JOURNAL OF ASSOCIATION FOR ENGINEERING EDUCATION OF RUSSIA

ENGINEERING EDUCATION

Общероссийская общественная организация АИОР 1992

ISSN-1810-2883

16'2014

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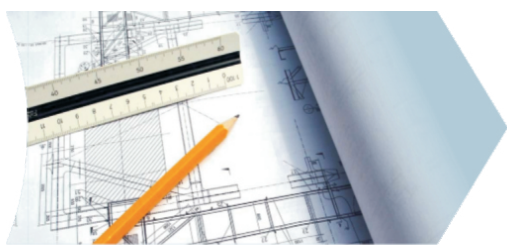

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CDIO Initiative.
New Approach to Engineering Education

Editorial board

Dear readers!

More and more attention to the quality of engineering education is paid in the world regarding the complexity of technology, engineering systems and increasing role they play in the economy and society in general.

The main contradiction in this area is the gap between the needs of stakeholders (employers, including industry, business, government structures, parents, students, ...) and the quality of training in the field of engineering and technology.

The reason why this contradiction still exists could be explained by the low prestige of engineering profession, weak link between higher education institutions and main stakeholders, conservatism of university community. Universities focus on developing and assessing knowledge competencies of future engineers, while list of employers needs includes competencies that allow university graduates to start solving tangible engineering problems immediately upon graduation from the educational program.

In particular, according to employers, graduating engineers are expected to be able to:

- conceive-design-implement-operate complex value-added engineering systems;
- effectively apply their knowledge to solve real engineering problems;
- think systematically and critically, find the problems and propose ways to solve them;
- engineering reasoning and problem solving, think creatively and invent ;
- work effectively as a team member and as a team leader;
- commit to professional ethics.

The reasons why positive changes in engineering education have not happened, really exist in both developed and developing countries. In fact, this is a contradiction, provoked by the challenges from the outside world to universities and research and academic community. As a rule, proposals to meet those challenges are not efficient enough and do not appear very often. Against this background stands out the CDIO Initiative (Conceive – Design – Implement – Operate), which was formed more than 10 years ago by Massachusetts Institute of Technology (MIT), one of the leading technical universities in the world. This points to the fact that MIT before others realized the importance of quality issues in engineering training, and proposed their route.

Vision of the CDIO-based education stresses the fundamentals, set in the context of Conceiving – Designing – Implementing – Operating systems and products. CDIO approach, to some extent, could be the universities' answer to these challenges. CDIO involves curriculum reform featuring active and experiential learning allowing graduates of engineering programs significantly reduce or even exclude the period of adaptation to the real engineering practice situations. CDIO approach is developed to meet the requirements of employers to the quality of training and close the abovementioned gap.

Over the past 10 years the CDIO Initiative joined more than 115 universities in Europe, North and Latin America, Asia, UK, Australia, New Zealand and Africa. In Russia, the first CDIO member university was Tomsk Polytechnic University, after 11 more Russian universities followed this approach: Astrakhan State University, Don State Technical University, Siberian Federal University, Ural Federal University, MAI, MEPhI, MIPT, Skolkovo Institute for Science and Technology, TUSUR, Kazan Federal University (Naberezhnye Chelny Institute).

Applying CDIO principles in engineering education could significantly change the approach to the development and implementation of educational programs and, as a result, enhance the competence of the graduates and increase their competitiveness in the international engineering labour market.

In particular, CDIO standards include:

- adoption of the principle that product, process, and system lifecycle development and deployment are the context for engineering education;

- specific, detailed learning outcomes for personal and interpersonal skills, professional competencies consistent with program goals and validated by program stakeholders;
- a curriculum designed to integrate personal and interpersonal skills, and product, process, and system building skills;
- an introductory course that provides the framework for engineering practice makes part of the curriculum;
- participation of students in two or more design-implement experiences at various levels;
- workspaces and other learning environments that support hands-on learning are fundamental resources for learning to design, implement, and operate products, processes, and systems;
- an environment for integrated nature of the learning process (training, real practice);
- teaching and learning based on active experiential learning methods;
- enhancement of faculty competence in CDIO implementation;
- students' assessment system focusing not only on acquisition of disciplinary knowledge, but also on evaluation of their ability to create new products, processes, and systems;
- evaluation of educational programs and educational technologies by all key stakeholders (students, employers, experts from the university community and relevant agencies).

The Editorial Board decided to dedicate this issue of the journal "Engineering Education" to the problems of CDIO approach implementation at universities training specialists in the field of engineering and technology. From the papers of our Russian and foreign authors you can find out the analysis of theoretical and practical points of the CDIO initiative, experience of CDIO Standards implementation in real university activities.

The Editorial Board hopes that presented articles will be useful for those who are interested in improving the quality of engineering programs and ready to take advantage of the good practice from colleagues working in different universities around the world.

Sincerely,
Editor-in-Chief,
Prof. Yury Pokholkov

Contents

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UDC 378: 37.026

CDIO: Objectives and Means of Achievement

Siberian Federal University
S.A. Podlesny, A.V. Kozlov

The system of CDIO standards in terms of implementation in Russian engineering education is analyzed. Particular attention is paid to the scientific and methodological elaboration of «Conceive» stage. To increase the efficiency of this stage, domestic TRIZ methodology is considered. Relevant didactics, CAI programs and virtual environments of professional activity are proposed. It is indicated that international standards are more effective when they are implemented in educational–scientific–industrial (innovation) complexes.

Key words: Conceive, TRIZ, applied dialectics, knowledge invention, innovative projects, CAI programs, virtual environments, technological engineering centers.

In the era of postindustrial information society and innovative economy specific emphasis are put on the training of engineers that are able to create new technics and technologies. CDIO International Standards guide towards a complex approach for the formation of such specialists. These standards stipulate system training of engineers able to conceive ideas, design, implement, operate and utilize products of engineering activity.

De facto, by far not every staff member of scientific and development divisions of the world leading corporations possesses a full set of qualities that are proposed by CDIO Standards. As a common rule, dedication to only one or two CDIO stages takes place in practice, for instance, a "Conceive – Design" or an "Implement – Operate" stage. According to psychologists' statistics only a small percent of people are able to generate up-to-date ideas and work in design. At the same time, it is essential for any engineer to fully understand all stages of new technics and technologies' life cycle.

Equal mastering of all four stages of CDIO model by all engineering students is a great challenge even for world leading universities due to the psychological characteristics mentioned above. On a national level of engineering education system this is impeded by insufficient laboratory facilities for experiential part of the second stage and poor facilities for the third and the fourth stages.

The second stage – "Design" – usually starts with routine calculations. Numeric parameters of the technical system elements are defined. The structure of the system is normally designed on the "Conceive" stage. To a big extent most engineering universities provide infrastructure for the first (estimation) part of the "Design" stage, namely the software for automated design systems: CAE (Computer Aided Engineering) systems and, as their component, CAD (Computer Aided Design) systems. Application of PML (Product Lifecycle Management) systems used not only for the second, but for the later stages as well, is expanding. Learning of the mentioned systems (according to the industry sector) is included in programs of corresponding educational directions and majors.

Next to the calculations of the "Design" stage is the experiential part, whose infrastructure is usually developed rather weak. Systems of multidimensional simulation and, later on, relevant subsystems of virtual domain for professional activities can become an up-to-date solution to this problem [1].

Exploitation of the industrial facilities from partner enterprises – "consumers" of engineering universities' graduates – for the third and fourth stages is available in most cases only to those students, who take part in contractual development projects on request from those enterprises. Best facilities are provided for students at Educational-Scientific-Industrial Networks and Educational-Scientific-Innovative Networks that unite universities, research and development organizations, technological engineering centers and production enterprises, with an extensive attraction of staff and students for their work activities. However, life cycle of real products usually lasts much longer than educational process at university.

Full-scale execution of the third and fourth stages at Russian universities can be conducted with the use of professional virtual domains enabling fast-track imitation of a product life cycle. This stimulates development of these stages for different educational directions and majors.

The most troubling situation regards the "Conceive" stage. It is on this stage that the creative process of conceiving new structures for technical devises and systems is executed. With the societal transition to the fifth and sixth wave of technology, the demand for breakthrough unconventional high-tech solutions development is rising. Therefore, employers expect engineering universities' graduates to have the ability to generate innovative ideas. And students have to learn this. Current state of infrastructure for development of breakthrough solutions can be characterized as following:

Analyzing CDIO Standards, it appears that they basically represent a set of objectives specifying the main aim of CDIO: "to ensure engineering educational programs' content and effectiveness in compliance with current level of technology development and employers expectations". Stepping stones for achieving the main aim are given in a generalized manner. For instance, "Students engage in the practice of engineering through problem solving and simple design exercises, individually and in teams" (Standard 4); "The curriculum includes two or more design-implement experiences" (Standard 5); "Professional graduates work in industry, partnerships with industry colleagues in research and education projects" (Standard 9), etc. Slightly more precise methods are listed in Standard 8: "…Active learning in lecture-based courses can include such methods as partner and small-group discussions, demonstrations, debates, concept questions, and feedback from students about what they are learning…".

The most specific means of CDIO elaboration are stated in Standard 2 "Learning outcomes" as the CDIO Syllabus [3]. A set of achievement methods for the listed outcomes, both for the reduced (three decomposition levels) and for the full (four decomposition levels) versions, can be found in the academic literature as well as in the articles on CDIO experience of different universities from various countries. The expansion of the university society implementing CDIO Initiative enables gaining valuable experience, selecting best practices and exchanging them within the network. It is worthwhile to create a constantly evolving database of such practices.

At the same time, there are some learning outcomes among the CDIO Syllabus that imply controversial opinions within scientific, pedagogical and engineering communities. In particular, this refers to the addressed "Conceive" stage, to which the Syllabus 2 is dedicated: Personal and Professional Skills and Attributes including 2.1. Analytic Reasoning and Problem Solving; 2.4. Attitudes, Thought and Learning. Most of the subparagraphs of the 2.1. Syllabus are dedicated to problem solving (although there is an opinion that this could be done in a different manner). Some of subparagraphs are devoted to learning outcomes; and only one subparagraph covers the solution itself. Many agree that problem solving is a creative artistic act usually leading to tailor-made ideas, however, the essence of creativity and possibility of its algorithmization evoke controversial opinions. From one common point of view, it is impossible to teach creative thinking; it comes as an insight, an epiphany. Such attitude logically leads to inability of the majority of students to successfully elaborate the "Conceive" stage, and, inevitably, all of the later stages.

Along with that, an opposite point of view has existed since the ancient times underlining the possibility and feasibility of creative thinking formation. It is becoming more and more fortified with help of methodological and, in the past decades, programming tools. Nowadays, the widest recognition as a biggest achievement in methodology of inventive solutions generation has been given to internationally acknowledged Theory of Inventive Problem Solving (TIPS, TRIZ), created by Soviet scientist Genrich Altshuller (1926-1998) and, later on, developed by his students and followers. TRIZ theory is highly effective, since it is not just a set of methods, but a "development philosophy" setting equivalence between innovation creation and development of anthropogenic world under the laws of didactics incorporating constructive methods of overcoming development contradictions, which results in inventive solutions generation.

