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University educational environment in forming practice – oriented specialist training approach

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Abstract. The article reviews the world experience of forming practice-oriented approach to highly qualified specialist training. Particular attention is paid to the approach of National Research Tomsk Polytechnic University to the organization of practical training of students in the framework of the implementation of World CDIO concept. The authors consider the main results of CDIO concept introduction and implementation of practical training of students, problem situations and their solution, as well as possible ways of further development of the educational environment of the University.

1 Introduction

The enhancing role of technology in economic development and the formation of the political configuration of regions increase the importance of technical specialists in the modern world. In the context of globalization and constant social, cultural, economic and geographic changes it is necessary to pay special attention to the development of personality, the conditions of its formation and self-realization. Higher education is also changing due to the active introduction of information and communication technologies, new teaching formats and methods. The university should create a special environment (the educational environment) which will promote the formation of professional and personal skills and abilities, harmonious education of students, developing their interest in learning, their soft social adaptation, as well as the realization of their desires, abilities and skills acquired.

According to many experts, the creation of such an educational environment is a complex, large-scale and multi-faceted task. The characteristic features of modern educational environment of any technical university are as follows:

- availability of high technology equipment;
- instructors' professional competence;
- continuous improvement of educational content;
- introduction of new teaching methods and educational technologies;
- organization of interaction between educators and trainees, when in joint activities certain relationships contributing to the activity of all participants of the educational process appear.

The following educational environment components are important:

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- space - availability of modern specialized classrooms, including classrooms with individual attractive design, advanced information and training facilities, modern teaching and laboratory equipment;
- social environment, communication - a system of interaction between students and instructors, high level of communicative culture;
- concept and content of education - possibility of realization of students' individual needs, academic freedom, focus on highly qualified specialist training.

Depending on the university, implemented educational programs, existing scientific schools and other factors, this list can be extended considerably. However, creation of the environment that provides practical training of specialists is an important strategic task for the administrative and teaching staff of all the universities.

2 International experience of the formation of special educational space at technical universities. Theoretical background of practice-oriented specialist training approach

Currently the world educational space shows a considerable number of examples of special educational environment construction, the introduction of non-traditional ways and means of education which are aimed at the development of students especially by applying practice-oriented approach.

General principles of practice-oriented approach to the organization of teaching are:

- interdisciplinary teaching model, focused on students, on the perspective, associated with real technological and social problems, based on real life experience;
- teaching is based on complex projects with active participation of students, which ensures their development and enables them to apply the acquired knowledge and skills;
- most of the information must be obtained by students on their own in the process of studying.

One of most striking examples of practice-oriented approach at technical universities is the Global Initiative CDIO (Conceive - Design - Implement - Operate). The Community of universities with practice-oriented teaching, using CDIO standards, declares and introduces a comprehensive approach to engineering education: a set of common principles for the curricula design, their logistical support, recruitment and teaching staff development.

The CDIO concept originated in the late '90s in the USA in response to the dissatisfaction of employers with the fact that university engineering education is too distant from practice [1]. Officially CDIO community appeared in 2000 thanks to the collaboration of the Massachusetts Institute of Technology (MIT) [2] with three Swedish universities - Chalmers University of Technology, Linköping University and Royal Institute of Technology. The author and co-founder of CDIO Initiative is Edward F. Crawley, professor of aeronautics, astronautics and engineering systems at MIT [3].

The education at universities working according to the CDIO Initiative principles is conducted mainly through practical activity focused on the needs of the external world, rather than on the solution of abstract problems within universities. Graduates from the universities where CDIO standards are applied are highly rated on the international lab our market.

Nowadays more than 100 universities from 25 countries, 10 of them - Russian, such as Scoltech (Moscow), TPU (Tomsk), UrFU (Ekaterinburg), TUSUR (Tomsk), MAMI (Moscow) and others joined the CDIO World initiative. In 2013 the «CDIO RUSSIA» community was established to promote project-oriented approach and the World CDIO initiative standards in educational process.

Each university has its own unique experience of implementing CDIO standards [4], including a unique educational environment formation, based on the construction of an integrated curriculum, special courses and educational modules, organization of students' working space.

2.1 Aalborg University experience (Denmark)

The «Problem Based Learning and Science Technology and Society» course is focused on the development of professional (my profession, language for profession and science, theoretical aspects of profession, professional environment) and social (how to interact with people) aspects. The course includes a number of small projects with mandatory analysis of all the implementation stages and project outcomes. Some examples of projects: "Giraffe" - project on the development of special software for children with autism, project on the conversion of PowerMILL Robot CAM-system for milling programming using an industrial ABB robot.

2.2 Linköping University experience (Sweden)

During the «Engineering project» course (25% of the semester study load) students learn group work, oral and written communication skills. The course implies a compulsory project implementation in a team consisting of 5-6 people. The examples of projects are indoor climate web monitoring system, car operation control system and others.

