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Practice-Oriented Education at Northern (Arctic) Federal University

Northern (Arctic) Federal University named after M.V. Lomonosov (NArFU)
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The article examines implementation of team design projects embracing the principles of interdisciplinary and practice-oriented training into education programmes. The urgency of launching the project aimed at developing not only engineering design skills but also personal and interpersonal skills is outlined.

Key words: engineering education, group design, CDIO initiative.

Recent scientific and engineering achievements, development of interdisciplinary research, as well as significant progress in high-tech technologies have contributed toward a new understanding of the engineer's role in industry, economy and society. The global economy also presents new requirements to engineering training. Employers today give priority not only to technical competence but also to a far broader range of basic skills including the ability to think globally, make decisions and assume responsibility for decision making, working in a team demonstrating corresponding personal and interpersonal attributes. Today, engineering employers are looking for the experts who exhibit a wide range of knowledge, skills and competences which can be applied within various technical and non-technical fields.

Foreign technical universities have already introduced into engineering curriculum the disciplines focused on engineering design, which are considered core disciplines in engineering training while other components of engineering curriculum serve to train graduates for future design activity. As a rule, module "Engineering Design" is taught during the whole period of education and includes Introduction to Design Methodology. At foreign technical universities, the course "Engineering Design" is of great importance, a special emphasis being laid on the learning outcomes which meet practical experience requirements imposed by employers. The same skills and attributes which a modern engineer should attain in order to become a competitive and mobile specialist in the labor market are specified by international engineering education accreditation agencies (Table 1) [1].

Russian universities are still training engineers equipped with knowledge of engineering theory, while the industries have shifted towards a more advanced level, which in turn has stipulated the need for the specialists with the above-mentioned skills and attributes. Thus, engineering training approaches, specifically quality assessments of educational programmes and engineering degree programme designs, should be revised and modernized. Russian engineering universities should introduce into the existing curricula an "Engineering Design" course designated to develop research and communication skills, ability to work collaboratively in a team. It is particularly necessary since the key success factor on a market is to stay ahead of the technological competition and, as a fact, research-and-development engineer, «R&D and Engineering & design», becomes the most required specialist. The recent research has indicated that innovation-related knowledge and interdisciplinary research skills are the most required. Based

Table 1. Engineering Education Competences

<table>
<tr><th>ABET, USA</th><th>Canada</th><th>JABEE, Japan</th><th>FEANI, European Union</th></tr>
<tr><td>Accreditation Board for Engineering and Technology,ABET, USA</td><td>Canadian Engineering Accreditation Board, CEAB, Canada</td><td>Japan Accreditation Board for Engineering Education, JABEE, Japan</td><td>Federation Europeenne d`Associations Nationales d`Ingenieurs, FEANI</td></tr>
<tr><td colspan="4">Upon completion, a graduate must attain the following professional competence/be able to:</td></tr>
<tr><td rowspan="3">Communicate effectively</td><td rowspan="3">Work in teams, communicate within the profession and with society at large</td><td>Design and solve engineering problems to meet specified needs of the society by exploiting various disciplines of science, engineering and information</td><td>Function as a leader demonstrating corresponding administrative, engineering, financial and personal attributes</td></tr>
<tr><td>Demonstrate communication competences including oral and written skills, debate abilities in native language, as well as basic skills for international communication</td><td rowspan="2">Demonstrate communication skills and ability to be engaged in life-long learning to sustain the required level of knowledge and competences</td></tr>
<tr><td>implement and organize works under given constraints</td></tr>
</table>

on the study of engineering specialists' skills and competences carried out by the Fund for Infrastructure and Educational Programs, it has been revealed that it is critical to train engineering graduates with the following skills and competences:

- innovation-related knowledge (strategic vision, creativity/ imagination, practical ingenuity, and persistence);
- creative thinking, multi-tasking ability, interdisciplinary research skills;
- problem solving, analytical and critical thinking skills (ability to reason effectively);
- business development skills;
- interpersonal communication skills (team building, teamwork);
- tolerance and intercultural dialogue, knowledge of foreign languages;
- management skills (leadership, project management, change management);
- social skills (interpersonal skills, networking, empathy);
- personal performance skills (planning, time management).