It is notable that TRIZ is not only a complex of methods corresponding with fundamental laws of didactics, but a constantly evolving and specifically structured database of various laws of nature – funds of phenomena: physical, chemical, geometrical, etc. Database of biological phenomena has been growing rapidly for the past few years. Development of psychological, social and other databases has started recently. It is not only the set of phenomena that makes databases valuable and significant, but the principles of its structuring that allow for its efficient use in inventive solutions development. These principles can and should be used when structuring new knowledge.

Nowadays, TRIZ is widely used by many leading transnational corporation for inventive solutions development. For instance, Intel Corporation, that has an Intel TRIZ Chapter division, states on its website that TRIZ technologies are "tracking millions of dollars saved". Samsung also has a similar division. The same methodology is actively applied by Boeing, Kodak, Procter&Gamble, LG, Western Digital, Motorola, Siemens and other companies.

Following CAD and CAM programs, CAE program class has been enriched by CAI (Computer Aided Invention) programs such as «Innovation Workbench», «Invention Machine Goldfire», «InnoKraft» and others, containing TRIZ methods, as well as phenomena databases. These programs are almost unknown in Russia, even though their predecessor, "Invention Machine", was created in former Soviet Union.

A number of universities using TRIZ in their educational practice for the purpose of updating students' ability to generate ideas is rising. Among such universities are: University of Oxford, Massachusetts University of Technology, Stanford University, universities from Europe, South-East Asia, South Africa, China, etc. Generally TRIZ distribution in different countries is initiated by expatriated or temporarily migrated specialists from Russia and other countries of the former Soviet territory.

Expanding implementation of CDIO system in universities of Russia – the motherland of TRIZ (together with other former Soviet Union countries) – creates new opportunities for TRIZ integration to CDIO. First of all, in order to comply with Standard 4, it is essential to develop a radically new course "Introduction to engineering" that would demonstrate essence of engineering, its scientific content, resource limitations (financial, ecological, social, technological, etc.), engineering problems on all stages from conceiving to utilizing, and levels of inventiveness in problem solutions (for example, based on Altshuller's 5-level scale). During the course conduction and its workshops and design projects, at least some students will have an opportunity to carry out the "Conceive" stage.

Russian universities have a significant advantage – existence of TRIZ pedagogy didactics invented in Russia that allows structuring scientific knowledge and learning of TRIZ methods in compliance with Standards 3, 7 and 8, and in integration with other disciplines: not only technical, but scientific and humanitarian. Engineering developments, namely the method of knowledge invention and the method of innovative projects [6, 7] conducted at Siberian Federal University and its partner educational establishments have disseminated this system to all stages of educational process. TRIZ pedagogy deepens understanding of disciplines, forms creator mindset, and complies with new ecological paradigm "Synergy with Nature". That is the reason why TRIZ pedagogy serves as basis for elaboration of educational technology in the context of sustainable development corresponding to the aims and objectives of the United Nations Decade of Education for Sustainable Development (2005-2014), supported by UNESCO, and the activities following the Decade [7].

Potential competitive advantage of CDIO introduction to the native engineering education mostly refers to the "Conceive" stage and incorporates availability of TRIZ specialists and didactic system of TRIZ pedagogy. This advantage does not only permit the development of a new "Introduction to Engineering" course, but provides teaching of various disciplines on different study years by method of knowledge invention ("reinventing" explored technical and other systems with the use of TRIZ methods), conceiving innovative ideas and inventions by inventive projects method of knowledge structuring within internships, design projects, scientific research projects and thesis projects, and effective application of CAI computer programs.

Aiming to comply with Standards 1, 2 and 4, regarding teamwork, it is essential to form project teams that include students with various skills, who would be able to: generate ideas, design, implement, operate project's life cycle, manage the project, provide marketing, etc.

Up to this date, Siberian Federal University (SFU), and former Krasnoyarsk State Technical University that is now a part of SFU, has gained sufficient experience in inventive solutions creation (conceiving) not only on the later years of study, but on the early stage of university education and pre-university education. Starting from 1994, high school students have been placing high or winning National Youth Scientific Forums on a regular basis. And they continue developing their projects and successfully present them on international forums once they enter the university. SFU students and university applicants team won a Big Science Cup of Russia in the "Step forward" program. Some of the latest achievements are: SFU future applicants' first place in the «Shustrik» competition organized by the Association of Innovative Regions of Russia (AIRR), second place diploma in "Baby Farm" competition of Skolkovo International Conference "Startup Village", "Best Invention of the Year" regional award-winning joint patent of SFU and its basic school – Krasnoyarsk school №10 named after academician Yu.A. Ovchinnikov – piloting the described methods. Numerous intensive summer schools of inventive-innovative profile in Krasnoyarsk Kray, as well as innovators clubs in national child centres «Orlyonok» and «Ocean», have been held according to the developed curriculum. A set of professional development courses for teachers of different educational levels and specialties, teaching them the knowledge invention and innovative projects methods, has been conducted at SFU. These courses were partly organized with support of grants from the Ministry of Education and Science of the Russian Federation and All-

Russian Fund "National Perspectives".

Thorough implementation of the CDIO system at Russian universities (and many foreign universities as well) takes time, therefore, it is viable to develop "road maps". Common features of such "road maps" can be as follows:

- Creation of Educational-Scientific-Industrial Networks, Educational-Scientific-Innovative Network, including technological engineering centers.
- Development of virtual environments for professional activity including subsystems similar to modern CAI class programs and in cooperation with PLM systems.
- Introduction of various disciplines on knowledge invention methods to the teaching process, and of innovative projects methods – to internships, design projects, scientific research projects and thesis projects.

Pursuit of these "road maps" shall lead to the development of innovative project model of the university that includes profound practice-oriented student training.

A full-scale implementation of CDIO International Standards permits development of engineers' systems thinking that is indispensable for innovative economy.

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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.

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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'

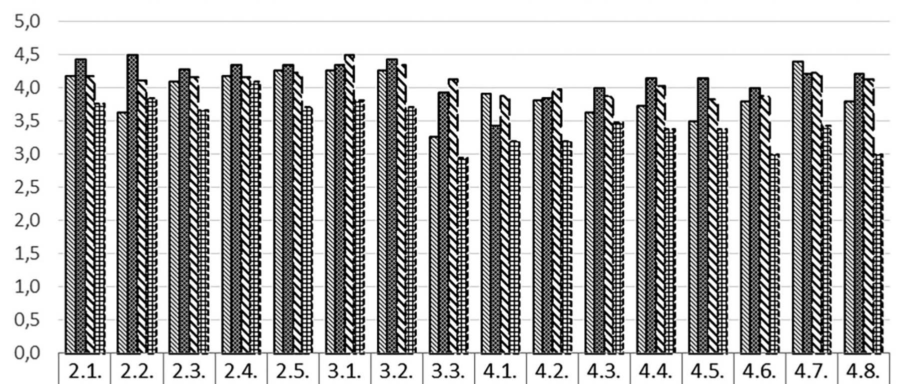
Table 2. Evaluation scale

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.

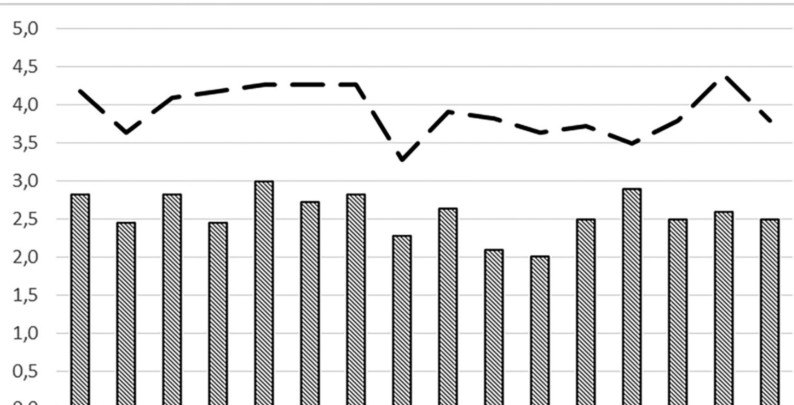
Employers found the closest approximation of the real level of developed

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

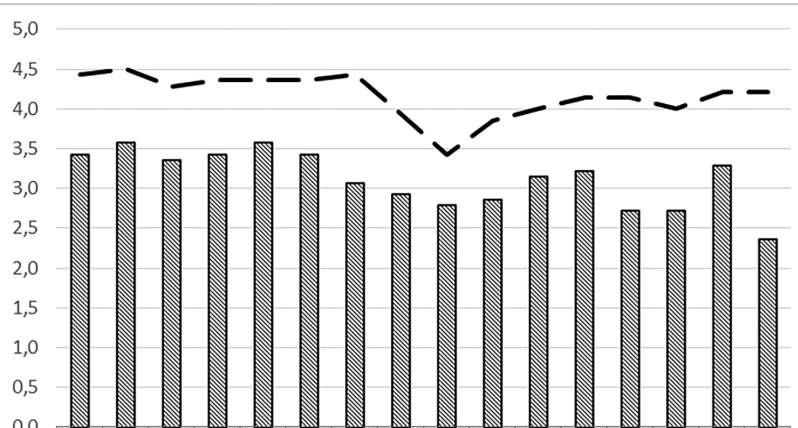
competence to the expected level of learning outcomes in implementing and operating electrical systems, professional ethics and responsibility. It is important to emphasize that employers also noted the high level of acquired communication skills in foreign language compared with apparently low level 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).

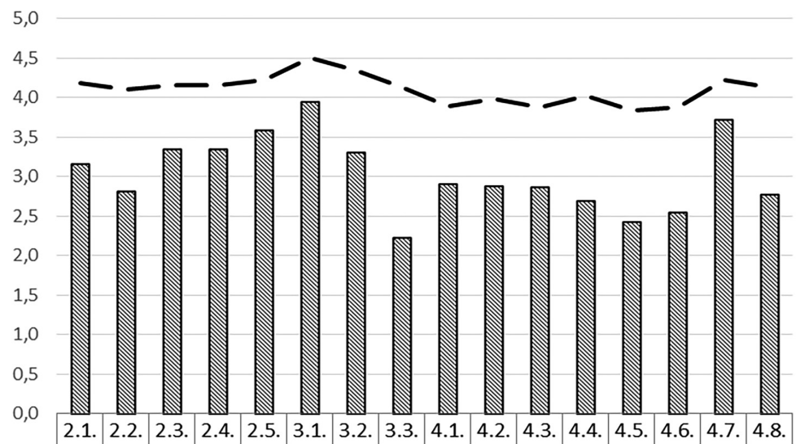
The conducted survey of the stakeholders' evaluation of acquired and expected learning outcomes at the educational programme 13.03.02

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



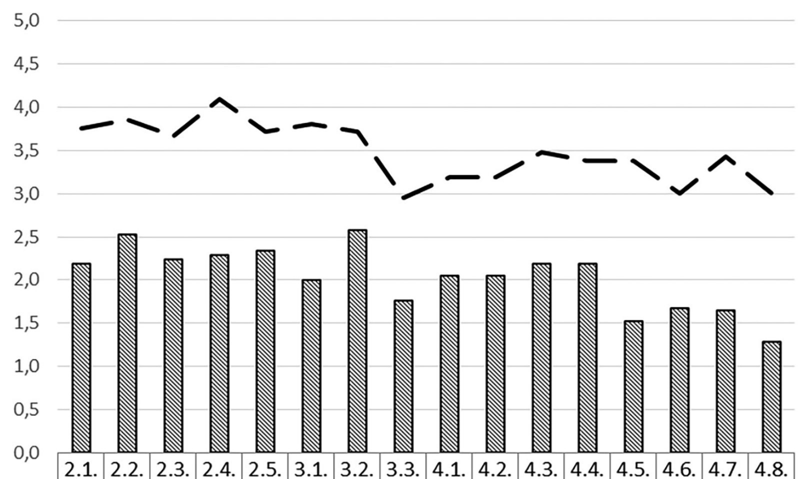
	2.1.	2.2.	2.3.	2.4.	2.5.	3.1.	3.2.	3.3.	4.1.	4.2.	4.3.	4.4.	4.5.	4.6.	4.7.	4.8.
Acquired level	3,43	3,57	3,36	3,43	3,57	3,43	3,07	2,93	2,79	2,86	3,14	3,21	2,71	2,71	3,29	2,36
Expected level	4,43	4,50	4,29	4,36	4,36	4,36	4,43	3,93	3,43	3,86	4,00	4,14	4,14	4,00	4,21	4,21

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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N. Kuptasthien

UDC 378

Integrated Curriculum Development in Industrial Engineering Program Using CDIO Framework

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N. Kuptasthien, S. Triwanapong, R. Kanchana

This paper shares Thai industrial requirements for new graduates entering real-life workplace and the development of an integrated curriculum using CDIO framework. The result from a questionnaire survey showed high needs for personal and interpersonal skills with strong industrial engineering background. These skills were integrated into courses in 4-year program.

