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UDC 378

Modernization of Engineering Education Based on International CDIO Standards

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The concept of engineering education modernization based on CDIO (Conceive, Design, Implement, Operate) Standards is considered. Comparative analysis of the CDIO Syllabus and the Association for Engineering Education of Russia accreditation Criterion 5 is given. The experience of the CDIO Standards implementation at Tomsk Polytechnic University is discussed. The CDIO Academy programme for Russian universities faculty professional development is described.

Key words: engineering education, modernization, CDIO, programme accreditation, professional development.

Modernization of national system of engineering education is on of the most important issues in the list of those, which have great impact on the future prosperity of the country, its technological development and economic competitiveness. On June 23,2014 a meeting of the Presidential Council for Science and Education of Russian Federation took place, where modernization of engineering education and improving the quality of technical specialists' training were the main subjects on the agenda [1]. At the meeting it was recommended to follow the concept «Conceive, Design, Implement, Operate» in order to improve the quality of training design engineers and engineering technologists. Although no direct links were given with high probability it referred to the CDIO concept, developed within the international project CDIO Initiative guided by Massachusetts Institute of Technology (MIT, USA) [2, 3].

CDIO Concept

International Project CDIO Initiative is aimed at resolving the apparent contradictions and establishing consensus between theory and practice in engineering education. The basis for the modernization of engineering education according to the CDIO concept is to prepare graduates for complex engineering activity at all stages of the life cycle of products, processes and systems, which include [3]:

- Defining customer needs; considering technology, enterprise strategy, and regulations; developing concepts, techniques and business plans (Conceive).
- Creating the design of engineering activity products on disciplinary and interdisciplinary basis (Design).
- Transformation of the design into the product, including hardware and software, manufacturing, coding, testing and validation (Implement).
- Using the implemented product to deliver the intended value, including maintaining, evolving and retiring the system (Operate).

CDIO concept focuses first of all on improving undergraduate engineering education (bachelor degree). It is based on two main framework documents: CDIO Syllabus, specifies the requirements for learning outcomes, and CDIO Standards, defines the requirements for educational programmes in the field of engineering and technology.

CDIO Syllabus provides the designers of educational programmes the opportunity to answer three main questions: «What should graduates know or be able to do?», «What activities are required to enable graduates do that?» and «How can graduates demonstrate the acquired level of competencies?». In other words, this means addressing three critical tasks: planning, achieving and assessing learning outcomes.

CDIO Standards define the main principles for undergraduate engineering educational programmes and address programme philosophy (Standard 1), curriculum development (Standards 2, 3 and 4), design-build experiences and workspaces (Standards 5 and 6), new methods of teaching and learning (Standards 7 and 8), faculty development (Standards 9 and 10), assessment and evaluation (Standards 11 and 12).

For each CDIO standard, the description explains the meaning of the standard, the rationale highlights reasons for setting the standard, and the rubric is a scoring guide that seeks to evaluate levels of performance. This allows designers of educational programmes at universities to conduct a comparative analysis of compliance with international CDIO Standards requirements and provides framework for continuous improvement. Many foreign universities use CDIO Syllabus and CDIO Standards for self-assessment purposes when preparing for programme accreditation, following the relevant criteria.

The competencies of bachelors in the field of engineering and technology, that are expected to be achieved upon graduation from the educational programme are classified by CDIO Syllabus into four categories at four levels.

Professional and general competencies of modern engineer corresponding to the second level of detail are listed below (CDIO Syllabus v2, 2011) [3]:

1. Disciplinary knowledge and reasoning.

1.1. Knowledge of underlying mathematics and science.

1.2. Core fundamental knowledge of engineering.

1.3. Advanced engineering fundamental knowledge, methods and tools.

2. Personal and professional skills and attributes.

2.1. Analytical reasoning and problem solving.

2.2. Experimentation, investigation and knowledge discovery.

2.3. System thinking.

2.4. Attitudes, though and learning.

2.5. Ethics, equity and other responsibilities.

3. Interpersonal skills: teamwork and communication.

3.1. Teamwork.

3.2. Communications.

3.3. Communications in foreign languages.

4. Conceiving, designing, implementing, and operating systems in the enterprise, societal and environmental context.

External and societal context.