Federal State Education Standards (FSES) seek to develop communicational competences and engineering design skills [2]. Indeed, all FSES of Higher Education embrace the following cultural competences (CC):

- ability to communicate both orally and in written form in Russian and foreign languages in order to resolve interpersonal and intercultural tasks (CC-5);
- collaborate in teams demonstrating tolerance for social difference and cultural diversity (CC-6);
- recognize the need for, and have the ability to engage in independent and life-long learning(CC-7).

Professional competences are as follows:

Design and engineering:

- ability to engage in design engineering products, processes, systems, and services in compliance with technical design specification and nominative documents as well as technical and environmental requirements;
- ability to provide appropriate grounds for engineering solutions.

Project engineering:

- demonstrate the ability to work in an engineering team involved in the development of project-engineering documents that embrace the design and modernization of production machinery and complexes;
- ability to apply fundamental knowledge of project and program design within a definite industry, carry out actions aimed to guarantee safety and effective operation of transport machines of different design including their units, components and systems, as well as handle activities to standardize technical tools, systems, processes, equipment, materials and to analyze various technical documents.

Common professional competences:

- ability to work collaboratively, lead teams, provide the documents necessary for developing an effective quality management system of production department.

In accordance with NArFU education standards, cultural competences also include system-related competence CC-S.1 which embraces the following design skills: ability to work cooperatively with others in order to resolve standard professional tasks (Bachelor's degree programs); ability to manage different types of projects (Master's degree programs).

To enhance the quality of higher education provided at NArFU, as well as to support educational innovation and stipulate its research-and-design potential, it has been decided to introduce the worldwide CDIO Initiative standards into engineering programmes. CDIO Initiative is a worldwide venture that aims to reform the levels of higher engineering education. The main principle of this project is to train students within a new engineering education model «Conceive – Design – Implement – Operate» that engages students into real processes, systems and products of real economy [3]. This CDIO teaching concept allows developing the following competences which are of great demand among local employers:

- deep knowledge in a corresponding professional sphere;
- ability to work collaboratively, operate and develop new products, processes and systems;
- understanding the impact of engineering solutions within social and environmental contexts.

Today, there are more than 100 universities in the world actively promoting CDIO initiative standards. In Russia, the CDIO participants are: Tomsk Polytechnic University (since 2011), Skolkovo Institute of Science and Technology (since 2012), Astrakhan State University (since March 2012), Moscow Aviation Institute (since October 2012), Tomsk State University of Control Systems and Radioelectronics (since March 2013) and Moscow Institute of Physics and Technology (since April 2013) [4]. As a result, the CDIO Initiative adopted 12 standards that describe teaching approach aimed at developing complex engineering activity of graduates, define curriculum design principles including learning outcomes intended as a result of engineering education, emphasize innovative teaching methods, faculty development in terms of CDIO-competences, detail assessment of student learning and the education programme as a whole.

A new trend in modern engineering education is innovative character of designed projects, processes and systems. Therefore, practice-oriented teaching approaches as a part of engineering education programmes are of great importance.

According to CDIO Initiative Standard 5, a curriculum should include two or more design-implement experiences intended to develop students' design skills [5]. On the basis of CDIO standards, NArFU has launched the project "Digital House" (Tsyfrovoy Dom) aimed at:

- developing the innovation potential of educational and research divisions of universities which are involved into the implementation of economic and social projects;
- designing a conceptual prototype of a low-rise apartment house applying modern technologies in civil engineering, power industry, water treatment, air purification, and other life-support systems, as well as digital control techniques;
- professional development of students and post-graduates in all fields, members of multidisciplinary teams while implementing the project on the basis of modern software.

In accordance with the priorities of the NArFU development program, the discussed project is being implemented with regard to climatic conditions of Northern European Russia and the Arctic.

