

# DEVELOPMENT OF CDIO ACADEMY IN RUSSIA

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## ABSTRACT

The CDIO approach to modernization of engineering education is becoming more and more popular in Russian HEIs. In the period of 2011-2014, 12 Russian HEIs have joined the CDIO Initiative. The objectives of the CDIO Initiative in educating and training of a new generation of engineers correspond exactly to the tasks of modernization of Russian engineering education.

Tomsk Polytechnic University (TPU) and Skolkovo Institute of Science and Technology (Skoltech) with assistance of Chalmers University of Technology and other participants of CDIO Initiative have launched the Russian “CDIO Academy” - the joined project aimed at proper preparation of managers and faculty staff at Russian HEIs to implement the CDIO Standards. In frame of the project the professional development programme “Applying CDIO Standards in Engineering Education” was designed and piloted in 2014.

The paper describes the structure, the content, implementation technology and approbation results of the programme “Applying CDIO Standards in Engineering Education”. The focus of the paper is given to the upgrading of the programme based on:

- programme evaluation and feedback of the trainees,
- reviews of the programme teachers on trainees’ performance,
- survey results amongst representatives of the Russian Universities on their challenges and tasks in CDIO implementation.

## KEYWORDS

Faculty development programme, faculty competencies, CDIO implementation, engineering education.

## 1. INTRODUCTION

The problem of faculty staff professional development is widely discussed within the CDIO Community. Thus, the problem is considered from two different angles. The first one is focused on application and implementation of CDIO Standards 9 and 10 prescribing teachers to be competent in pedagogical, personal, interpersonal skills, and product, process, and system building skills (Cárdenas at all, 2013; Loyer& Maureira, 2014). The second one covers a wider spectrum and addresses the issue of CDIO-based system modernization of educational programmes. CDIO members recognize the fact that the success of reforms depends on faculty staff motivation to accept changes and on their ability to apply all CDIO Standards in practical activity of the university (Malmqvist at all, 2008; Crawley at all, 2014).

Despite high interest to faculty staff training in the field of CDIO approach application a relatively small number of articles and reports deals with design and implementation of faculty development programmes, which would include complex preparation of the faculty staff for CDIO approach application: starting with setting objectives and learning outcomes of the educational programme to evaluating its quality.

In Russia the issue of faculty staff development with regard to CDIO implementation is rather important. During the last 3 years 12 Russian universities have joined the CDIO Initiative. They try to use the CDIO approach to reframe and reform their educational programmes. In order to ensure proper preparation of managers and faculty staff at Russian higher education institutions (HEIs) to use the CDIO approach Tomsk Polytechnic University and Skolkovo Institute of Science and Technology (Skoltech) have recently designed and piloted a joint professional development programme “Applying CDIO Standards in Engineering Education”.

## **2. PROFESSIONAL DEVELOPMENT PROGRAMME “APPLYING CDIO STANDARDS IN ENGINEERING EDUCATION”: STRUCTURE, CONTENT AND IMPLEMENTATION TECHNOLOGY**

The objective of professional development programme “Applying CDIO Standards in Engineering Education” is to shape a particular set of skills of managers and faculty staff of Russian HEIs that provide engineering programmes aimed at successful and efficient implementation of the CDIO approach with the purpose of modernization of engineering education content and technologies.

The programme has a modular structure and consists of the following sections:

M1. The CDIO approach to engineering education.

1.1. Engineering activity and engineering education.

1.2. The system of the CDIO Standards.

1.3. CDIO Standard 1. The CDIO approach in the context of engineering education.

1.4. CDIO Standard 2. Intended learning outcomes based on the CDIO Syllabus.

Module project (P.1): Planning the learning outcomes for particular engineering programme (module, course) based on the CDIO Syllabus.

M2. Design of engineering programme based on the CDIO approach.

2.1. CDIO Standard 3. The integrated curriculum design.

2.2. CDIO Standard 4. The module “Introduction to engineering”.

Module project (P.2): Designing particular engineering programme (module/course) based on the CDIO approach.

M3. Organization of the teaching and learning processes based on the CDIO concept.

3.1. CDIO Standard 5. Organization of the students project work and innovation activities.

3.2. CDIO Standard 6. Workspace for students engineering activities.

3.3. CDIO Standard 7. Technology of integrated education.

3.4. CDIO Standard 8. Active learning methods.

Module project (P.3): Development of project and innovation topics for the students engineering activity within particular engineering programme (module/course).