Key words: CDIO, engineering education, integrated curriculum, curriculum development, industrial engineering.

Introduction

CDIO framework has been influencing the reformation of Engineering Education for the last decade. Founders of the CDIO framework are professors from world class institutes; namely, Chalmers University of Technology, KTH Royal Institute of Technology, Linkoping University in Sweden and Massachusetts Institute of Technology (MIT) in the USA since 2000. The key stakeholders of engineering education mentioned that the engineering students should be exposed to professionalism in their school through conceiving, designing, implementing, and operating. Those are the most important contexts of engineering professions [1]. In 2004, 12 CDIO standards were defined to distinguish a CDIO program. They serve as guidelines for educational program reform and evaluation, create benchmarks and goals with worldwide application, and provide a framework for continuous improvement [2].

Industrial Engineering Program at RMUTT

Rajamangala University of Technology Thanyaburi (RMUTT) has long been developed and has gained high recognition for its educational quality for over 30 years under the name of Rajamangala Institute of Technology (RIT). RIT with its 35 nationwide campuses became 9 Rajamangala Universities of Technology on January 18, 2005. Among the nine universities, its original main campus is called RMUTT. The university still maintains the original focus on quality teaching and the learning of science and technology and aims for high recognition from industries and organizations for its qualified graduates who are well-equipped with professional knowledge and practical skills. The vision is to produce professional hands-on graduates in the field of science and technology. Presently, RMUTT has 10 Faculties and 1 college of Thai traditional medicine. The university offers four levels of educational programs in various disciplines: diploma programs in vocational education, a bachelor's degree, a master's degree and a doctoral degree programs [3].

The Faculty of Engineering puts its focus on the development of engineers well-equipped with professional knowledge, skills, and the ability to apply the knowledge and skills in the working situations [4].

The programs offered are as follows:

1. Four-year bachelor's degree program in Engineering for graduates with a vocational education or grade 12 certificate (Science and Math). Both full time and part time programs include the following disciplines: Civil Engineering, Electrical Engineering, Mechanical Engineering,

Industrial Engineering, Electronic & Telecommunication Engineering, Textile Engineering, Computer Engineering, Chemical Engineering, and Material & Metallurgical Engineering.

2. A credit-transferred three-year bachelor's degree program in Engineering for graduates with a diploma in vocational education.

3. Master degree programs in Engineering for bachelor degree graduates of any fields. The programs include the following disciplines: Civil Engineering, Mechanical Engineering, Electrical Engineering, Industrial Engineering, Production Engineering, Textiles Engineering, Electronics & Telecommunication Engineering, Chemical Engineering, Materials Engineering and Agricultural Engineering

4. Doctoral degree programs in Electrical Engineering and Materials and Energy Engineering.

RMUTT has participated in Conceive, Design, Implement, and Operate (CDIO) Framework for Re-Thinking Engineering Education, Thailand supported by Temasek Foundation and Singapore Polytechnic. After one year of implementation, the CDIO framework has proved to be the most appropriate framework to produce hands-on graduates. RMUTT has been appointed as CDIO collaborator in the CDIO Worldwide Initiatives since March 2014. Out of 8 disciplines, Industrial Engineering and Textile Engineering programs are only two programs which fully implemented the CDIO framework.

Industrial Needs Survey

The on-line questionnaire survey was distributed to major employers of RMUTT graduates. The designated respondents were plant/factory managers, production managers, quality control, production planning & control as well as industrial engineers who have at least 3 years of work experience. The questionnaire had 3 parts: part 1 – industrial engineering responsibility in the workplace, part 2 – levels of expectation of proficiency, part 3 - general information of respondents. Of the 300 questionnaires, 212 were returned, resulting in a response rate of 71%. The Cronbach's Alpha equaled 0.979 which was higher than 0.7 yielding in accepting the survey reliability. The data received were statistically analyzed using the Statistical Package for the Social Sciences software application (SPSS). The statistical analysis is composed of percentage, arithmetic mean, and standard deviation.

Table 1 showed the result of the industrial engineering responsibilities in the workplace. From the score of 1 (least important) to 7 (most important), the Likert scale could be used to interpret the average score as shown.

The highlight of the survey was in part 2; when the respondents were asked about knowledge, skills and attitudes relating to CDIO knowledge, and skill sets. The 1 – 5 scores were used to indicate levels of expectation of proficiency for each component; 5 = to be able to lead or innovate, 4 = to be skilled in the practice or implementation of, 3 = to be able to understand and explain, 2 = to be able to participate in and contribute to, and 1 = to have experienced or been exposed to. Table 2 showed the result from the survey.

Fig. 1 showed proficiency expectation from the industrial group. Referring to the findings of Crawley [5] in 2002, the survey of faculty members, industries and alumni of MIT, there were similarities in the results. Personal skills (2.4), Teamwork (3.1) and Communication skills (3.2) were in those top 5 from both surveys where Enterprise & business context (4.1) and External & societal context (4.2) had the lowest expectation proficiency.

Integrated Curriculum Development

The 12 CDIO Standards address program 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),

Table 1. Industrial engineering responsibility in the workplace

No.	Responsibility	Mean	Std. Dev.	Meaning
1	Method/Time/Productivity Improvement	6.2217	0.98467	Most important
2	Quality Control/Assurance/ Improvement	5.9245	0.82838	Very important
3	Production Planning and Supply Chain Management	5.8066	1.07331	Very important
4	Product Design/Development	5.6840	1.18006	Very important
5	Manufacturing/Tooling/ Maintenance	5.3538	1.16925	Very important
6	Project Management	5.2642	1.27908	Important
7	Training/Technology Transfer	5.2311	1.30561	Important
8	Inventory Management	5.0566	1.22633	Important
9	Financial decision making, break-even analysis, investment	4.7358	1.33705	Important

and assessment and evaluation (Standards 11 and 12). Of these 12 standards, seven are considered essential because they distinguish CDIO programs from other educational reform initiatives. An asterisk [*] indicates these essential standards [3]. The curriculum development process involved with 5 the CDIO standards. The standards are listed below:

Standard 1. CDIO as Context*

Adoption of the principle that product and system lifecycle development and deployment -- Conceiving, Designing, Implementing and Operating -- are the context for engineering education.

Standard 2. CDIO Syllabus Outcomes*

Specific, detailed learning outcomes for personal, interpersonal, and product and system building skills, consistent with program goals and validated by program stakeholders.

Standard 3. Integrated Curriculum*

A curriculum designed with mutually supporting disciplinary subjects, with an explicit plan to integrate personal, interpersonal, and product and system building skills.

Standard 4. Introduction to Engineering.

An introductory course that provides the framework for engineering practices in product and system building, and introduces essential personal and interpersonal skills.

Standard 5. Design-Build Experiences*

In order to meet standard 1, the statement indicating that the Industrial Engineering curriculum 2015 has adopted CDIO as a context for industrial engineering education. For implementation of standard 2: RMUTT has defined its graduate attributes as stated in the university vision as "to produce hands-on graduates" who are ready for real-life work. The graduates' attributes are conformed to CDIO knowledge and the skill sets from CDIO Syllabus as shown in Fig. 2.

Standard 3: from the survey, the top 5 expectations from the industrial group requested for Teamwork Skills, Personal

Table 2. Mean and Standard Deviation of Proficiency Expectation by Industries

No.	Knowledge, Skills, Attitude	Mean	Std. Dev.
3.1	Multi-disciplinary Teamwork	4.1698	0.80839
2.4	Personal skills & Attitudes	4.0425	0.82788
1.2	Core engineering & fundamental knowledge	4.0236	0.74427
4.5	Implementing	4.0189	0.74122
3.2	Communications	3.9575	0.82788
2.3	System thinking	3.9198	0.8135
2.1	Engineering reasoning & problem solving	3.9104	0.74559
4.4	Designing	3.8962	0.79607
4.6	Operating	3.8962	0.7145
4.3	Conceiving & engineering systems	3.7972	0.72947
3.3	Communications in Foreign Language	3.7453	0.89296
2.2	Experimentation & knowledge discovery	3.6604	0.99655
1.3	Advanced engineering fundamental knowledge	3.6085	0.92492
2.5	Professional skills & Attitudes	3.4811	0.97096
1.1	Knowledge of underlying science	3.3255	0.78052
4.2	Enterprise & business context	3.2170	0.82617
4.1	External & societal context	3.1604	0.85028