4.2. Enterprise and business context.

4.3. Conceiving and engineering systems.

4.4. Designing.

4.5. Implementing.

4.6. Operating.

4.7. Leading engineering endeavours.

4.8. Engineering entrepreneurship.

Participants of the international project have been continuously developing and improving CDIO Syllabus by making comparative analysis and compliance of the learning outcomes with the requirements from the industry. In particular, the Boeing Company and professional accreditation organizations (ABET, USA) were involved in the survey. The requirements of the European Qualifications Framework (EQF) and EUR-ACE Standards were taken into account, as well as the UNESCO Four Pillars of Learning and others.

CDIO syllabus vs AEER criteria

The results of comparative analysis of the CDIO Syllabus and Criterion

5 «Professional Qualification» of the Association for Engineering Education of Russia for accreditation of Bachelor degree programmes in the field of engineering and technology are presented in the Table 1 [4]. Columns numbering corresponds to the described above CDIO Syllabus requirements, and lines numbering – to the AEER Criterion 5 [5]. Those Bachelor's competencies according to the AEER Criterion 5 that have total correspondence with CDIO Syllabus requirements are marked with (x) and principal equivalence is marked with (o).

The analysis shows total correspondence of the CDIO Syllabus requirements and the AEER Criterion 5 in greater part of the positions: fundamental mathematics and science, core engineering knowledge, Bachelor's competences in design, research, project and financial management, communications, individual and team work, professional ethics and social responsibility. The requirements of the AEER Criterion 5 regarding the Bachelor's readiness for engineering analysis (1.2) actually coincides with the CDIO Syllabus requirements for their abilities for analytical reasoning and problem solving (2.1) and for system thinking (2.3). The AEER Criterion 5 requirements for engineering practice (1.5) and employer orientation (1.6) agree with basic requirements of the CDIO Syllabus regarding Bachelor's readiness for solving the tasks of conceiving, designing, implementing and operating the products of engineering activity (4.3 - 4.6). The AEER Criterion 5 requirements for lifelong learning (2.6) correspond to 2.4 of the CDIO Syllabus (attitude, thought and learning).

A range of the CDIO Syllabus requirements concerning leadership and entrepreneurship were not included in the comparative study with the AEER Criterion 5 as more related to Master degree programmes.

The advantage of the CDIO Syllabus is that in comparison with the requirements of professional accreditation criteria (including the AEER Criterion 5), the requirements are subdivided in four levels [3]. This level of detail has many benefits for educational programmes developers to implement the outcome-based approach efficiently, i.e. to define in details the additional data for programme design and to set the tasks for professors responsible for modules and disciplines of the programme in the field of engineering and technology.

Implementing CDIO approach in TPU

In 2010 National Research Tomsk Polytechnic University (TPU) has started modernization of bachelor's and master's degrees programmes in the field of engineering and technology on the basis of new Federal State Educational Standards (FSES) and the CDIO Standards, including adjustment of the goals and intended learning outcomes in accordance with the CDIO Syllabus. For the full implementation of CDIO Standards a number of pilot educational programmes were selected. In 2011 TPU was the first Russian university to join the CDIO Initiative, that today has more than a hundred member universities from different countries [6]. In 2012 TPU put into action new version of The Standards and Guidelines for Quality Assurance of Bachelor's, Master's and Specialist's Programs in TPU Priority Areas, which takes into account the CDIO Standards [7].

One of the pilot programmes selected for full-scale modernization based on the CDIO Standards was Bachelor degree 13.03.02 «Power and Electrical Engineering». The programme was developed in full compliance with the CDIO Standards: intended learning outcomes corresponding the CDIO Syllabus, integrated curriculum, additional course «Introduction to Engineering», work space for hands-on learning of product, process, and system building, enhancement of faculty competencies in active learning and assessment tools. In 2014 first students graduated from the new Bachelor programme.

Table 1. Comparative analysis of CDIO Syllabus and AEER Criterion 5

AEER \ CDIO	1.1	1.2	1.3	2.1	2.2	2.3	2.4	2.5	3.1	3.2	3.3	4.1	4.2	4.3	4.4	4.5	4.6
1.1	X	X	X														
1.2				O		O								O			
1.3															X		
1.4				O	X												
1.5			O											O	O	O	O
1.6														O	O	O	O
2.1													X				
2.2										X	X						
2.3									X								
2.4								X									
2.5												X					
2.6							O										

For expert assessment of the achieved level of the intended learning outcomes in compliance with the CDIO Syllabus, the key stakeholders were interviewed: teachers (programme manager responsible for the preparation of profiles, internship, course and diploma projects supervisors and others), graduate students, employers and alumni who graduated a few years ago from undergraduate programmes in the field of power and electrical engineering. The survey was conducted in order to obtain expert assessment and compare the expected and the achieved level of complex learning outcomes (professional and general competencies), to determine priorities and the degree of satisfaction of key stakeholders, to identify and eliminate further problems by improving the educational programme at planning and design stages, and resource support of the programme. It is important to note that the survey concerned most required (demanded) personal and professional attributes, interpersonal skills (teamwork and communication) learning outcomes regarding conceiving, designing, implementing, and operating systems in the enterprise, societal and environmental context (second level of detail of 2-4 CDIO Syllabus).