The project work is carried out under the guidance of the instructor, project results are evaluated by experts. The project is executed in steps: plan, contract that specifies the rules of group work and ways of resolving conflicts, regular reporting to the «customer» according to the design assignment.

2.3 The experience of Moscow State University of Engineering (Russia)

The university is actively implementing STEM (Science, Technology, Engineering, Math) education enabling students to bridge the gap between educational objectives and genuine activities of a scientist and engineer. The examples of conducted STEM-games are «Pandora» (tasks for geology, ecology, biology, botany, geography, astronomy), «Ecological settlement» (targets for transport, pharmaceutical industry, environmental protection, information technology), «Orbit» (tasks for physics, mechanics, electronics) and others.

Compulsory mastering the «Project Activities» course (1st year) involves a variety of engineering projects including those on the employers' orders. The project involves 4 to 12 people receiving education in various majors; the defense of projects is carried out in technical committees.

The best projects are selected by participating in competitions and tournaments like «Engineering start».

3 Experience of practice-oriented educational environment formation at Tomsk Polytechnic University

With the accession to CDIO World initiative Tomsk Polytechnic University (TPU) launched an active and full-scale formation of practice-oriented educational environment in 2011. TPU was the first university in Russia to join this initiative. The University set the task of compulsory introduction of most CDIO concept standards to provide complex engineering training even at a bachelor level.

One of the first decisions at TPU was to introduce CDIO Standard 4 which presupposes the existence of an introductory course which would lay the foundations of engineering practice in product and system development and would be aimed at teaching basic personal and interpersonal competencies [3]. In 2012 TPU developed a new educational module «Introduction to engineering» for all technical educational programs, which is the basis of an integrated curriculum [5].The module concentrates on the acquisition of basic skills and first practical experience that motivate and prepare students for a better understanding of theoretical concepts. Methodically, this introductory course gives the students first impression of engineering features of the major, skills of project work and group communication, which are further developed in the framework of professional disciplines of the program, practice-oriented project implementation and graduate qualification work. The given course is the basis of the practice-oriented training system at the university [6].

Within the module, students are involved in engineering practice by solving problems and simple design tasks, carried out individually and in teams. The introductory course is aimed at stimulating interest and increasing motivation to engineering in students, focusing on practical benefits of basic disciplines.

General structure of a practice-oriented complex engineering training system is presented in table 1.

Table 1. General structure of a practice-oriented complex engineering training system TPU.

Semester	Modules
1	Educational module «Introduction to engineering» (Theoretical part), 1 credit
2-4	Educational module «Introduction to engineering». Creative projects, 3 credits (1 credit per semester)
5-8	Projects within the framework of studying and research work of students
5-8	Complex projects for professional cycle disciplines Preparation of graduate qualification work

The «Introduction to engineering» module consists of two parts: a theoretical part including elements of project activity and a practical part, characterized by a number of team projects carried out under the tutor's guidance. An important feature of the "Introduction to engineering" module is its practical orientation –the formation of students' ideas about their future professional activity and engineering practices in general occurs at the initial stage of training.

The theoretical part focuses on:

- development of students' interest in engineering;
- formation of ideas about future professional activity, engineering practice at early education stages;
- development of basic knowledge and set of skills necessary for solving engineering problems;
- increase in motivation to acquire knowledge and skills in the field of professional training according to the chosen major;
- conscious choice of individual educational path for a particular profile/specialization within a certain major;

The practical part focuses on:

- obtaining deep practical knowledge of professional technical basics;
- development of skills in new product and system creation and operation;
- understanding the importance and strategic value of scientific and technological development of the society;
- acquisition of knowledge about planned educational profile within the major;

The implementation of the theoretical part is based on:

- attracting external specialists in the field of educational programs (leading professors, graduates, employers)
- organization of real (virtual) tours to specialized enterprises, research laboratories, etc.
- solving small theoretical problem-oriented tasks (in the format of an essay, glossary, mini-conferences);
- acquiring project work skills within small project-oriented tasks;

The implementation of the practical part consists in:

- use of team building techniques (team skills, team spirit, team building);
- involvement of external experts in the Main Curriculum implementation (leading professors, graduates, employers) in management;

- solution of short-term practice-oriented problems of applied and research background [7];
- implementation of projects under real production conditions;
- keeping semester journals, drafting project passports, writing analytical reports and analysis on the results of project implementation with advanced IPC support;
- public project defense (with the demonstration of results) with the involvement of external persons concerned;

A sample structure of the theoretical part of the module within "Mechanical Engineering" major is presented in Table 2.

Table 2. Structure of the theoretical part of the module «Introduction to engineering».