Fig. 1. Proficiency Expectation by Industrial Group

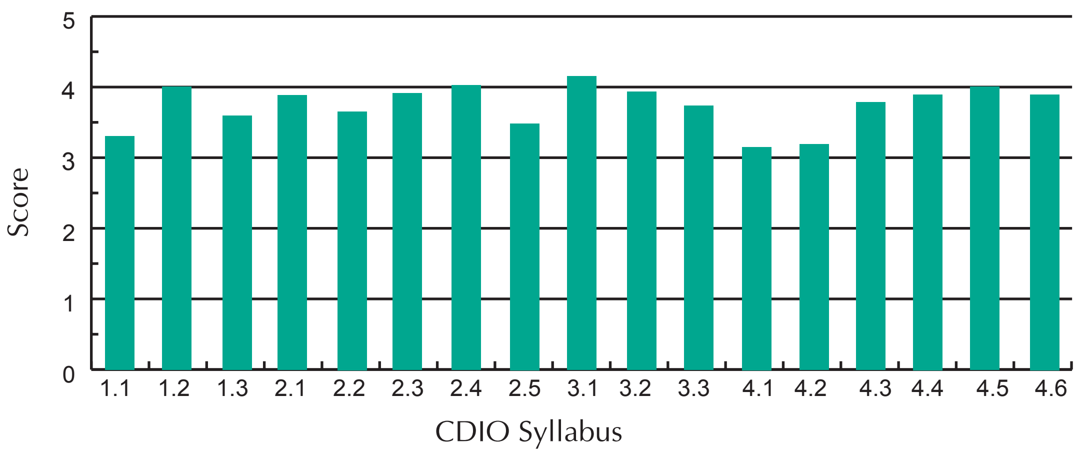
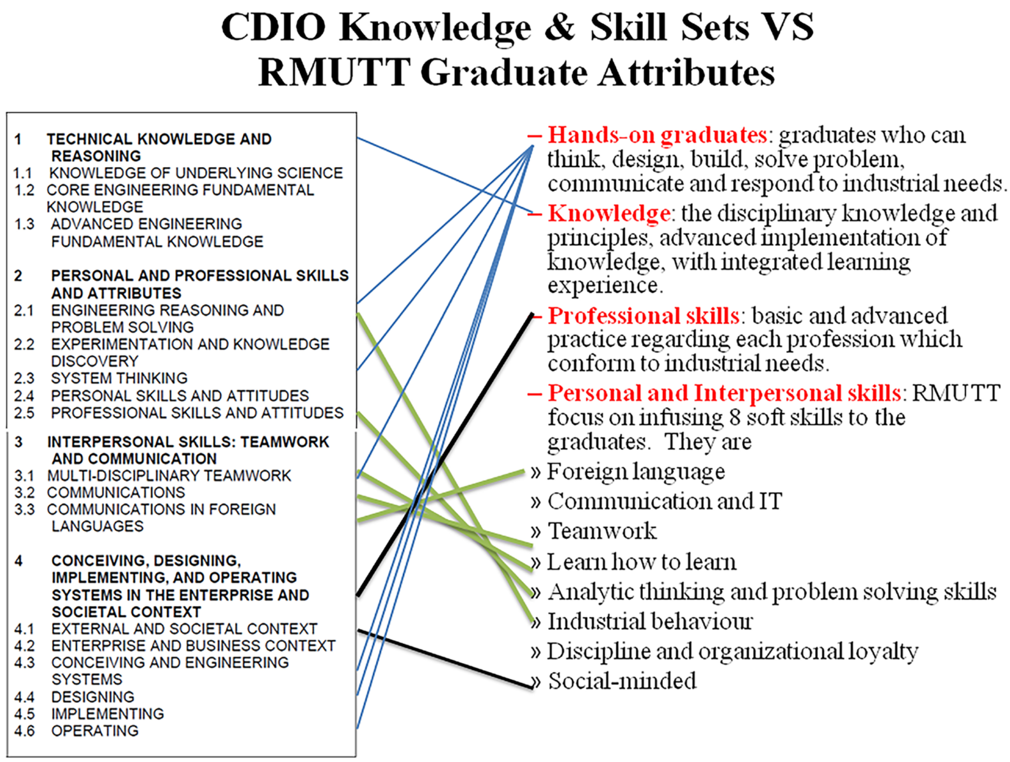


Fig. 2. CDIO Knowledge & Skill Sets VS RMUTT Graduate Attributes



skills & attitudes, Core engineering & fundamental knowledge, Implementing skills, and Communication skills. The gap analysis and skill mapping were analyzed by the program manager and department members. The full integrated curriculum is shown in fig. 3.

Teamwork skills (purple line with circle symbol), Personal skills & attitudes (blue line with hexagonal symbol) and communication skills (red line with rectangular symbol) were integrated into existing courses. The letter T=Teach means the skills will be taught to the students. The letter U = Use means the students will use the skills in that course. The letter A = Assessment means the teacher will assess the students on those particular skills. For teamwork skills, Basic Engineering Training and Computer Programming courses (semester 1, year 1) are offered to the student. The teacher will teach and will let the student use teamwork skills via class activities. Figure 4 shows the teamwork activity for the Computer Engineering course in which the students must build simple robot kits and program the robot depending on the task they receive. From year 2 to year 4, teamwork skills are integrated in IE Design & Build, Mini Project, IE Pre-Project, Co-operative Education, IE Project and Industrial Plant Design which allow the students to use teamwork skills and be assessed by the teacher. In addition, new courses: Productivity Management, Feasibility Study & Project Management, Design of Experiment and IE Laboratory aim to equip the student with teamwork skills and experiential learning. The students are expected to be able to form effective teams, manage and participate in them.

Fig. 3. Integrated Curriculum for Industrial Engineering Program

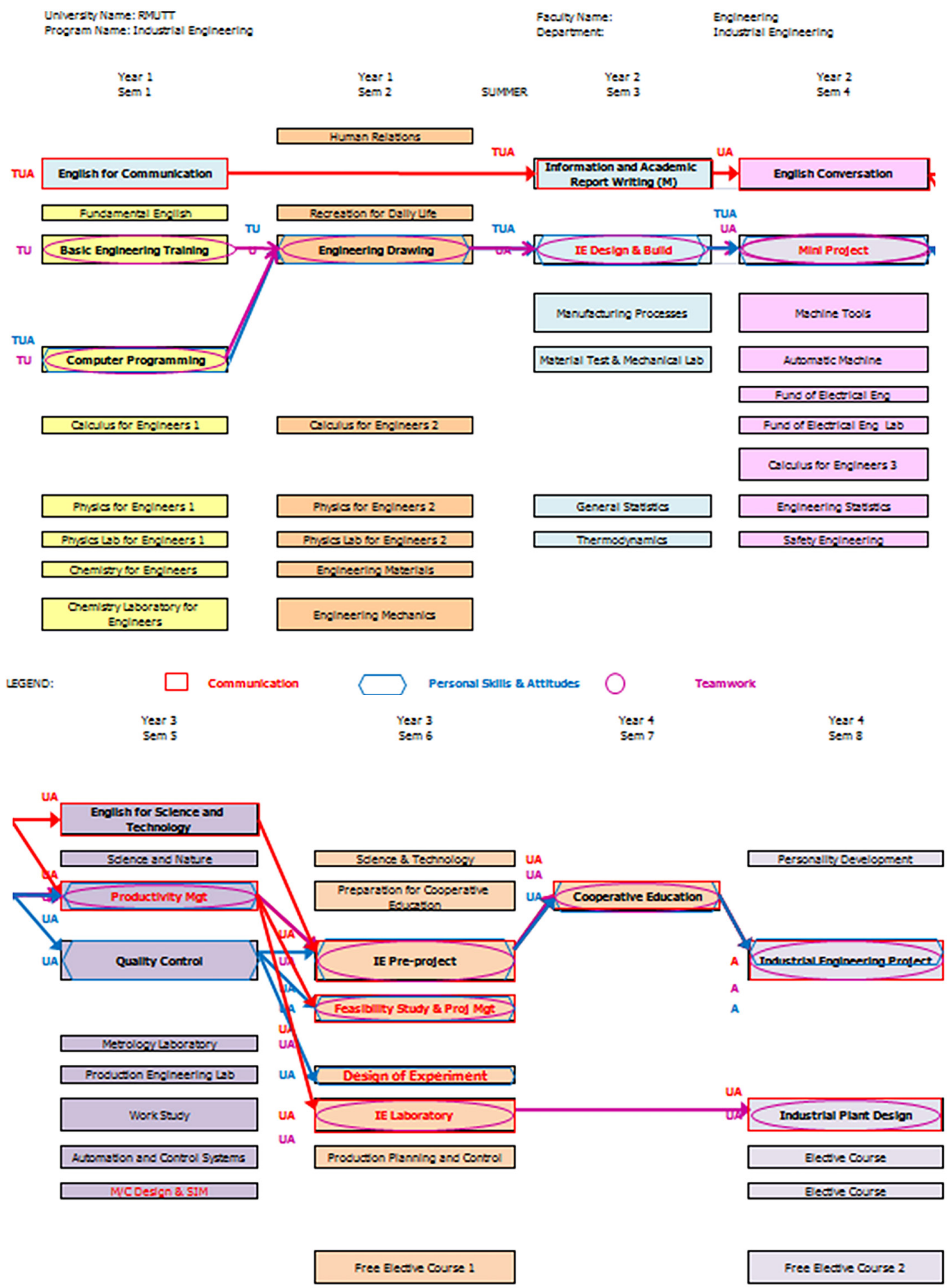


Fig. 4. Teamwork skills within the course «Computer Engineering»

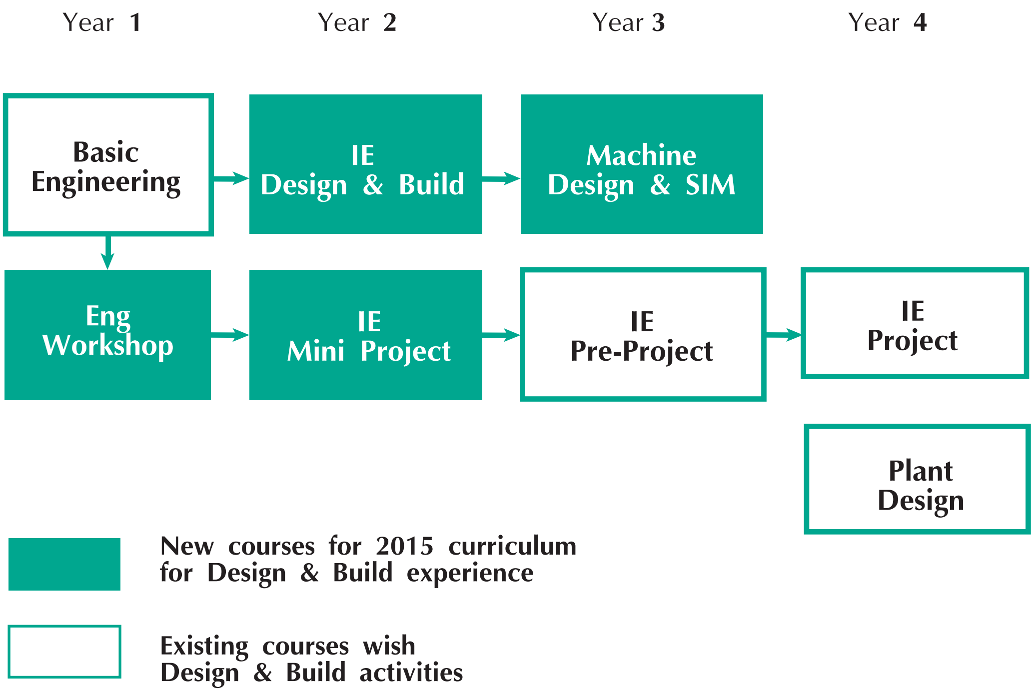
For communication skills, 3 courses of English and 1 course of report writing are offered as background. Furthermore in the study plan, the student will exercise and be assessed on their communication skills in the context of the industrial engineering profession in Productivity Management, Feasibility Study & Project Management, IE Laboratory, Pre-project, Project, Cooperative Education and Industrial Plant Design. Personal skills and are well integrated into both existing and new courses.

The existing course "Basic Engineering" plays a role as "Introduction to Engineering" which offers fundamental engineering practice as stated in Standard 4. Four new courses were added to enhance the implementing skills along with Design & Build experience (Standard 5) as shown in Fig. 5.

Conclusion

The developed curriculum is now in the process of stakeholder validation, academic council, higher education commission and the council of engineering approvals. The curriculum will be launched in August 2015. Other factors leading to the success in implementing the curriculum are faculty member enhancement in their professional skills as well as teaching skills. Reflections by the assessment at course level and program level will contribute to continuous improvement.

