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Goal-Content Integrity of the Discipline «Introduction to Engineering» in the Framework of Worldwide CDIO Initiative

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The comparative analysis of FSES of the higher professional education and CDIO standards has revealed that design-innovation competency as the ability and willingness to implement the entire cycle of a product or system development is learning outcome of engineering education. The article considers the value and role of the discipline "Introduction to Engineering" and its significance in the process of design-innovation competency development.

Key words: engineering, the discipline «Introduction to engineering», goal, function, content of discipline modules, complexity.

Innovative educational strategy in modern engineers' training, which develops professional skills necessary for future engineering activities, is connected with students' awareness of the entire technological cycle: from idea origin to design with the subsequent production and application of the product [1].

In spite of the fact that such an idea is not absolutely new for the Russian engineering education, the concept of Worldwide CDIO initiative imparts its complex-systematic composition introduced into all forms of academic activity and all parts of an educational program. Under these conditions, the key outcome of the educational process is the development of the competence, which implies that the graduate is aware of and ready for the entire cycle of product and system building in accordance with the algorithm: Conceive, Design, Implement, Operate. The content of such engineering competence allows us to call it design-implementation competence (DIC). The requirements for DIC development for different majors are detailed in corresponding Federal State Educational Standards (FSES) for Higher Professional Education (HPE) 3+, depend on production requirements, and are completed with the requirements of the relevant competences in CDIO Syllabus [3].

Based on the contemporary level of competence approach development, let us define DIC as an integrated dynamic personal quality of future bachelor of engineering, defining efficiency of his/her professional activity and manifesting itself in awareness of essence and the significance of design-implement activity for engineering work (motif-value component), professional knowledge and skills (cognitive component), rational choice of project decisions and their optimization in case of multiple choice alternatives (activity and estimating component) [4, 5].

DIC meets the requirements in multidimensionality, interdisciplinarity, and multifunctionality, i.e. «refers to the general interdisciplinary content of education», according to A. V. Khutorskoy. Therefore, it is a key competence in engineering activity [5], which emphasizes how significant it is to create the competence in the academic process.

Thinking of the DIS concept as an activity characteristic of a future bachelor of engineering, it is important to discover the

content of motif-value, cognitive, activity, and estimating components to direct the academic process and use its potential for DIC development. To reach the goal, one needs to turn to the requirements for the competences [3, 7].

A DIC motif-value component performs axiological function and characterizes future bachelor's understanding of socially valuable engineering activity, engineer's role and responsibility, influence of engineering activity on the society and environment, contemporary relations in the sphere of engineering and technology. The competences mentioned in the structure of a DIC motif-value component are designated in FSES HPE 3+ as universal competence (UC-1), while the corresponding CDIO competences are represented by the competences 2.5.4; 4.1.1; 4.1.2.

DIC cognitive component is based on the student's relevant intelligence, basic cognitive skills (analysis, synthesis, systematization, generalization, abstract thinking, modeling, classification, cause and effect analysis – PC-1 FSES HPE 3+), which define the following types of thinking: developed and integrated (2.3.1 CDIO), creative (2.4.3 CDIO), critical (2.4.4 CDIO), and innovative (4.7.2 CDIO).

To develop DIC in the academic process it is necessary for students to have definite basic disciplinary and interdisciplinary knowledge in fundamental and professional subjects (universal professional competence (UPC)-1, UPC-2, UPC-3, UPC-4 FSES HPE 3+; 1.1, 2.1, 2.3 CDIO), project design and management methods (UPC-4 FSES HPE 3+; 4.3 CDIO) and specifically those implying information and communication techniques (UC-2, UC-4 FSES HPE 3+; 3.2.4, 4.8.5 CDIO).

The activity component of DIC is disclosed via the following developed skills and attributes:

- to analyze professional engineering situation and figure out complex engineering problems (UC-1 FSES HPE 3+; 2.5.3, 4.1.5, 2.4.1, 4.7.1 CDIO);
- to define the degree to which an engineering problem has been elaborated in research literature and engineering practice through searching for information relevant to theoretical and practical bases for further problem solving (UC-1, OK-3 FSES HPE 3+; 2.2.2, 2.5.4, 4.1.3, 4.1.4, 4.1.5, 4.8.6 CDIO);
- to propose possible solutions in project activities on the basis of the revealed specific factors and innovation-related characteristics of the engineering situation, as well as to specify the project's goal (UC-1, UC-5 FSES HPE 3+; 2.2.1, 4.7.3, 4.7.4, 4.7.8 CDIO);
- to provide a clear explanation and justify assessment criteria for the ideas, which propose the ways to solve engineering problems and evaluate project activity results (UC-2 FSES HPE 3+; 4.2.7, 4.8.2, 4.8.4, 3.2.10, 4.2.4 CDIO);
- to analyze and interpret the proposed ideas, to justify and make a rational choice in case of multiple choice alternatives in accordance with the justified criteria (UC-1 FSES HPE 3+; 2.3.1, 2.5.3, 4.1.3, 4.2.7, 4.7.5, 4.2.2, 4.8.4, 3.2.9, 4.2.1 CDIO);
- to manage and prioritize problem solving process identifying the steps and formulating project objectives to be achieved at each step of project implementation (UC-2 FSES HPE 3+; 4.7.6, 4.8.7, 4.8.5, 2.4.7, 4.7.8 CDIO);
- to demonstrate the ability to design on the basis of the acquired knowledge in design tools and technologies (UC-2 FSES HPE 3+; 4.7.6 CDIO).