For evaluation of the intended and achieved levels of the learning outcomes the Likert Scale was used with the educational levels of Feisel-Schmitz taxonomy[8]: 1 – Define, 2 – Compute, 3 – Explain, 4 – Solve, 5 – Judge, adapted to the engineering field (Table 2).

The survey involved 21 teachers of professional upper division courses, 58 students, 11 employers – representatives of power and electrical engineering companies, 14 graduates. Results of stakeholders assessment of the expected learning outcomes level relevant to CDIO Syllabus are shown in Fig. 1.

The survey shows that key stakeholders estimate expected level of learning outcomes between 3 and 4,5 points. The major part of the evaluation results vary between 3,5 and 4 points. In other words stakeholders believe that while studying professional and general competencies of future engineers should be developed at sufficiently good (advanced) level of understanding and practical experience. It should be noted that the survey results coincide with the average statistical estimate (3.7 to 5-point scale) given by Russian employers in 2013 and presented at the meeting of Presidential Council for Science and Education of Russian Federation [1].

Comparative analysis of the evaluation results (Fig. 1) reveal difference (in some aspects very significant) in opinion of employers, alumni, faculty and students on expected level of learning outcomes relevant to CDIO Syllabus. Both graduates and students score the importance of mentioned learning outcomes proficiency higher than other respondents. In most cases scores of the employers are lower than those of the students and graduates. The faculty members evaluated the expected learning outcomes lower than all other groups of stakeholders.

Figures 1-5 demonstrate the expected and real level of acquired learning outcomes according to the evaluation made by employers, graduates, students and teachers tacking into account CDIO Syllabus.

Analysis of the data indicates that the most «fulfilled» expectations are in the group of graduates and students (Fig. 3, Fig. 4). From their point of view, 75% of expected learning outcomes were really achieved. Employers are satisfied with only two thirds of the results (Fig. 2), and university teachers – with less than 60% (Fig. 4). Given the fact that faculty expectations were the lowest among all stakeholders, we can conclude that teachers were the most pessimistic stakeholders in the evaluation of the quality of students'

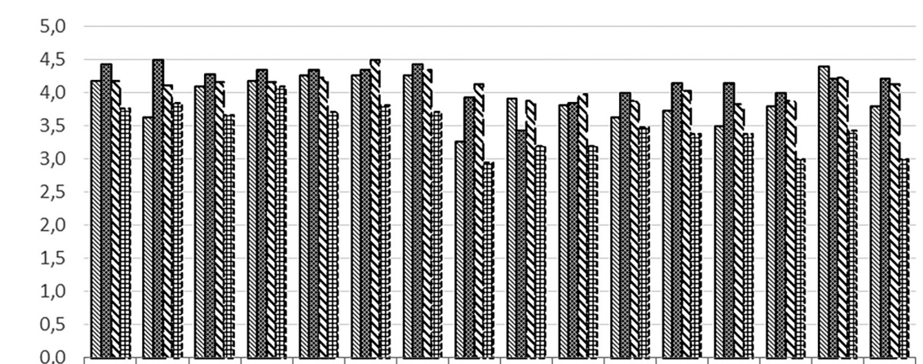
Table 2. Evaluation scale

Point	Educational level (Feisel-Schmitz Taxonomy)	Interpretation in terms of educational level justification
5	Judge	To be ready for innovations
4	Solve	To have practical experience
3	Explain	To be able to understand and explain
2	Compute	To be able to find and demonstrate a typical solution
1	Define	To have some experience in execution and implementation
0	Lack	Lacking learning outcome (not developed)

undergraduate training. Obviously, this is also explained by exacting requirements to the real learning outcomes, and in the future they will make efforts to achieve a higher level of graduates' preparation for professional engineering activities.