The objectives of project "Digital House" (Tsyfrovoy Dom) are as follows:

1. To design a control and work coordination system that involves structural subdivisions which have necessary key competences for project implementation.
2. To develop conceptual bases of the project and specify topic areas which are essential for project implementation.
3. To stipulate active participation of such NArFU divisions as – Design & Prototyping Centre, Institute of Energy and Transport, Student Design Office "Arktiktkh", Radio Engineering Monitoring Center, etc.
4. To provide deep integration of the research, innovation and training process.
5. To stimulate university faculty to apply modern techniques for interdisciplinary team management.
6. To apply up-to-date information technologies at all stages of project implementation.
7. To implement university

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innovations and new technologies.

8. To provide sustainable business, authority and an international organization cooperation system.

9. To develop students' and post-graduates' team work competences.

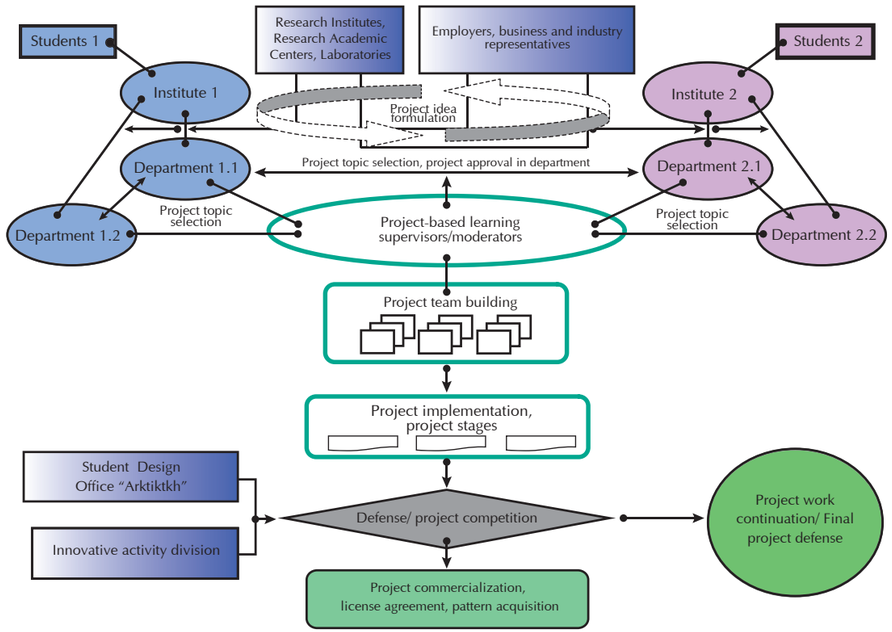
The members of design team are assigned special functional areas and specific responsibilities for which they are accountable. The project is intended to allow students to engage in a real professional environment and foster the development of engineering-design skills by introducing mutually supporting disciplinary courses into the existing education programmes.

At the start of the project, interdisciplinary project teams are built. As the project itself has an interdisciplinary character and it involves modeling, solving the issues concerning environmental safety and energy efficiency, designing the interior of smart house with due regard to economic feasibility, the project team is made up of students from different degree programmes. Each team member takes the lead on a definite project task. A working group of the project "Digital House" (Tsyfrovoy Dom) develops technical design specifications which should be considered by project team leaders in order to achieve the project goals. The flowchart of team-based learning in Engineering Design implemented at NArFU is provided in fig.1.

Such projects will expand students' knowledge of a wide variety of disciplines, make them understand the importance of their professional activity and take the responsibility for their solutions and actions, as well as develop team work skills in design project contexts. Thus, engineering programmes offered by NArFU are not delivered through the traditional subject- or discipline-oriented learning, but within project-based contexts.

Project-based learning inevitably leads to the application of modern methods and procedures for training process design, fosters the enhancement of faculty teaching competences and contributes to quality improvement of student learning. It is essential to provide faculty with the opportunities to develop and improve their competences, elaborate new techniques for assessing expected learning outcomes and teaching materials.

Fig.1. Team-based Learning in Engineering Design at NArFU



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