M4. Assessment of learning outcomes and evaluation of the engineering programme.

4.1. CDIO Standard 11. Assessment of the students learning outcomes.

4.2. CDIO Standard 12. Evaluation of the engineering programme.

Module project (P.4): Development of indicators and assessment methods aimed at learning outcomes achievement within particular engineering programme (module/course).

M5. Training faculty staff to implement the CDIO concept.

5.1. CDIO Standard 9. Faculty staff development for CDIO implementation.

5.2. CDIO Standard 10. Enhancing faculty staff competency for teaching.

Professional development programme and topics of faculty staff module projects are designed in compliance with the CDIO model: Conceive, Design, Implement, Operate. At the initial stage the trainees define the particular engineering programme (module/course) to be improved in the course of education by applying the acquired knowledge and skills. While studying the sections of the first module (M1) the trainees pass through the 'Conceive' stage of the particular engineering programme (module/course): they develop programme (module/course) objectives and learning outcomes necessary for future professional activity and make them aligned with the key stakeholders (employers). Projects of the second (M2) and third (M3) modules are focused on the 'Design' and 'Operate' stages of the particular engineering programme and its elements: design of integrated curricula implying progressive sequential development of professional, personal and interpersonal competencies of students by means of project-based learning technologies. During the fourth module (M4) at the 'Implement' stage, the trainees develop assessment methods and criteria of students learning outcomes achievement, as well as evaluate the particular engineering programme for its compliance with CDIO Standards.

The professional development programme is scheduled for implementation for a period of 16 weeks (one academic semester) and involves three face-to-face sessions (interactive lectures and practical classes), two internet on-line webinars, and independent homework of trainees (development of four projects). The programme is based on the experience and best practices of engineering programmes modernization at universities participating in the CDIO Initiative. In total 27 experts from 6 Russian HEIs: TPU, Skoltech, Ural Federal University, Astrakhan State University, Moscow Institute of Physics and Technology, Tomsk State University of Control Systems and Radioelectronics and 5 foreign HEIs: Chalmers University of Technology, KTH, (Sweden), Delft University of Technology (The Netherlands), Technical University of Denmark (Denmark), Massachusetts Institute of Technology (USA) were involved in the design of teaching and learning materials, as well as in programme implementation itself. Study of the experience and best practices of the CDIO Standards application was arranged at the CDIO member universities where face-to-face sessions were held: the trainees became familiar with the organization of the workspaces for students' engineering activities, providing of methodological support for problem-based learning, etc.

### **3. RESULTS OF THE PROGRAMMES' APPROBATION**

Implementation of the programme "Applying CDIO Standards in Engineering Education" started in spring semester of academic year 2013-2014. The first face-to-face session (M1) took place in January 2014 at Chalmers University of Technology (Gothenburg, Sweden), the second session (M3) was held in March at Tomsk Polytechnic University and the third session (M5) took place in May at Skolkovo Institute of Science and Technology in Moscow. Broadcasting of on-line Internet-webinars (M2) and (M4) were arranged by Tomsk Polytechnic University in February and in April 2014. All organizational, teaching and learning materials of the programme are available on the TPU website (<http://cdio.tpu.ru/>).

Feedback of stakeholders focused on the programme quality assessment and data collection for its improvement and modernisation was provided during pilot implementation of the programme.

Programme monitoring included programme quality assessment by various stakeholder groups:

- programme evaluation and feedback of the trainees,
- reviews of the programme teachers on trainees' performance,
- survey results amongst representative of the Russian Universities on their challenges and tasks in CDIO implementation.

### **3.1. Results of programme evaluation done by the trainees**

The pilot group of trainees consisted of 24 managers and faculty staff of 12 Russian HEIs. The categories of positions held by programme participants are as followed: professors at HEIs (43% of trainees), HEIs administrative staff (38% of trainees), managers of HEIs departments (29% of trainees), officers of HEIs units for engineering pedagogy and methodology (5% of trainees). Thus, the group of programme participants is represented by various position categories with different level of responsibility for the implementation of engineering programmes.