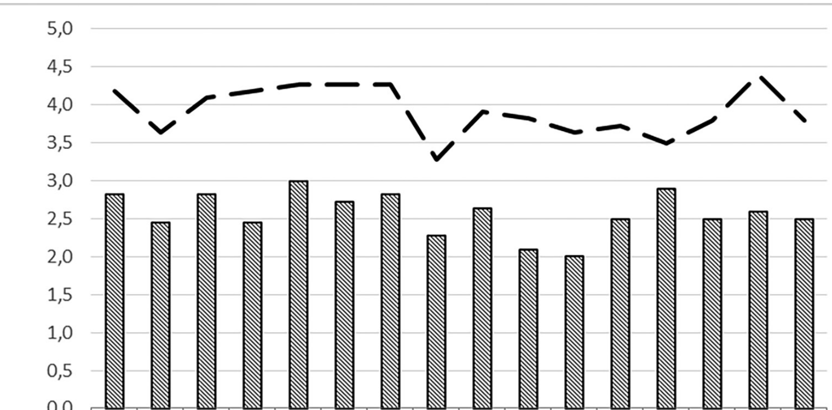
Employers found the closest approximation of the real level of developed

Fig. 1. Expected level of learning outcomes for group of stakeholders



	2.1.	2.2.	2.3.	2.4.	2.5.	3.1.	3.2.	3.3.	4.1.	4.2.	4.3.	4.4.	4.5.	4.6.	4.7.	4.8.
employer	4,18	3,64	4,09	4,18	4,27	4,27	4,27	3,27	3,91	3,82	3,64	3,73	3,50	3,80	4,40	3,80
graduate	4,43	4,50	4,29	4,36	4,36	4,36	4,43	3,93	3,43	3,86	4,00	4,14	4,14	4,00	4,21	4,21
student	4,19	4,11	4,16	4,16	4,23	4,50	4,35	4,13	3,89	3,98	3,88	4,03	3,83	3,88	4,23	4,13
teacher	3,76	3,86	3,67	4,10	3,71	3,81	3,71	2,95	3,19	3,19	3,48	3,38	3,38	3,00	3,43	3,00

Fig. 2. Acquired and expected level of proficiency (evaluated by employers)



	2.1.	2.2.	2.3.	2.4.	2.5.	3.1.	3.2.	3.3.	4.1.	4.2.	4.3.	4.4.	4.5.	4.6.	4.7.	4.8.
Acquired level	2,82	2,45	2,82	2,45	3,00	2,73	2,82	2,27	2,64	2,09	2,00	2,50	2,90	2,50	2,60	2,50
Expected level	4,18	3,64	4,09	4,18	4,27	4,27	4,27	3,27	3,91	3,82	3,64	3,73	3,50	3,80	4,40	3,80

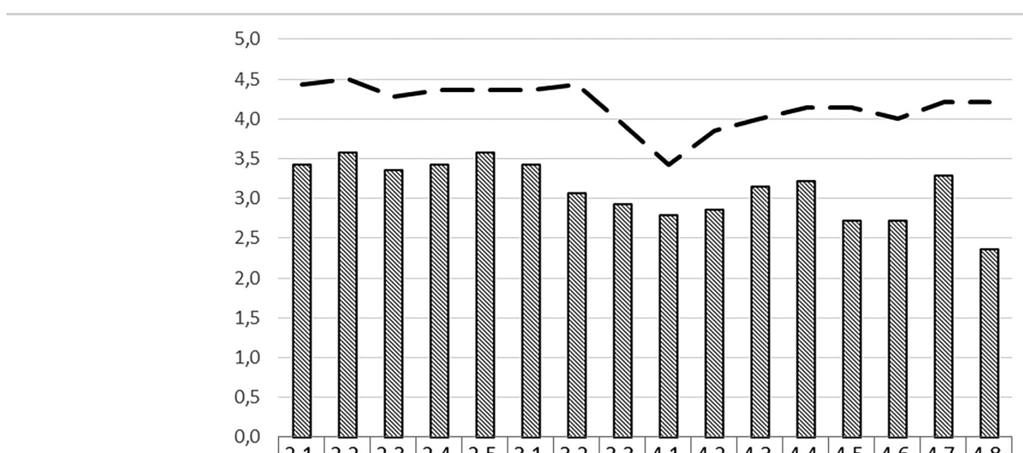
competence to the expected level of learning outcomes in implementing and operating electrical systems, professional ethics and responsibility. It is important to emphasize that employers also noted the high level of acquired communication skills in foreign language compared with apparently low level of expectations (Fig. 1). Relatively low were evaluated the learning outcomes associated with the business context of conceiving and designing engineering systems, as well as leading engineering endeavours. It is noteworthy that leadership attributes were the most highly evaluated learning outcomes by this group of stakeholders (Fig. 2).

