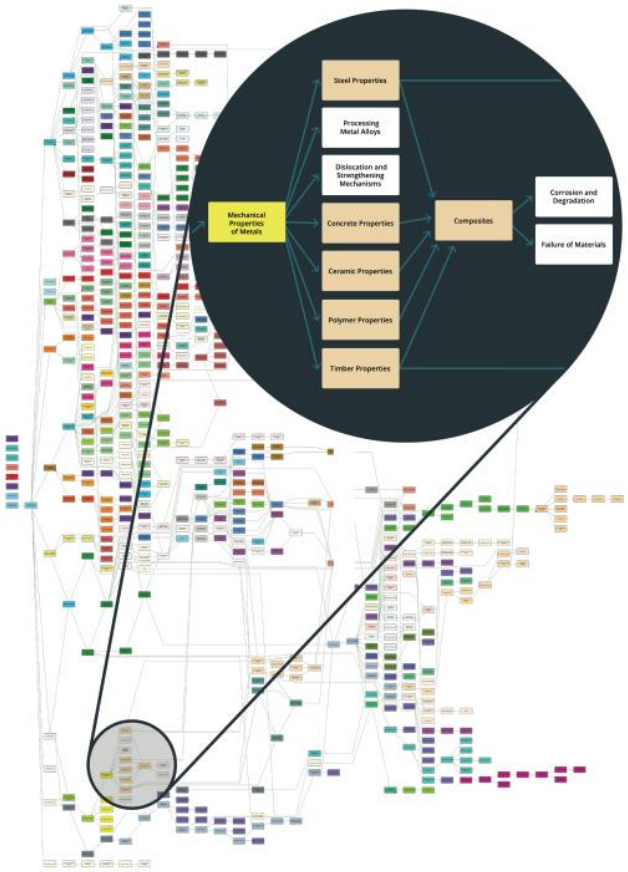

Fig. 2. Educational model «topic-tree» at Charles Sturt University (Graham, 2018)

In the second year, Master's program includes a 12-week internship in the company to obtain data for the qualification thesis.

Nowadays many Russian universities and universities in Europe and U.S.A. transform format of defensing qualification work from the standard format to a format "Startup as Diploma/Business Startup Diploma." In Russia such format has been described in the Digital Economy program. This format is focused on the development of technological entrepreneurship among students. The program "Startup as Diploma/Business Startup Diploma" allows graduates to acquire additional professional competencies in the field of project management, leadership, and entrepreneurship, as well as to implement their own business project (Kudinova *et al*., 2018; Floricel *et al*., 2014; Toichkin, 2019).

Qualification work in the format of "Startup as Diploma/Business Startup Diploma" represents business projects of the following types (Artemenko *et al*., 2014):

1) Startup as business-project based on the application of new business-models, which can be performed in the economy area. Such a startup describes the idea which has been already realized in the form of the prototype and now the projects are on the stage of choosing ways of financing.
2) Technological startup-a business project based on technological innovation developments and their commercialization. The goals of the projects are focused on advanced production technologies, digitalization of business and international sustainable development (Kasatkina *et al*., 2011).
3) Social entrepreneurship startup-a business project aimed at solving social impact problems and/or contributing to the solution of social problems in society (Whyte *et al*., 2022; Konanchuk *et al*., 2013).

Stanford University has unique experience in the organization of the new lab-Startup Garage. Students receive training in design thinking, finance, and business fundamentals. In specially organized spaces, students prepare their projects followed by data presentation. 130 companies were organized based on the results of "Startup Garage" activities (Artemenko *et al*., 2014).

As it can be seen from the above examples, integration of the project model by any university is carried out comprehensively and represents both modernization of the educational process (inclusion of elective disciplines in the curriculum) and organization of project-research activities.

III. Conclusion

The article analyzes the approaches of integrating the project model in higher education institutions. The main stages of project activities and requirements for the projects are considered. The main task of project activities is to develop professional and universal competencies of students during the work on solving real industrial problems. The project models realized by the universities in Russia, as well as in Europe and USA are aimed at increasing the interaction between universities and companies. At the same time this interaction leads to global structural and personnel reorganizations: independent structural units are created, responsible for innovative activity, and also for legal support in solving problems of intellectual property rights. If we consider the example of European universities, it is indicative that project activities are carried out not as part of a single project, but as part of interdisciplinary interaction of several departments / laboratories or in some cases can serve as the basis for the formation of an educational model – "topic tree" model.

Conflict of Interest

Authors declare that they do not have any conflict of interest.

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