For every section of the programme the trainees were offered to evaluate from 1 to 5 (5 is the highest on the scale) the levels of following aspects:

- relevance (to what extend the subject of the section is relevant for modernization of engineering programme),
- practical importance (to what extend the materials of the section and acquired knowledge and skills will be used),
- novelty (to what extend the content of the section systematizes and enlarges the knowledge of programme participants in corresponding fields).

Approximately half of the faculty staff was representatives of the universities that already joined the CDIO Initiative. They were aware of the CDIO approach and had some experience in applying and reforming educational programmes. Hence, the results of professional development programme evaluation are shown separately in Table 1 (evaluation by the faculty staff of the HEIs being members of the CDIO Initiative and evaluation by the faculty staff of the HEIs outside the CDIO Initiative).

Table 1. Results of programme evaluation done by the trainees

| <b>Programme's aspect</b> | <b>HEIs - CDIO members</b> | <b>HEIs - not CDIO members</b> |
|---------------------------|----------------------------|--------------------------------|
| relevance                 | 4,51                       | 4,48                           |
| novelty                   | 4,01                       | 4,30                           |
| practical importance      | 4,23                       | 4,56                           |

In general, the trainees gave high scores to all aspects of the programme. As predicted the representatives of HEIs - CDIO members ranked novelty and practical importance of programme materials slightly lower than representatives of other universities. However, it is noteworthy that both groups of respondents ranked high the level of programme relevance.

According to the opinion of the trainees the following programme sections, the subjects of which are particularly challenging for the Russian engineering education, should be considered in more details, with demonstration of examples and master-classes:

- CDIO Standard 3. The integrated curriculum design (40% of trainees),
- CDIO Standard 7. Technology of integrated education (30% of trainees),
- CDIO Standard 2. Planning intended learning outcomes based on the CDIO Syllabus (20% of trainees),

- CDIO Standard 5. Organization of the students project and innovation activities (20% of trainees),
- CDIO Standard 8. Active learning methods (20% of trainees).

The trainees identified several topics that can be additionally included into professional development programme as separate sections:

- design and assessment of learning outcomes, which traditionally were not considered 'engineering' ones, however become important when engineering graduates competencies are concerned: personal and interpersonal skills, leadership, entrepreneurship and teamwork,
- management of educational change processes at Russian HEIs, including identification of barriers and obstacles for large-scale and sustainable educational reform and consideration of Russian federal requirements and methodical aspects.

### **3.2. Reviews and recommendations of the programme teachers**

Programme teachers opinion study was done via personal conversations and on the basis of teachers' reports on practical tasks and projects completed by the trainees. Teachers were asked to give recommendations on programme modernization and list the following in the reviews:

- basic problems that the trainees faced when fulfilling practical tasks and projects, as well as problems related to CDIO Standards implementation at Russian universities;
- major difficulties that the teachers faced when delivering, checking and assessing tasks and consulting the trainees;
- identify strengths and weaknesses of projects performed by the trainees.

Limited format of this paper does not allow to list all views and conclusions made by the teachers. Let us indicate the most critical ones where programme teachers were aligned on their opinions.

When fulfilling their projects many trainees were creative, gave innovative ideas and suggested projects on educational programmes modernization. Such ideas and suggestions present interest due to their unconventional approach, however they require time check and adjustment against testing results. In order to ensure professional development programme advancement and to spread the experience of the CDIO Initiative implementation it is recommended to trace the results of project activity by the trainee groups' at certain intervals, successes and failures of implementation with regard to programmes and plans designed by the trainees within their project tasks.

When fulfilling practical tasks and projects the majority of the trainees used best practices and experience of educational programmes reforming available at their universities and shared their ideas. Professional development programme will have 'high added value' provided the organization of the educational process implies peer learning and contributes to maximum experience sharing among the trainees.

One of the biggest difficulty that programme teachers faced is that the majority of the trainees do not clearly define their role in the process of educational programme modernization at their universities, they do not see the degree of their responsibility for educational programme outcomes. To some extent this negative factor may be reduced thus including tasks aimed at self-analysis and self-assessment of programme trainees.