Students, as well as employers, consider the acquisition of leadership skills in the engineering profession one of the major intended learning outcomes. However, unlike the employers they are quite optimistic about the real level of achievement of this result (Fig. 4). In addition, students are satisfied with the relatively high level of competence development in the field of system thinking, ethics, responsibility and teamwork. Low scores were given by students to designing, implementing and operating electrical engineering systems, as well as communications in foreign languages.

Graduates note that educational process allows developing at good level skills in engineering design, experimentation and investigation, new knowledge acquisition, system thinking and teamwork (Fig. 3). However, in contrast to the students, graduates relatively low score leadership qualities. At the same time they share students' opinion on the lack of proficiency in implementing and operating electrical engineering systems. Obviously, students and alumni, and especially teachers (Fig. 5) are more demanding regarding these learning outcomes compared with employers, who quite appreciate the level of undergraduate training programs in the field of producing electrical engineering equipment (Fig. 2).

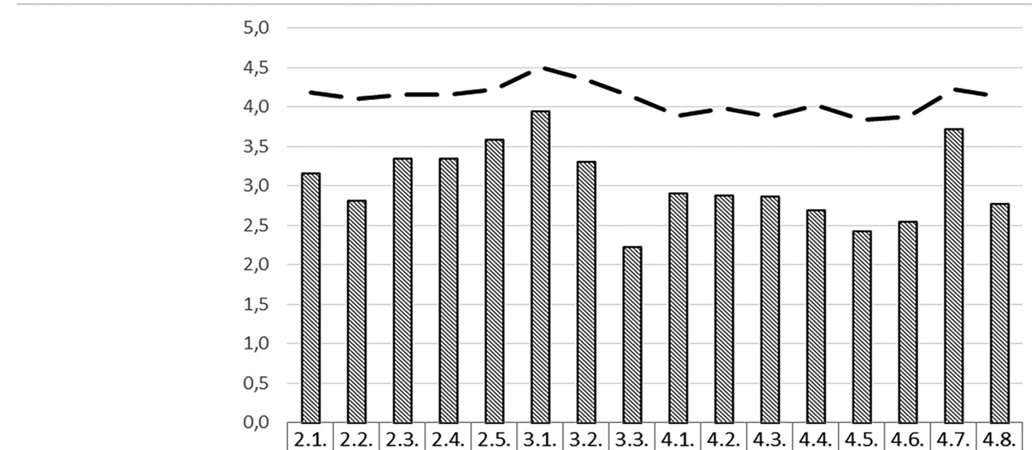
The conducted survey of the stakeholders' evaluation of acquired and expected learning outcomes at the educational programme 13.03.02

Fig. 3. Acquired and expected level of proficiency (evaluated by graduates)



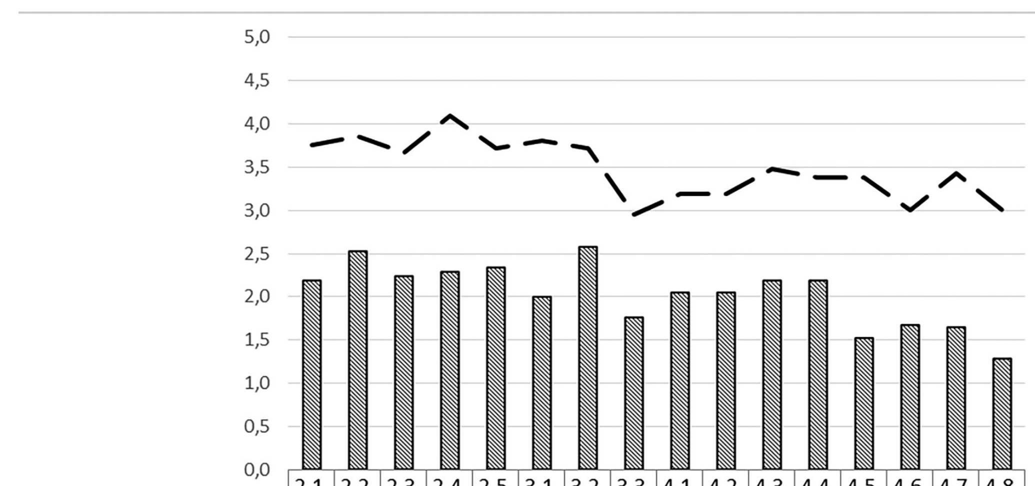
	2.1.	2.2.	2.3.	2.4.	2.5.	3.1.	3.2.	3.3.	4.1.	4.2.	4.3.	4.4.	4.5.	4.6.	4.7.	4.8.
Acquired level	3,43	3,57	3,36	3,43	3,57	3,43	3,07	2,93	2,79	2,86	3,14	3,21	2,71	2,71	3,29	2,36
Expected level	4,43	4,50	4,29	4,36	4,36	4,36	4,43	3,93	3,43	3,86	4,00	4,14	4,14	4,00	4,21	4,21