Fig. 5. New courses: Implementation Skills and Design & Build Experience



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UDC 378.1

Experience and Practice of Management Problem Solution at CDIO Implementation in University Education

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There have appeared a great number of management problems at universities first introduced CDIO ideology. Taking into account the fact that the ideology itself leads to critical technologies development in the current education system, solution of management problems is to result in significant changes in a university. The article lists and describes the problems solved in a definite university and the results.

Key words: managerial tasks, critical technologies, public-private partnership, project approach.

At present both in the world and in the country there is a situation of crisis in education both in general and in engineering education in particular. These conditions are observed at different levels of society and different institutions [1, p. 6-11]. Transition to competence approach and failure of education to measure new developed learning outcomes and the impossibility of manufacturers to develop professional standards have contributed to crisis, which, in its turn, has resulted in their recognition of the problem at the governmental level. For instance, during the summer of 2014, despite major efforts performed within 2 recent years, the top public officials arranged the meetings on problems of crisis in the engineering education and were charged with the task of solving them.

As a result, over the last years every university providing engineering training arrived at the decision of searching for ways to bailout. In this case the solution could be negative as well, i.e. the absence of crisis recognition. The key question to which the answer is sought for by the Ministry of Education and Science of the Russian Federation, Agency of Strategic Initiatives, Skolteh, leading universities and others: How to reform engineering education for real production? To answer the question, it is necessary to solve a number of management problems in the university in case of a positive decision in management and the crisis response measure committee: to determine definite outcomes of this job and ways of its measurement, define the requirements for entrants and ways of finding and attracting youth to university, determine and provide a new academic process technology for the results revealed, perform personnel selection and development for this technology. In fact, engineering universities received a well-based project management task. Its specificity consists in the approach that has been chosen in the university as anti-crisis. One of them, but not the only one, is the CDIO international ideology [2, p. 6-8]. The characteristics of such an approach are, on the one hand, its sufficient development and testing in the world allowing it to be technologically realized in separate parts of academic process, on the other hand, range and flexibility of ideology itself permitting it to be adjusted and used in different real-life environment of academic process in engineering training [4, p. 1418-1420].

At Siberian Federal University the crisis of engineering education was recognized at the management level several years ago. Hence, there started the search for a tool of engineering education development and foundations for its choice. CDIO ideology was accepted as one of the approaches involved in performance by the university authorities. Therefore, more than a year ago the university started four engineering major developments: Heat technology and heat engineering, Metallurgy, Software engineering, Informatics and computer engineering. In such a case a number of management problems mentioned above were solved at the university, management approaches found in our project can be applicable for their scaling in other majors and allow development of engineering education. Let us consider the solution of management problems mentioned above at the stage of international CDIO ideology introduction into the university. Such management problems and approaches to their solution are models for the system of engineering education of the country and can be performed at different universities.

Solving the first problem in defining educational directions for CDIO ideology implementation, we determined the criteria of their selection: it is necessary for management personnel of the major to have internal professional motivation and capacity to critically develop their activity; demand for graduates' labour at the market; presence of a definite employer. As a result, apart from direct choice of four majors, we got potential employer – participator of approach implementation and definite people capable of being "drivers" in the process. Hereafter, consistency of the chosen majors depends significantly on the employer's activity. The key point in the considered approach is not a unit management decision taking, but development of critical views with which one can perform the management of different syllabuses. Hence, the solution of the first problem on the choice criteria of an academic major can be used many times.

The next (second) problem was development of culture in CDIO ideology introduction activity in academic process of the selected majors. Obviously, this introduction approach as a project was chosen again. Perception of necessity and the possibility of the project approach itself for CDIO introduction management was spiral. On the one hand, this was required by the approach, on the other hand, due to its criticality the public cultural design of some experiments in educational practice conversion into the project was stimulated at the university. In this case the internal local acts were performed, project participators and their functions were clearly defined, resources and separate budgets were established etc. The crucial point here is awareness and registration of project priority developing education through their gaining the university status "Strategic project". Performing the development of activity into project we, taking into account great content-engineering differences of the chosen majors and employers' spectra, created the separate project in each major in addition to The Concentration Programs (CP) based on CDIO ideology [3, p. 6-8]. The four projects were common, united in the university; there were performance plans specified in each project in terms of their features, an information field devoted to CDIO, and expert-management activity.

The principle management issue at the university was resource allocation (staff, time, facilities and other) for CDIO implementation preparation. Therefore, projects themselves covered just that activity (preparation), control and expertise of which were performed during the whole academic year. Decisions of university administration were taken at the end of the year to admit CDIO to be introduced in definite syllabuses with new enrollment.

Thus, solving the second problem of management approach to CDIO introduction we chose the design of existing different approaches in science and education, developed four different projects united by common management, and performed the initial recruitment for this job. Then it was necessary to select the personnel and assess their work.

Solving the problem in personnel preparation for the project we defined the content, time, and principles of the process. The experience has shown the inconsistency of initially low level of teachers with the necessary content, absence of staff for working with teachers and the high intensity of such a job. As a result, for this task we had about 70 teachers involved in different forms of qualification upgrade. Among them – about 30 teachers took a year-upgrading course. The key task for the next stage is search for the personnel responsible for such upgrading courses and their assessment.

In the course of the problem solutions in development and the agreement of new results in the project team and the existing university system we came across emotional professional rejection of the approach by the essential part of university workers. We spent a lot of time solving this problem, involved the employers capable of reaching common grounds and engagement in the development of the new academic process, revealed the agreement of Federal State Educational Standards (FSES) and CDIO, and developed the management concept of self-refuse to accept a position and teachers' motivation to participate in the project. In solving the problem we failed to achieve the acceptance of content and new results by all the project participators. It was impossible within such a period taking into account the level of personnel preparation for such an activity. The work was prolonged for the next stage.

The next management problem was to design syllabus and Concentration Program based on CDIO ideology in the arranged major project teams and new obtained educational outcomes. The syllabuses underwent changes due to new disciplines, changes in existing disciplines, the arrangement of continuous project activity focused on a student's professional growth [5, p. 1]. The main result of the process became an assigned view of project participators on principles of syllabus design, its integrity and focus on the outcomes of every part, internal agreement of every discipline part [7, p. 46-48] etc., which is suggested by CDIO ideology itself:

- defining a real employer for the syllabus;
- establishing goals and requirements for a graduate together with the employer;
- division of those requirements into credits in terms of each requirement's significance;
- design of a competence matrix in years and modules with credits;
- development of a module syllabus.

Such an approach allows for public-private partnership. The results of public-private partnership are advantageous for all participators in a definite syllabus:

Company: training of students possessing professional skills and competence according to a company's requirements;

Development of personnel corresponding to the quality and structure of production demands; development of skills of future specialists' corporate professional culture; possibility to influence the content of the Concentration Program; shortening the adaptation period for conditions and the content of professional activity; upgrading courses for company employees in the educational-academic environment with the involvement of university teaching and research personnel; an increase in a company's competiveness;

University: extension of possibilities in joint publications; involvement of highly-qualified manufacturers in the academic process; efforts of the participators in research, engineering, and project-design developments; investments of companies in the development of the university's material and technological resources; upgrading the courses of university workers in research and production spheres; support of university workers participating in the program; an increase in university

graduates' competiveness;
Student: job placement after graduation; learning specialist disciplines in demand at production; development of corporate professional culture skills; fostering advanced professional skills; possibility of participation in research, engineering, project-design developments; support of students by the company; shortening of adaptation time to the conditions of company production. Hence, public-private partnership became a base for syllabus development in the educational sphere.

In the course of planned syllabus implementation in terms of CDIO ideology management problem of methodical aid preparation was solved for the subjects of the first year on the basis of active training. The main technique was project-based learning, but it was not the only one. To the best of his/her professional preparation for the performance, every teacher made an attempt to plan such classes. Some elements of the new methodical aid were tested in the real academic process [7, p. 155-156]. The question of project activity monitoring and project learning outcome measurement in terms of the outcomes specified in the Concentration Program remained undetermined. These are the issues of the next stage.

At the end of the year while implementing CDIO ideology in the academic process we solved a number of university management problems pertaining to positioning the approach itself as a priority at the university, choice of majors for ideology implementation, selection and preparation of managers, teaching staff, development of employer's active attitude to the academic process from the time of its design, preparation of methodical aids based on active training techniques, material and technical support, improvement in students' enrollment. The criteria of syllabuses availability are as follows:

- The Syllabus is: to be clearly focused on practice through the outcomes of CDIO 2, 4 performance; contain project activities via multi-leveled integrated projects and projects within a discipline or definite activity. The outcomes are expressed through: a list of competences agreed upon with the employer; determination of significant competence indicators with employer; determination of hierarchy and place of competences over four years of study; determination of modules (disciplines) forming competences (competence matrix); coordination of modules (disciplines) in the syllabus through program annotation (didactic units) and place in the syllabus with CDIO standards; development of module integrated syllabus; development of academic schedule with reference to project activity; development and approval of Concentration Program; mutual approval of concentration program with employer; signing of an agreement with employer on his participation in academic process; and the presence of the discipline "Introduction to engineering".
- Personnel are: to be enough in quantity to deliver learning within the syllabus with required professional upgrading in CDIO, take an active part in CDIO seminars, with definite roles and responsibilities in students' project supervision, involve auxiliary educational staff for arrangement of laboratory facilities in project activity.
- Methodical support. The outcomes are expressed through: selection of project themes, performance requirements (project passport), role in the academic process; development of curricula for the first academic year with the learning outcomes according to CDIO standards; preparation of teaching materials for modules (disciplines) of the first academic year using active teaching techniques (%); methodical aids for the discipline "Introduction to Engineering";

availability of textbooks for the first academic year.

- Enrollment of school-leavers should be arranged with definite students and planned outcomes. The outcomes are expressed through: plan of CDIO enrollment; preparation of advertising material; carrying out activities with entrants possessing the experience of project, research and other extracurricular work; availability of entrants' database with their achievements valuable for CDIO.
- Working place should meet the requirements for planned first year projects. The outcomes are expressed through: necessary working space for the whole syllabus; working space for the first year; preparation of class rooms for the first year of project work; preparation of facilities for project work; preparation of consumables; access to electronic resources for the first study year.
- Project monitoring. The outcomes are expressed through: regularity of working sessions on project (yes/no); the number of involved teaching staff into project meetings who can implement CDIO.

In fact, the work performed in university with CDIO was traditional for the project approach:

Initiation: initiation of the request for project as a critical technique of engineering education transformation on the part of university authorities with the support of Skolteh; appointment of project managers and selection of the project management team in Concentration Program 4.

Planning: development of project management plan for a year; development of the project content; selection and preparation of executives; taking a decision about further project realization.

Hence the planned work should be as follows:

Performance: performance of the fourth-year project; monitoring the fourth-year project; correction of the project due to the monitoring results.

Project completion: introduction of the project into continuously realized approach.

Therefore, based on the preceding year's results the university authorities are to take decisions on the following issues: models of the strategic project (admission of all four syllabuses to realization or admission of some syllabuses based on all CDIO ideology requirements with the result presentation to the Ministry of Education and Science, CDIO Initiative etc., development of the definite CDIO principles in some syllabuses), on the bases of syllabus preparation analysis for CDIO performance the management models of CDIO university project performance were revealed.