Estimating component of DIC is disclosed via the following skills and abilities:

- to be engaged in self-reflection on and estimation of the project activity

through identifying effective project activity technologies;
- to be engaged in operational reflection in reconstructing and analyzing project activity steps;
- to be engaged in final reflection related to the conformity of the project activity result to the set project goal and objectives;
- to predict the impacts of project implementation, and to provide possible risks assessment (UC-1, UC-2 FSES HPE 3+; 2.5.3, 4.1.1, 4.1.2, 4.1.3, 4.2.7, 4.7.6, 4.7.7 CDIO).

Despite the fact that under DIC we mean an integrative personality characteristic, it is desirable to distinguish it as a personality component.

The content of this component is represented below, that, in our opinion, gives grounds for its separate consideration.

A personal component of DIC describes a student as an educational agent that is characterized by the following abilities: to identify problems and paradoxes, to set goals and objectives of the activity, to show initiative and readiness to problem solving including decision making under conditions of uncertainty (UC-4, UC-5 FSES HPE 3+; 2.4.1, 4.7.1 CDIO), to be persistent in achieving goals (UC-5 FSES HPE 3+; 2.4.2 CDIO), to reflect on results and the process of activity. It is essential for a personality to be in constant development accompanied by self-understanding and self-consciousness (UC-1 FSES HPE 3+; 2.4.5 CDIO), will to life-long self development (UC-5 FSES HPE 3+; 2.4.6 CDIO), the ability to perform productive intellectual activity and provide effective use of resources (UC-5 FSES HPE 3+; 2.4.7, 4.7.3, 4.7.4 CDIO). To solve problems of modern science-based industry, team building skills are required. Thus, the ability to work effectively in a team demonstrating tolerance towards social, cultural and ethnical differences is an important constituent of engineering professional activity. Such interpersonal skills as inquiry and effective listening, negotiation, advocacy, and net working condition effective team building and team management in the process of particular problem solving (technical and interdisciplinary team) (UC-4 FSES HPE 3+; 3.1.1, 3.1.2, 3.1.5, 3.2.1 – 3.2.8 CDIO).

The content of the DIC components described above proves the complexity of DIC and brings about requirements for the curriculum disciplines focused on the competence development. The competences required for bachelors in engineering science are developed during the whole training course. "Introduction to Engineering" (standard №4 CDIO), project activity implemented in disciplines of professional area, as well as disciplines of humanities and basic sciences areas, contribute to the development of the competence. Regarding engineering as a complex of intellectual activities aimed at achieving optimal results by means of hand-on resources for the entire technological cycle of product and system building (design, implementation and production), let us determine the important role of "Introduction to Engineering" in the competence development. While justifying the structure and content of the discipline, we rely on the necessity to ensure the development of the above discussed DIC components, as well as to specify training hours of each module and curriculum consistency.

Table 1. Structure of «Introduction to Engineering» Discipline

Term	Module
1	Introduction Engineering (Metallurgy history. Introduction to engineering activity. Scientific bases in intellectual activity).
2	Information resources (Strategy of source searching. Information structuring. Quotation rules. Text, report, article formatting).
3	Professional culture (Psychology. Business language).
4	Design engineering methods.
5	Theory of invention problem solution
6	Engineering strategic management (general principles of engineering).

The bachelor's syllabus (School of Non-Ferrous Metals and Material Science) of 2014 enrollment year includes the subject «Introduction to Engineering» as a part of the following modules (Table 1).

Such a discipline structure of «Introduction to Engineering» would allow, firstly, the performance of axiological – the program ensures that the future bachelor has profound understanding of the idea and significance of engineering activity, an engineer's role and responsibility, the influence of engineering activity on society and the environment, contemporary relations in the sphere of engineering and technology. Secondly, supporting the DIC development process methodologically, the discipline performs the system-forming function at the methodological level, synthesizing the experience of a practicalproject activity attained by the students in the course of professional training.

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