Fig. 4. Acquired and expected level of proficiency (evaluated by students)



	2.1.	2.2.	2.3.	2.4.	2.5.	3.1.	3.2.	3.3.	4.1.	4.2.	4.3.	4.4.	4.5.	4.6.	4.7.	4.8.
Acquired level	3,16	2,82	3,34	3,34	3,59	3,94	3,31	2,22	2,91	2,88	2,87	2,69	2,43	2,55	3,72	2,77
Expected level	4,19	4,11	4,16	4,16	4,23	4,50	4,35	4,13	3,89	3,98	3,88	4,03	3,83	3,88	4,23	4,13

Fig. 5. Acquired and expected level of proficiency (evaluated by teachers)



	2.1.	2.2.	2.3.	2.4.	2.5.	3.1.	3.2.	3.3.	4.1.	4.2.	4.3.	4.4.	4.5.	4.6.	4.7.	4.8.
Acquired level	2,19	2,52	2,24	2,29	2,33	2,00	2,57	1,76	2,05	2,05	2,19	2,19	1,52	1,67	1,65	1,29
Expected level	3,76	3,86	3,67	4,10	3,71	3,81	3,71	2,95	3,19	3,19	3,48	3,38	3,38	3,00	3,43	3,00

«Power and Electrical Engineering» is not a unique one. TPU studies on the annual basis stakeholders opinion (employers, graduates, students, teachers) for planning and assessing the achievement of professional and general competencies, as well as to improve the content of training programs in various fields. The scores given to estimated and achieved learning outcomes depend on the educational programme profile, as well as the field of engineering activity of the specific industrial companies. The results of the survey also reveal general trends to be considered for the continuous improvement of the content and techniques for the whole list of educational programmes in the field of engineering and technology.

Assessment of the learning outcomes based on CDIO Syllabus was held for the first time. It allowed to identify how the intended level of learning outcomes and the real level of competence for professional engineering activity meet the requirements of modern engineer. Using the received data and following recommendations of the CDIO Standards further modernization of the bachelor degree program 13.03.02 « Power and Electrical Engineering» will be completed, as well as improvement of other educational programmes in engineering and technology to ensure their compliance with international CDIO standards. With further improvement of engineering programmes it is important to find out the reasons of significant differences in the evaluations of the key stakeholders, to study better their expert opinion, to approve with them the expected learning outcomes at the designing stage of educational programme development, to make adjustments to the content and educational technologies in order to reach a consensus.

CDIO Academy Programme

As already noted, today more than one hundred universities around the world have joined the international project CDIO Initiative and implement CDIO approach like "innovative educational framework for producing the next generation of engineers". After TPU several Russian universities became members of the CDIO Initiative: Astrakhan State University, Skolkovo Institute for Science and Technology, Moscow Aviation Institute (2012), Tomsk State University of Control Systems and Radioelectronics, Moscow Institute of Physics and Technology, Ural Federal University (2013), Siberian Federal University, Don State Technical University, Moscow Engineering Physics Institute (2014).

CDIO concept is becoming increasingly popular in Russian engineering universities. The successful implementation of CDIO approach in the educational process depends on the willingness and ability of educational programme leaders, developers and teachers to respond flexibly to changes in engineering activities, their ability to fill the educational programmes with actual content and use innovative technologies to achieve the intended learning outcomes. In order to prepare faculty of Russian universities to apply CDIO approach Tomsk Polytechnic University and Skolkovo Institute for Science and Technology have developed and introduced a joint network training programme «CDIO concept implementation in engineering education» [9].