As options for project implementation management the experiene of other Russian uiversities were considered, such as a selected management in a separate department, setup of a separate new structure within the existing university structure with CDIO functionality or realization of CDIO practice in the existing institution. When analyzing the experience – special attention was paid to the results of each approach and potential risks. From the point of view of risk minimization the decision to create special departments in the institutes was taken.

In future it is necessary to come to the following solutions: transformation of the management system through transition to syllabus management; shift away from the syllabus discipline approach to integrated modules with common outcomes; non-linear schedule of academic process using labour coefficient, but not hours in the form of quality assessment of students' syllabus proficiency; development of an engineer's motivation and intercultural competences in the course of the new subject "Introduction to engineering" including humanity subjects; teachers – "agents" of engineering education innovation, creators of new teaching teams.

Hence, choosing the tools for solution of the management problems we have tested the approach to preparation of academic process using innovation teaching experience and found solutions valuable for the theory and practice. Due to their universal character those solutions can be used in other syllabuses and engineering universities after adapting to the conditions. The results obtained set new tasks for us.

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UDC 37.022:37.032:378.1

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CDIO within the System of Continuous Education "From School to Higher Education Institution (HEI)": Stage "Conceive" at School

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The article describes the system of methods to reveal potential intellectual giftedness of pupils. The system is designed by the authors and based on TRIZ-pedagogy. Within this system the pupils, who are regarded as future university applicants, are related to innovative HEI (higher education institution) through innovative project activity. The authors have analyzed how appropriate the system is to introduce stage «Conceive» at school preparation for HEIs implementing CDIO system.

Key words: Conceive, TRIZ, applied dialectics, TRIZ-pedagogy, knowledge invention, innovative projects, CAI programs.

Making engineering education applicable to solving practical tasks is a topical problem for engineering institutions all over the world, so, many institutions have tested the technologies which may be effective to handle the problem. The task in common caused the similar results but different in terms of the stage of completion. CDIO initiative developed at Massachusetts Institute of Technology became the most complete and holistic system of standards. Many universities which applied similar approaches became the participants of CDIO world initiative. Many universities disseminated these approaches among the schools thus involving pupils into scientific and project activities under the supervision of both university and school teachers. Upon university education completion, these former school leavers got more opportunities to become promising specialists.

Classical example is the Russian scientific and social program for pupils and youth «Step into Future». The authors of the article participated in the program as scientific supervisors for many years, became prizewinners of national conferences and exhibitions, took part in international youth scientific forums. This is the program of leading Russian HEI: Bauman Moscow State Technical University, Lomonosov Moscow State University, Mendeleyev University of Chemical Technology of Russia, Moscow State University of Design and Technology – Kosygin Institute of Textiles and others. The idea of the program is to find gifted youth in all Federal districts of the Russian Federation.

To increase the educational level of applicants, the methods reveal potential giftedness (the term is introduced in the Concept of Giftedness [1]) were applied at leading regional universities, such as Krasnoyarsk State Technical University (KSTU), which in 2007 was included into Siberian Federal University (SFU). KSTU together with schools of Krasnoyarsk and Krasnoyarsky Kray, as well as the Institute of Continuing Professional Development of Educational Staff, began to use TRIZ-theory by G.S. Altshuller [2] (TRIZ is Russian abbreviation from «theory of inventive problem solving») and apply didactic technology of TRIZ-pedagogy [3]. The authors of the paper were supervisors of pupil's projects, organized continuing professional development courses on TRIZ-pedagogy for school teachers. As a result, the teachers, who were the most successful in doing the courses, ensured support for pupils to win the prizes of different categories at national conferences and exhibitions. During more than 15 years of TRIZ-pedagogy development and application at schools, it was amplified with some new methods. Along with the method of creative tasks [4], the authors of the paper contributed to development, testing, publication and introduction into the courses of continuing professional development the methods as follows: method of knowledge invention and method of innovative projects [5, 6]. These two allow applying TRIZ-pedagogy to all types of educational process, supplementary education, and scientific and technical creative activity of youth (STCAY).

TRIZ-pedagogy developed by the authors is relevant to modern standards of school education, including the systemic activity approach, and improves some essential meta-subject skills.

Over the past years the technology of substantial educational development (SED) [7] based on TRIZ-pedagogy has been introduced by the authors of the paper in collaboration with Scientific and Educational Centre of UNESCO (university department) «New materials and technologies», Siberian Federal University (SFU).

The method of innovative projects (which combines the project methods by J. Dewey and W.H. Kilpatrick with TRIZ by G.S. Altshuller) served as a basis to relate intellectually gifted applicants (i.e. those with revealed potential giftedness) to innovative HEI through innovative project activity. Under innovative project activity we mean the activity of pupils, whose results are innovative ideas on solutions to complicated problems and inventions. Doing an innovative project under the supervision of university scientists and teachers in collaboration with school teachers, the pupil, who is a future applicant, knows that to continue his or her project and reach success, he or she should enter the particular university and the particular department, where the project supervisors work.

The method of innovative projects has been tested many times at both creative studios of schools and youth intensive schools within the special sessions. The studios were established at Academician Ovchinnikov school № 10 and school № 82 in Krasnoyarsk, which are basic schools of UNESCO department «New materials and technologies», SFU. The studios work according to the schedule during the academic year. The innovative projects of pupils from studios were awarded with different prizes at regional and national conferences and STCAY exhibitions. Scince 1999 pupils worked out their projects within intensive schools: summer intensive schools in Krasnoyarsk, sessions of different profiles in national child centres «Orlyonok» and «Ocean», child health and education camp «Yunyj Neftyanik» of «Surgutneftegaz». In collaboration with «Orlyonok» book «Youth Intensive Schools of Innovative Era» was prepared and published [8].

In 2009, within the session of Zvorykin Project Forum «Seliger» a grant by National Fund «National Prospects» was awarded to project «Pupil's Creativity on the basis of TRIZ»; the money was spent on continuing professional development courses for teachers and publication of the book [6].

In 2013, the first patent «Protective system of the sportsman» was granted to school № 10 and SFU: the authors are scientific supervisors, pupils and students of SFU. There are other applications for patents being prepared at the moment.

CDIO being implemented and supported by Strategic Initiative Agency in Russia, it is reasonable to analyze the ways to provide «connecting link» of gifted applicants with universities, in particular, with those departments where CDIO is being implemented.

Within the system of such «link» new ideas are generated by applicants, which is relevant to the first stage of CDIO – «Concieve» (stage of reflection and planning, according to Standard 1), and primary elaboration of constructions, schemes and algorithms takes place, which is partially relevant to stage «Design» (stage of designing).

The particularities of «link» model suggested by the authors in comparison with classical ways to provide STCAY are content and methods of «Conceive» stage. The compliance of the model with CDIO and Syllabus standards is stated as follows:

CDIO Standards [10]:

Standard 4. Introduction to Engineering.

Working on innovative projects, future applicants get basic knowledge of TRIZ, which is considered to be the most effective technology of ideas generation all over the world. Today, TRIZ is taught at several leading universities, including Massachusetts Institute of Technology, where CDIO was developed, and there are researches on application of CDIO and TRIZ in common. Thus, future applicants study the important block of «Introduction to Engineering» in advance, being involved in engineering through solving problems.

Standard 6. Engineering Workspaces.

The space is broadened through employing facilities of schools, supplementary education centres, child centres (within intensive schools), computer classrooms, as well as centres of youth innovative activities and centers of prototyping established in several regions, where models and patterns may be designed. It is possible to provide the efficient use of the above-mentioned facilities applying CAI programs, such as «Innovation Workbench», «Invention Machine Goldfire», «Tech Optimizer».

Standard 7. Integrated Learning Experiences.

The methods of innovative projects and knowledge invention mentioned above are implemented: they incorporate TRIZ in disciplinary subjects, foster the learning of disciplinary knowledge simultaneously with personal and interpersonal skills, and product, process, and system building skills.

Standard 8. Active Learning.

The methods of innovative projects and knowledge invention are active learning methods engaging students directly in thinking and problem solving activities.

Standard 10. Enhancement of Faculty Teaching Competence.

The courses of continuing professional development for teachers of different types and education stages have been implemented and are being continuously enhanced.

Standard 11. Learning Assessment.

Assessment criteria measure innovativeness of solutions based on a five-level scale by G.S. Altshuller, the author of TRIZ. These criteria made it possible not only to compare innovative ideas form different fields and determine achievements within separate sections but also to provide overall ranking of participants at scientific competitions and conferences. The method of assessment was conducted at different final conferences within intensive schools, as well as multidisciplinary Olympiad «Young Innovators» hold by SFU.

CDIO Syllabus [11], Standard 2, CDIO learning outcomes:

1.2. Core Fundamental Knowledge of Engineering.

TRIZ methods being applied in transnational corporations and leading universities all over the world, prove the principle importance of fundamental knowledge of core engineering at the time of transition to the fifth and sixth technological modes.

2.1. Analytical Reasoning and Problem Solving.

TRIZ contains well-developed intellectual instruments of analysis and problem solving: laws of existence and system development, methods to overcome technical and physical contradictions, standards of contradiction elimination, algorithms of inventive tasks solving (today, that is ARIZ-85V, Russian abbreviation from «algorithm to solve inventive tasks», other algorithms are being intensively developed).

2.3. System Thinking.

TRIZ contains universal «intellectual instruments» of system analysis and synthesis, including «nine-screen scheme of talented thinking» – system operator (SO)).

2.4.3. Creative Thinking.

TRIZ is conceptually a method of creative thinking, based on fundamental dialectic laws of anthropogenic and non-anthropogenic worlds development: not only divergent thinking, which «steps aside» from stereotypes, but also convergent thinking, which «steps towards» innovative problem solutions.

2.5.3. Proactive Vision and Intention in Life.

TRIZ makes it possible to provide more accurate foresight (medium-term foresight), which is admitted by the prominent foresighters (for example, S.B. Pereslegin uses the system operator), as soon as it helps to foresee quality changes in different anthropogenic systems on the grounds of fundamental development laws. Sometimes it is possible even to combine the forecast of a solution with the solution itself. Based on applied dialectics, i.e. TRIZ going beyond the scope of anthropogenic systems, the explorations on man's intention in life are being conducted, where man is considered as a subject of world development.

4.1.7. Sustainability and the Need for Sustainable Development.

Based on TRIZ-pedagogy in collaboration with UNESCO, research and development of didactic education system are provided to ensure sustainable development [7, 12].

4.2.6. New Technology Development and Assessment.

Fig. 1. Mayor of Krasnoyarsk E.Sh. Akbulatov at city STCAY exhibition is being declared about patent «Protective system of the sportsman» received by school № 10 and SFU

TRIZ is a new technology of development (laws, methods, standards) and assessment of innovative solutions (five-level scale).

4.7.1. Identifying the Problem or Paradox.

In TRIZ there are effective methods to determine contradictions and identify «operational conflict zone».

4.7.2. Thinking Creatively and Communicating Possibilities.

The methods of innovative projects and knowledge invention based on TRIZ contribute to development of creative thinking in accordance with algorithms correlated to world development laws.

4.7.3. Defining the Solution.

Defining the solution of a problem is based on the notions of «ideal system» (IS) and «ideal final solution» (IFS) with «intellectual instruments» of TRIZ being applied.

4.7.9. Inventions.

In the process of «link» system development, more and more patentable solutions are found (for example, [9]).