### **3.3. Survey results amongst the Russian Universities - CDIO members**

Opinions of Russian higher educational institutions implementing CDIO principles regarding professional development programme are of a great importance since particularly those universities serve major customers and ‘consumers’ of competencies developed by employees within the programme. Questionnaire distributed among administrative staff responsible for CDIO implementation at the university was carried out to assess the quality of professional development programme by HEIs - CDIO members. The following were primary objectives of the questionnaire:

- to define basic areas and scope of measures held by Russian universities with regard to educational programmes modernization on the basis of the CDIO approach and to specify major difficulties of this process;
- to identify the level of programme alignment with tasks set forth by Russian universities during educational programmes modernization in compliance with the CDIO Concept.

Following this process 15 questionnaires from 10 Russian universities were obtained.

The results of the survey showed wide variety of programmes on the basis of the CDIO approach at Russian universities. This concerns different levels of education (research oriented and practice oriented bachelor and master studies) and various fields of education. As for Russian universities the CDIO concept is implemented in programmes of engineering sciences, management and humanities. No doubt such dispersion of areas where CDIO is applied causes some difficulties both among the trainees and teachers themselves. Moreover, this creates a certain challenge not only to the faculty development programme but also to the whole CDIO community. Demonstration and discussions of the CDIO approach application will expand the experience of both trainees and teachers and will contribute to differentiation of requirements imposed on various CDIO programmes. Table 2 shows distribution of trainees’ responses regarding basic reasons preventing application of CDIO Standards at higher educational institutions.

Table 2. Trainees’ responses regarding basic reasons preventing application of CDIO Standards at higher educational institutions

| <b>Response</b>   | <b>% of responses from the number of respondents</b> |
|---|--|
| Lack of methodical resources  | 54%  |
| Lack of financial resources   | 52%  |
| Low motivation of faculty staff to changes something  | 48%  |
| Lack of experience / insufficient faculty staff qualification   | 74%  |
| Poor involvement of employers into the educational process  | 39%  |
| Organizational difficulties preventing system-based transformations (cooperation between various university structures) | 63%  |

Table 2 shows that among major difficulties of applying the CDIO Standards higher educational institutions identify insufficient faculty staff qualification and organizational difficulties preventing system-based transformations (cooperation between various university structures) as the most critical ones. Consequently, many respondents specified that lectures and practical classes of programme modules shall include materials on design principles of

strategy and tactics of educational programmes modernization on the basis of CDIO Standards, where such materials shall cover the analysis of problem-based situations in engineering education, definition of the scope of transformations and their resources.

All respondents mentioned that during educational programmes modernization and design at their universities they use teaching and information materials of professional development programme 'Applying CDIO Standards in Engineering Education'. As a rule, programme materials are adjusted to peculiarities of the educational process at the universities. Table 3 shows distribution of university responses to the question "Materials of which programme sections were the most useful for modernization of educational programmes at your university?".

Table 3. Programme sections, the materials of which were the most useful for modernization of educational programmes at Russian universities

| <b>Response (professional development programme section)</b>                              | <b>% of responses from the number of respondents</b> |
|---|--|
| 1.1. Engineering activity and engineering education                                       | 22%  |
| 1.2. The system of the CDIO Standards   | 35%  |
| 1.3. CDIO Standard 1. The CDIO approach in the context of engineering education           | 33%  |
| 1.4. CDIO Standard 2. Intended learning outcomes based on the CDIO Syllabus               | 71%  |
| 2.1. CDIO Standard 3. The integrated curriculum design                                    | 83%  |
| 2.2. CDIO Standard 4. The module "Introduction to engineering"                            | 29%  |
| 3.1. CDIO Standard 5. Organization of the students project work and innovation activities | 71%  |
| 3.2. CDIO Standard 6. Workspace for students engineering activities                       | 29%  |
| 3.3. CDIO Standard 7. Technology of integrated education                                  | 64%  |
| 3.4. CDIO Standard 8. Active learning methods   | 64%  |
| 4.1. CDIO Standard 11. Assessment of the students learning outcomes                       | 74%  |
| 4.2. CDIO Standard 12. Evaluation of the engineering programme                            | 32%  |
| 5.1. CDIO Standard 9. Faculty staff development for CDIO implementation                   | 31%  |
| 5.2. CDIO Standard 10. Enhancing faculty staff competency for teaching                    | 41%  |

As Table 3 shows the universities consider the most useful teaching materials of those sections where trainees fulfill module projects (sections 1.4., 2.1., 3.1. and 4.1.) and which, correspondingly, are being worked out in details by the trainees with the help of teachers-consultants.