Taking into account that CDIO Standards serve as guidelines for educational programme reform the introduced faculty development programme outlines the following expected learning outcomes:

- ability to apply CDIO philosophy adopting the principle that product, process, and system lifecycle development and deployment -- Conceiving, Designing, Implementing and Operating -- are the context for engineering education (Standard 1 CDIO);
- ability to plan specific, detailed learning outcomes for personal and interpersonal skills, and product, process, and system building skills, as well as disciplinary knowledge (Standard 2 CDIO);
- ability to develop an integrated curriculum, designed with mutually supporting disciplinary courses, with an explicit plan to integrate personal and interpersonal skills, and product, process, and system building skills (Standard 3 CDIO);
- ability to develop and implement an introductory course within the integrated curriculum, that provides the framework for engineering practice in product, process, and system building, and introduces essential personal and interpersonal skills of graduates (Standard 4 CDIO);
- ability to organize design-built activities of students through the implementation in an integrated curriculum of at least two or more design-implement experiences at a basic and advanced levels (Standard 5 CDIO);
- ability to create engineering workspaces and laboratories that support and encourage hands-on learning of product, process, and system building, disciplinary knowledge, and social learning (Standard 6 CDIO);
- ability to ensure integrated learning experiences that lead to the acquisition of disciplinary knowledge, as well as personal and interpersonal skills, and product, process, and system building skills (Standard 7 CDIO);
- ability to apply active learning methods (team work, case-study, games, problem based learning, context learning) improving the quality of training and enhancing the level of acquired learning outcomes (Standard 8 CDIO);
- ability for actions that enhance faculty competence in personal and interpersonal skills, and product, process, and system building skills (Standard 9 CDIO);
- ability for actions that enhance faculty competence in providing integrated learning experiences, in using active experiential learning methods, and in assessing student learning (Standard 10 CDIO);
- ability to assess student learning in personal and interpersonal skills, and product, process, and system building skills, as well as in disciplinary knowledge (Standard 11 CDIO);
- ability to evaluate educational programme against all CDIO standards, and provide feedback to students, faculty, and other stakeholders for the purposes of continuous improvement (Standard 12 CDIO).

Faulty qualification development programme has a modular structure and consist of the following sections:

Module 1. CDIO concept in engineering education.

1.1. Engineering and engineering education.

1.2. CDIO Standards.

1.3. Standard 1 CDIO. CDIO as the context for engineering education.

1.4. Standard 2 CDIO. Planning programme learning outcomes regarding CDIO Syllabus.

Individual assignment 1. «Planning programme (module, discipline) learning outcomes based on CDIO Syllabus».

Module 2. Design of educational programmes based on CDIO concept.

2.1. Standard 3 CDIO. Integrated curriculum.

2.2. Standard 4 CDIO. Introduction to Engineering.

Individual assignment 2. «Design of educational programme (module, discipline) based on CDIO concept».

Module 3. CDIO based educational process.

3.1. Standard 5 CDIO. Providing design-implement experiences.

3.2. Standard 6 CDIO. Engineering Workspaces.

3.3. Standard 7 CDIO. Integrated

Learning Experiences.

3.4. Standard 8 CDIO. Active learning.

Individual assignment 3. «Development of the topic for students' design-implement experiences within educational programme (module, discipline)».

Module 4. Learning Assessment and programme evaluation.

4.1. Standard 11 CDIO. Learning Assessment.

4.2. Standard 12 CDIO. Programme evaluation.

Individual assignment 4. «Development of evaluation tools and criteria of programme (module, discipline) learning outcomes achievement».

Module 5. Training faculty for CDIO approach implementing.

5.1. Standard 9 CDIO. Enhancement CDIO Competence of Faculty

5.2. Standard 10 CDIO. Enhancement of Faculty Teaching Competence.

Each module of the programme aims to achieve the relevant learning outcomes and provides a set of teaching materials that students receive before the training starts: abstract and curricula, presentations and lecture notes, glossary of terms, recommended reading list, questions for self-control, practical and individual tasks.

The program and topics of the individual assignments are developed in line with CDIO concept: Conceiving – Designing – Implementing – Operating.

At the initial stage, students determine the educational programme or a separate discipline, they will be improving within the training process, applying the acquired knowledge and skills in practice. The first module deals with conceiving competence for educational programme (discipline): formulate objectives and learning outcomes of students (competencies) required for future professional careers and agreed with the main stakeholders (employers). Individual tasks of the second and third modules focus on "designing" and "implementing" of educational programme and its elements: integrated curricula development, involving personal and professional skills development by means of project-based learning technologies. In the fourth module, at the "operating» stage, students develop tools and criteria for assessment of students' progress and educational programme evaluation in CDIO approach. Workshops and individual assignments are focused on developing students' ability to critically assess their own teaching activities in terms of planning, assessment and achievement of learning outcomes.

The programme is delivered during 16 weeks (academic semester), including three on-campus sessions (lectures and practical training), two webinars, studying the best practice of implementing CDIO Standards in Russian and foreign universities – CDIO Initiative members, as well as independent work of students (completing 4 individual assignments with professors consulting support). The programme totals 150 hours.