To conclude, the developed system of «link» of intellectually gifted applicants to innovative universities through innovative project activity based on TRIZ is in compliance with a number of CDIO standards and CDIO Syllabus expected learning outcomes, is considered to be hands-on and thus, might be suggested to CDIO community as a system of pre-university preparation.

Fig. 2. Winners of «Shustrik» competition organized by Association of Innovative Regions of Russia (AIRR): N. Bezrukikh and Ye. Ilyasova, pupils of the 7th grade of school № 10 of Krasnoyarsk, are presenting the project on utilization of «litter islands» in the ocean «Clear Island» at Baby Farm, Startup Village conference in «Hypercube», Skolkovo

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S.I. Osipova

UDC 378.1

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 DIC 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

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).

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.

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 practical project activity attained by the students in the course of professional training.

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L.B. Jensen

UDC 378

Students as Agents – Connecting Faculty with Industry and Creating Collaborative Projects

Technical University of Denmark
L.B. Jensen

Collaborative projects between partners in the building industry and students constitute important means for addressing more advanced parts of the CDIO Syllabus 4. In this paper an existing internship program is revised in order to enhance collaboration between industry and faculty/students and perform as a vehicle for addressing challenging parts of the CDIO syllabus.

Key words: industry involvement, design process, integrated learning experience, system design, multidisciplinary design project, industry collaboration, innovation.

INTRODUCTION

The technical University of Denmark embraced the CDIO program as one of the first Universities. It was a top down management decision to choose the CDIO syllabus as backbone for developing the engineering curriculum. The initial years concerned implementing the basics:

- developing learning objectives that match the syllabus and work within the 12 CDIO standards;
- mapping the progression in competence matrices;
- developing Design-build projects.

After the initial years, attention was given to the more complex parts of the CDIO program such as Syllabus 4.1.-4.4 Conceiving, designing, implementing and operating systems in the enterprise and societal context. Syllabus 4.1-4.4 is closely connected to a long line of other CDIO syllabus focus points concerning professional, communication, personal skills – and of course with technical knowledge as the starting point. Working explicitly with the enterprise and societal context of the engineering program thus came in late.

In the following the process of developing a model for direct student-industry collaborative design and development projects in the framework of CDIO is presented.

METHOD

Student involvement in the design of the industry related educational activities is demonstrated and the results are presented.

RESULTS

BACKGROUND

A 5 month internship period in the Architectural Engineering B. Eng. program was for a decade placed in the 5th semester. Its purpose was to enhance professional engineering attitudes early on in the students' curriculum and by this enable the student to choose a specialization for the remains of the curriculum and aid the transition to an actual job after the 7th semester.

Implicit was also that the internship program was meant to serve as a way to maintain the link between faculty and the building industry by means of mandatory visits by faculty to internship companies. However these visits were too rare.

Having the CDIO syllabus in mind, an inquiry to see if more could be gained from the internship period was set forth. Could the internship period be made to add to a controlled progression in CDIO skills, instead of being viewed as a kind of 5 month break during studies? Could the internship period be a starting point for innovation projects between industry, faculty and students?

ENTERPRISE AND BUSINESS CONTEXT 4.2

The assessment of the internship period was always based on three assignments: a 'logbook' (a record of daily events), an 'internship-company-report' and a so called 'special report' on a self-chosen technical – scientific subject.

The internship company report was changed into having objectives addressing syllabus 4.2:

4.2.1. Appreciating Different Enterprise Cultures

4.2.2. Enterprise Strategy, Goals and Planning

4.2.3. Technical Entrepreneurship

4.2.4. Working Successfully in Organizations (1).

The new approach prescribes that after just 2 weeks in the company the students describe the organizational structure in the company and from what the company earns a profit. This is described in the 'internship company report'.

The sharper focus and the early deadline for this report has changed the report into a kind of tool for meeting the objectives of syllabus 4.2 instead of a dreary obligation handed in by the end of the internship period, which was the order during the previous decade.

The 'special-report' was also altered in order to address the CDIO syllabus 4.2 An idea to make the students agents for finding out the innovation potentials and development interests of the internship enterprises came forth. This demanded that the students should understand 'their' enterprise and the market quite deeply and extensively.

The newly developed approach involves a meeting before starting the internship period and one during the period, where students are presented with the task of looking for design- and development projects within 'their' internship enterprise. These company preferences – as perceived by the students - are now what determine the choice of subject for the 'special report'.

The criteria for the choice of subject:

The internship company should find this particular subject so interesting that they would be willing to invest a minimum of, monthly, a one hour meeting with the students after ending the intern period. This means that the company should be willing to continue developing and designing together with the students after ending the internship period within the framework of the subject.

DESIGNING 4.4

The largest step in making better use of the internship period in the curriculum is concerning design processes. These are placed high on Bloom's Taxonomy(2) and when adding industry collaboration it is a great challenge. Getting ideas for projects from industry is not extraordinary, but explicitly aiming at creating real design- and development projects between industry and students is a completely different matter.

It was also decided that this 'active integrated learning experience' with industry should be for all the students in the program, the best and the worst. It could thus be a mandatory feature. Spring 2014 the first round of these new design and development projects took place.

During the previous decade, 6th semester mandatory CDIO Integrated Learning Experience projects existed in the program. It was scheduled to lead up to the final thesis project and the topics of the projects were outlined by faculty. In reality that meant that the topics for the 6th semester project were derived from the realm of research with a tendency to repeat the same projects year after year. The topics chosen by faculty were presented in a project pamphlet, for students to choose from.

It was thus interesting to observe if the new projects topics 'harvested' from the internship companies would be a lot different from the ones faculty provided.

The actual 'harvesting' of innovative, industry collaborative project ideas were organized as follows:

- After having pinpointed a project or topic within the internship company, the student will write a report with a literature survey or 'state of the art' survey. This replaced the report where the topic was chosen by the student.
- During a workshop just before the start of the 6th semester and just after the end of the intern period, the students present the harvest of ideas via power point shows to faculty and each other. They range the level of company interest (meaning how many hours the company will invest in meetings and supervision). At the same time faculty present at the event try to compose groups of potential faculty supervisors for each design project ideas.

The task is made even more complex because the students should have their specialization in mind: the project should also serve the further development of individual disciplinary core engineering competences.

The result Spring 2014, was two main project topics:

- 'Holistic Refurbishment': Urban and building transformation of 1970's housing developments viewed as a whole.
- 'Health Care': design of the ideal hospital ward.

Under the main frame of 'Holistic Refurbishment', were topics such as: financial models for refurbishment, structural calculations in refurbishment projects, local drainage of rainwater, social transformation of housing developments from the 1970's, wind conditions in urban spaces, solar mapping as tool for designing urban spaces, simulation of indoor climate and energy consumption.

'Health Care' framed topics as: facade engineering and daylight/lighting design, evidence based design theory, accessibility, and infection retardant ventilation systems.

The setup was initially not planned to be interdisciplinary. Fortunately it ended up being it, and thus addressed the syllabus 4.4. precisely.

MAPPING OF MODELS FOR COLLABORATION WITHIN THE STUDENT GROUP

The interdisciplinary character of the projects mirrors how industry actually works. In that sense it is of course natural that the students would point in that direction.

However there were no precedents for a multidisciplinary project like that in the department and it was again decided to use the students as agents and survey what they would point to as a valuable way to structure the work process within the student group.

4 models were outlined from which students could choose from and comment on. They were asked to choose the model that aligned with the design and development processes they had experienced in their internship companies.

The 4 Models were.

The result of the survey was a preference for model nr. 3. It is the model with an extra 'design loop' in the process which also mirrors an industry development process. The clear ownership of specialization in this model and precise borderline between specialization and multidisciplinary design project is a choice that could also be found in real life industry.

The assessment of this preferred project-process is: 1/3 based on the report, 1/3 based on the 'extreme' design project and 1/3 on the multidisciplinary 'compromise' design proposal.

MAPPING OF INDUSTRY/ UNIVERSITY COLLABORATION MODELS

A survey among the students was made in order to identify the best model for collaboration between students, faculty and the industry partner. Again the students were considered to be the experts because they knew the companies well in contrast to the university faculty. The students could choose from 4 models (that had come forth during the second workshops discussion) and were asked to choose the model that

Fig. 1. Model 1.

Students develop 2-3 person sub-groups that work on separate technical reports. Students participate in an ongoing design process from day 1 and work on the same design and development project all together from the start.

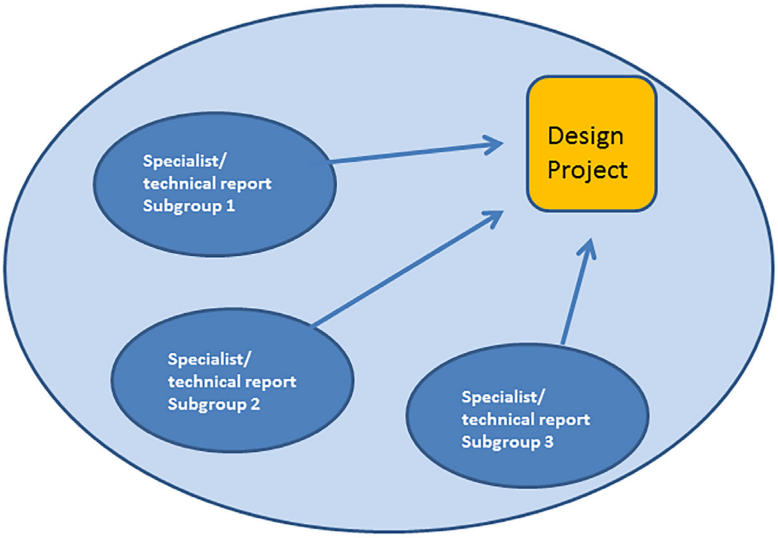


Fig. 2. Model 2.

Students develop 2-3 person groups that each work on chapters in the main groups' mutual report. After the delivery of the mutual technical report the main group all work on the same design project together.

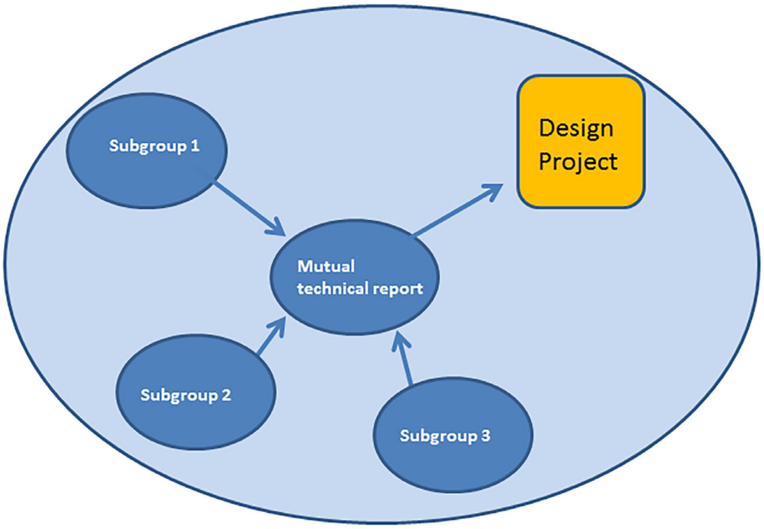


Fig. 3. Model 3.

Students develop 2-3 person groups that work on the reports. After handing in the report, students develop an extreme design proposal based on their groups' special focus on the mutual topic and present these projects at the mutual interim presentation.