№ week	Topics, discussed issues	Type of classes	Forms / teaching methods	Task types / results
1	Introduction to the discipline. General requirements for discipline studying. The initiation of engineering activity, its essence and functions. The development of engineering activity, engineering profession and special education	Lecture	Information lecture	-
2		Practical class	Team skills, team spirit, team building	Group Code
3	The history of training profile 1 ("Information and measuring equipment and technology"), the main directions of educational and research activities, graduates' main customers, practice and employment	Lecture	Overview lecture	Essay on the scientific fields of the training profiles
5	The history of training profile 2 …	Lecture		
7	The history of training profile 3 …	Lecture		
4	Excursion to electrical and electronic engineering laboratories, CAD, mobile object control systems and devices, orientation and navigation devices laboratories	Practical class	Lecture - discussion	
6	Excursion to the thermal control laboratory, radiological material and product testing, acoustic emission methods testing laboratories	Practical class		
8	Excursion to medical engineering laboratory, alternative energy sources (physics of solar elements) laboratory, control devices for cable industry laboratory	Practical class		
9	CONFERENCE WEEK. Theoretical mini-conference	Lecture	Lecture - conference	Group report on scientific subjects of the profiles, group defense in front of the assessment board
10	Basic concepts and definitions in the field of measurement and measurement equipment. Creative projects on profile 1	Lecture	Binary lecture (theorist and practitioner of each profile)	Glossary of measuring devices (distribution of work by letters of the alphabet in groups, compilation of a common glossary)
12	Basic concepts and definitions in the field of non-destructive testing. Creative projects on profile 2	Lecture		
14	Basic concepts and definitions in the field of precision instruments. Creative projects on a profile 3	Lecture		
11	Theoretical and practical principles of project activity. Part 1.	Practical class	Project group work	Map model of an island state (history, flag, population, infrastructure, life

№ week	Topics, discussed issues	Type of classes	Forms / teaching methods	Task types / results
				support, etc.)
13	Theoretical and practical principles of project activity. Part 2.	Practical class		Facility model (house, enterprise, power plant, launch site, etc.). Design, calculations, model work stock. Distribution of roles: designers, foreman, workers, quantity surveyors and others.
15	Debate. The organization of research work of students.	Practical class	Debate	-
16	CONFERENCE WEEK. Practical mini-conference	Lecture	Lecture - conference	A new (own) measurement instrument or device model, preparation of a group report on the basis of semester work, group defense in front of the assessment board.
17	Final practical class	Practical class	Group work	Glossary-based crossword puzzles. Doing rival groups' crossword puzzles
18	Credit test	Practical class	-	Test

The practical part of the module represents the implementation of creative projects for 3 subsequent semesters. The project is an independent solution of a particular teacher-led appliedtask by students or a study on a stated topic. The complexity of the ongoing projects increases from semester to semester and is set in accordance with a list of learning achievements planned for the corresponding semester.

Each semester students are offered a separate list of creative projects with a brief description and a list of the learning outcomes achieved. A list of creative projects is developed by the departments responsible for the profile teaching.

In a real laboratory students learn to solve engineering problems from conception, describing the theoretical (mathematical / physical) model of the future product to its manufacture and operation (they gradually pass through all the stages of engineering activity: «Conceive», «Design», «Implement» and «Operate»).

At the university much attention is paid to the educational environment requirements (CDIO standards 5, 6). Those standards require that [3]:

- students must participate in at least two educational and practical tasks for the design and development of products, one of which would be performed at a primary stage, and the second - at an advanced stage;
- University must have classrooms which would make it possible to organize practical approach to learning creating products, systems and design skills, to transmit disciplinary knowledge, as well as to organize social training.

To meet the requirements of Standards 5, 6 different variants of students' areas-working spaces, intended for project activity organization, have been created at TPU.

4 Results and problems of the formation of practice-oriented educational environment at Tomsk Polytechnic University. Development path

During the formation of practice-oriented educational environment, including the implementation of educational module «Introduction to engineering», a number of problem situations have been faced:

- by the teaching staff (project coordinators):
  - lack of experience of teaching junior students;
  - lack of understanding/awareness of the objectives and processes of a new educational module implementation;
  - reluctance to make changes to the educational process, to his/her own pedagogical activity;
  - unreadiness for innovative activity, especially in the field of applied engineering problem solutions;
  - failure to organize independent work of students;
- at the university:
  - the complexity of scheduling of all the activities related to creative project implementation;
  - low interest/motivation of students;
  - absence of efficient financing schemes of creative projects.

During the educational module implementation from 2012 to 2016 a number of problems were solved. Transparent schemes of all student project activities from the enrollment to graduation have been developed. Several supplementary education programs for teachers, allowing overcoming internal fear of working with junior students, engaging them in real engineering problems, have been designed. Various schemes of student project financing (from departments funds as well as from university funds) have been worked out.

Institutes and departments have started considering the integration of efforts to implement small multi-disciplinary, inter-department educational projects, as well as large-scale interdisciplinary research projects.

5 Conclusion

It should be noted that educational environment of the university with its specificity and structure has a huge impact on training of future professionals. Simultaneously, one of the educational environment quality criteria is its ability to provide all the participants of educational process withopportunities and conditions for effective self-development.Well-organized educational environment is a criterion of success of any university since itforms future generation of specialists, who are directly responsible for their country’s future.

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