For methodological support of the programme and lecturing representatives of Russian and foreign CDIO-member universities are invited, who share best practice and understanding of CDIO Standards for reforming educational programmes in the field of engineering and technology.

Full-time sessions for studying best practice of CDIO approach implementation are held at Russian and foreign universities joining CDIO Initiative: students are introduced how to organize design-build workspace that supports hands learning and innovative activities.

The training process is based on electronic learning environment LMS Moodle, including training materials and records of webinars, consulting support and tools for individual assignments assessment (http://cdio.tpu.ru).

One of the distinguishing characteristic of the qualification development programme is a great amount of independent and individual work of students in cooperation with teachers and tutors, that concludes with development of teaching materials for educational programme (module/discipline) updated by the trainees. Students are certified in accordance with the results of their individual assignments assessment. Upon graduation students are awarded certificates of professional qualification development by Tomsk Polytechnic University and Skolkovo Institute for Science and Technology.

The programme «CDIO concept implementation in engineering education» was introduced in the spring semester of 2013-2014 academic year. The first on-campus session covering Module 1 took place in January 2014 in Chalmers University of Technology (Gothenburg, Sweden), the second and the third were held in March in Tomsk Polytechnic University (Module 3) and in May in Skolkovo Institute for Science and Technology (Module 5). Broadcast of Internet – webinars was organized by TPU: Module 2 – in February, Module 4 – in April 2014.

In the pilot programme for faculty professional development 24 teachers from 12 Russian took part. For teaching materials development and programme delivery 27 experts from 6 Russian and 6 foreign universities – CDIO Initiative members were involved ,including: Royal Institute of Technology, Chalmers University of Technology (Sweden), Delft University of Technology (Netherlands), Turku University of Applied Sciences (Finland), Technical University of Denmark (Denmark), Massachusetts Institute of Technology (USA).

The most interesting topics for programme participants were those related to problem analysis in engineering education, modernization of educational programmes, education reform and required resources, top management and faculty motivation to make changes in content and learning methods, cooperation with industry, students and alumni. During the discussion, experts and students agreed in opinion that educational programmes reform cannot be considered as an event, but as a never ending process that needs goal-setting and starting effort as well as continuous monitoring, analysis and evaluation.

Analysis of students' individual tasks performance identified the main challenges teachers face when implementing CDIO approach in the training process. The list of main challenges includes developing an integrated curriculum and providing interdisciplinary training. As part of the essay «Problems of interdisciplinary tasks and projects» students were able to express their views about the difficulties of project based learning implementation at their own universities. It was noted that the main problem of interdisciplinary projects development and implementation is low motivation and unavailability of teachers to step out their subject field to act and cooperate in order to develop interdisciplinary knowledge and practical skills of their students. When forming a working programme of discipline teachers are guided by their own vision of a subject and focus on theoretical training and general issues without paying attention to specific attributes of particular educational programme. Partly that could be explained by disciplinary approach commitment in educational programmes design. A set of disciplines used before often becomes a starting point in curriculum design and learning outcomes (competencies) are linked to the disciplines only after the curriculum is already formed.

During the discussions participants exchanged their views on how to increase motivation of teachers to actively use modern educational technologies and develop their own engineering and pedagogical skills. It was pointed out that changes could be more effective and far-reaching if faculty professional development training would be goal-oriented and systematic.

Students of the pilot programme often emphasized that successful reform could be ensured when there is an all-round support from the university management including sufficient resources and legal regulation. Also it is important to find compromise solutions in case there is conflict of interest of those participating in the reforming process. The discussion results demonstrate how important and topical are those issues covered in the training modules, individual assignments and practical tasks for faculty of Russian universities. Analysis of the difficulties that students faced while working with individual and practical tasks will be used for further improvement of the training materials in relevant modules.

One of the main results of the pilot CDIO Academy programme has become an effective discussion platform to share good practice and discuss problems and prospects of national engineering education system development. The interaction of the participating Russian and foreign universities, CDIO Initiative members, allows us to compare the results and assess the perspective application of CDIO Standards to reform engineering educational programmes, develop joint approaches to create informational and educational resources that facilitate CDIO adaptation to educational principles and environment of Russian universities. Tomsk Polytechnic University and Skolkovo Institute for Science and Technology plan to make further steps in developing CDIO training programme for faculty of Russian universities including electronic educational and consulting resources like MOOCs and other Internet-technologies.

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