#### **4. DEVELOPMENT OF THE PROGRAMME**

On the basis of feedback data integration obtained from various stakeholder groups the professional development programme 'Applying CDIO Standards in Engineering Education' was substantially modernized. Changes covered 3 aspects of the programme:

- content of programme modules and project tasks;
- technology of programme implementation, application of learning methods and aids;
- system of educational process assessment and diagnostics.

#### **4.1. Changes in the modules' content**

In compliance with stakeholder demand the following topics were included in lecture and practical classes of programme sections:

- comparison of requirements and restrictions of Russian federal educational standards with international standards of engineering education: CDIO Standards, AEER criteria of public professional accreditation, EUR-ACE and ABET criteria;
- peculiarities of implementing the CDIO approach into the educational process of Russian universities taking into account requirements of the Russian legislation to legal and methodical support of educational programmes, including development of an institutional legal base;
- HEI joining the CDIO Initiative: objectives, tasks, application submission procedure, programme modernization results, cooperation of universities within the CDIO Network;
- development of strategy and tactics of educational programmes modernization on the basis of CDIO Standards, definition of the scope of transformations and their resources.

Besides, the programme is added with the topics of practical experience related to the application of the CDIO approach in practice oriented bachelor studies (Ural Federal University experience), master studies (Skoltech experience), programmes on humanities (Astrakhan State University).

#### **4.2. Changes in implementation technology**

In general, the area of topics covered by the programme corresponds to the content of its sections and fits within the existing structure. The expansion of the spectrum of the considered issues without the increase in programme total workload became possible due to reinforcement of active and integrated learning methods.

First and foremost, all programme sections imply that trainees discuss issues and problems related to CDIO application in educational experience of the university.

Secondly, at all face-to-face sessions of the programme the teachers hold master-classes and trainings for activation methods of students' cognitive activity and efficient management of students' project activity. Furthermore, this goes alongside with the demonstration of both Russian and international integrated learning experience (problem-based learning, project-based learning, contextual learning, etc.).

Thirdly, every section of the programme contains case-studies for trainees' independent work. Case-studies include examples of applying the CDIO approach in Russian and foreign universities at various stages: starting with the idea to initiate the reforming process to the assessment of the obtained results, development of project-based courses (modules) and integrated curricula.

The biggest part of practical tasks is done by trainees in teams, which ensures peer learning and sharing experience on educational programmes modernization with each other. Some

practical tasks are focused on trainees' self-analysis and self-assessment: questionnaires, debates, analysis of personal experience.

There are active forums on the basis LMS Moodle, which is an open-source learning platform. They are used to consult the trainees, to get feedback and exchange opinions regarding relevant topics.

#### **4.3. Additions to the methods of assessment**

Certification of trainees is done following the results of 4 module projects assessed by teachers. The basic change in the system of program evaluation is introduction of peer assessment method. This contributes to trainees learning about the experience and ideas of each other and promotes active discussions among them.

### **5. CONCLUSION**

Successful implementation of the CDIO approach in engineering education depends on the commitment of university managers, programme designers and faculty staff to react to changes taking place in engineering profession, to be able to define appropriate programme objectives, to fill educational programmes with relevant content and to apply innovative technologies to achieve intended graduate learning outcomes.

The objective of design and implementation of the faculty development programme 'Applying CDIO Standards in Engineering Education' is complex training of academic and administrative staff of Russian universities for systematic modernization of engineering education implied by the CDIO approach. The programme is based on advanced experience of Russian and foreign universities which apply CDIO Standards to improve the quality of educational programmes.

In the framework of programme pilot implementation (January – May, 2014) the system of its quality monitoring was launched and tested. Trainees, teachers and Russian HEIs - CDIO members were involved into program evaluation. The opinion poll of professional development programme participants showed that its content is relevant and bears a high level of practical importance for all respondents. In compliance with feedback results and recommendations of stakeholders, the programme was significantly improved. The major changes concern improvement of programme implementation technology. With regard to learning methods high emphasis is placed on trainees' self-analysis, peer learning and exchange of experience.

Various projects are tested and best practices of Russian universities with regard to educational activity reforming are identified and aligned during work and communication between programme teachers and its trainees. According to the opinion of respondents the biggest success of the programme is the fact that it develops Russian teaching community, which in its turn is motivated and interested in developing the engineering education in general.

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