Finally all sup-groups develop a multidisciplinary design project, where all the extreme solutions merge into one supposedly perfect compromise.

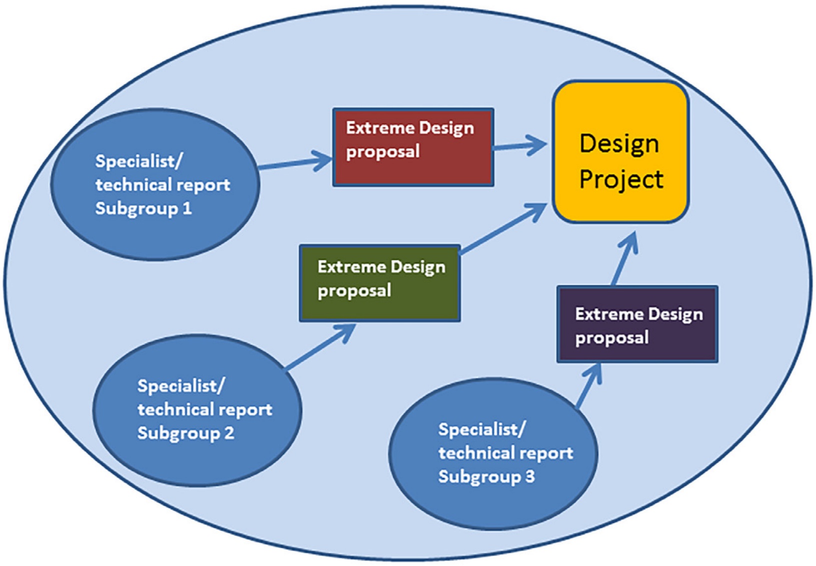


Fig. 4. Model 4.

All students in the main group work on a mutual technical report and design project together.

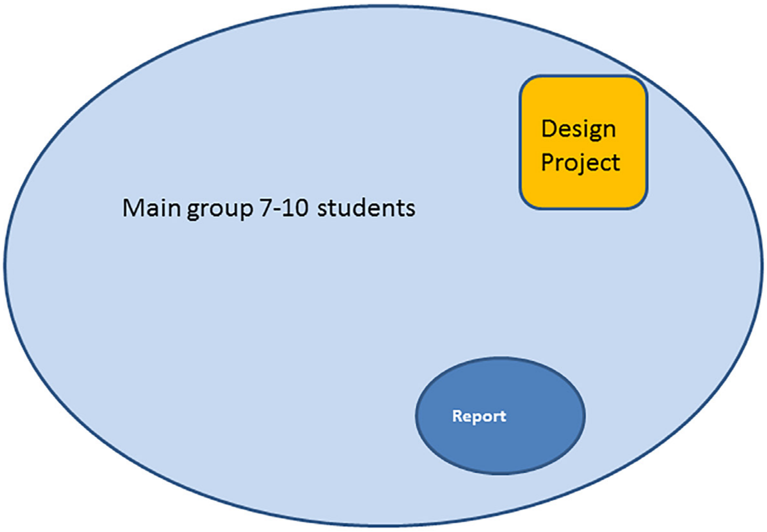
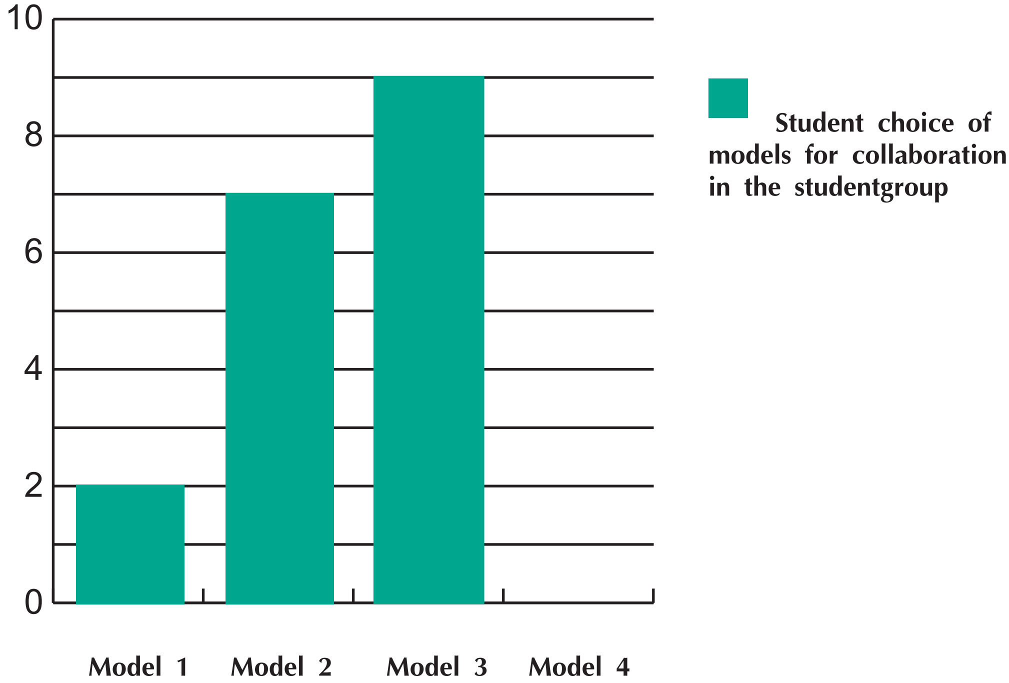


Fig. 5. Result of survey where students were asked to choose the model for collaboration that at best mimed the process in the industry.



would suit their internship company best.

The result of the survey was a clear preference for model number 2. This model both allowed for the simplicity of collaborating with few large stakeholders that because of their size held different specialist knowledge within them, but at the same time a door was kept ajar if a student had an industry contact from the internship company that he or she really wanted to be part of the project.

MATCHMAKING BETWEEN STUDENTS, FACULTY AND INDUSTRY

From the survey, a prioritized list of internship companies was made, linked to each of the two topics. At the same time a list of faculty supervisors was attached.

Concerning 'Health Care', there was a very positive response form the first-priority industry stakeholder who immediately started working on outlining the project.

Concerning the second theme, 'Holistic Refurbishment' it proved to be more of a challenge. Difficult questions came up: can a state financed university contribute to an ongoing competition involving many companies and thus creating possible imbalance? Obviously not. Finally an agreement with a company that had already won an entry for a competition that none of the other stakeholders had interest in was chosen.

Concerning faculty supervisors, at least 3 different were needed in order to facilitate the broad, interdisciplinary perspective, challenging the cost-effectiveness of the supervision.

From top: Example of Technical Report on wind measurement, wind tunnel and solar simulation. Then 'Extreme Design' viewed from only the point of wind specialists. Below; final proposal with solutions from both indoor climate specialists (solar shading), structural

Fig. 6. Model 1.

Supervision meeting every second week, interim critique every 6 weeks, company participates in final presentation.

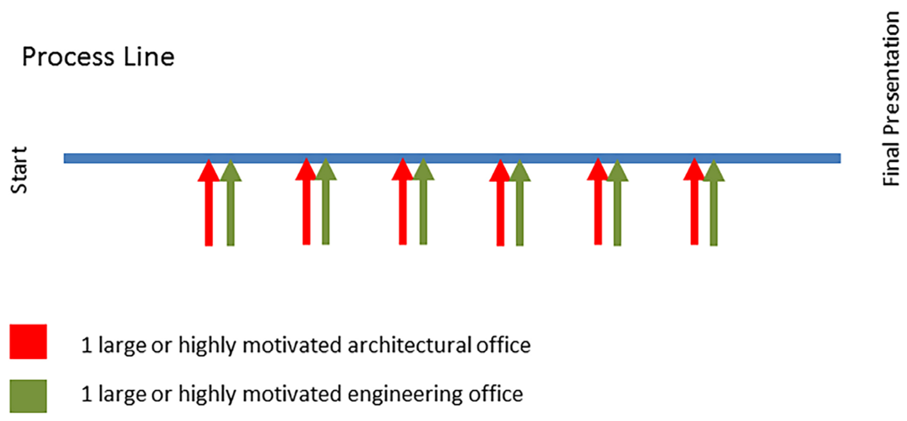


Fig. 7. Model 2.

Few large companies are principal but smaller companies or individuals can be invited to interim presentations to supplement with special focus or because students want them as supervisors.

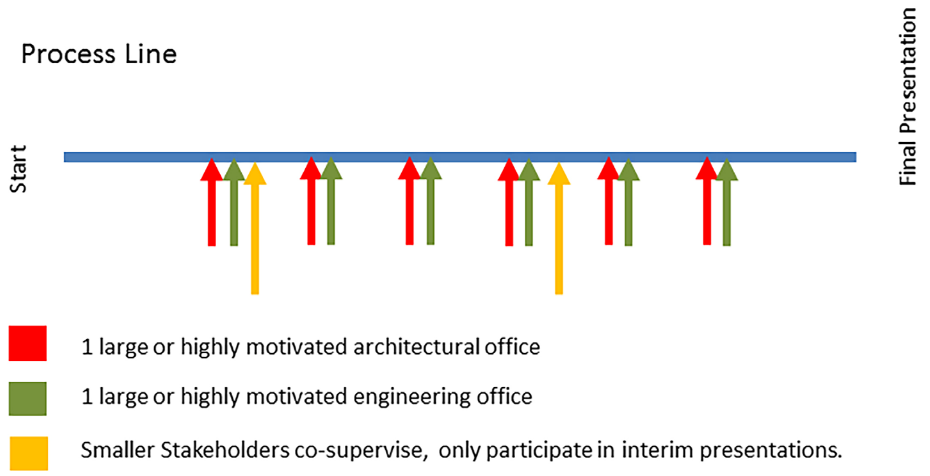


Fig. 8. Model 3.

All subgroups in the main group have their own company supervisors from many different companies, which all participate in all meetings and interim presentations as well as the final examination.

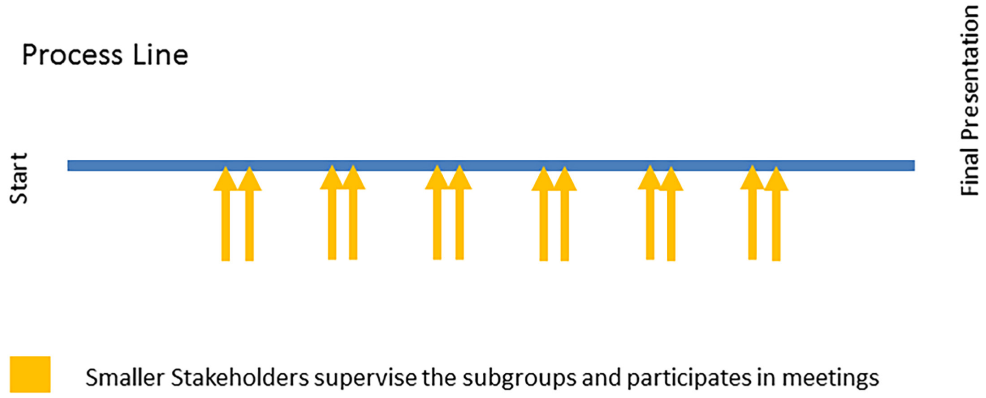


Fig. 9. Result from student survey.

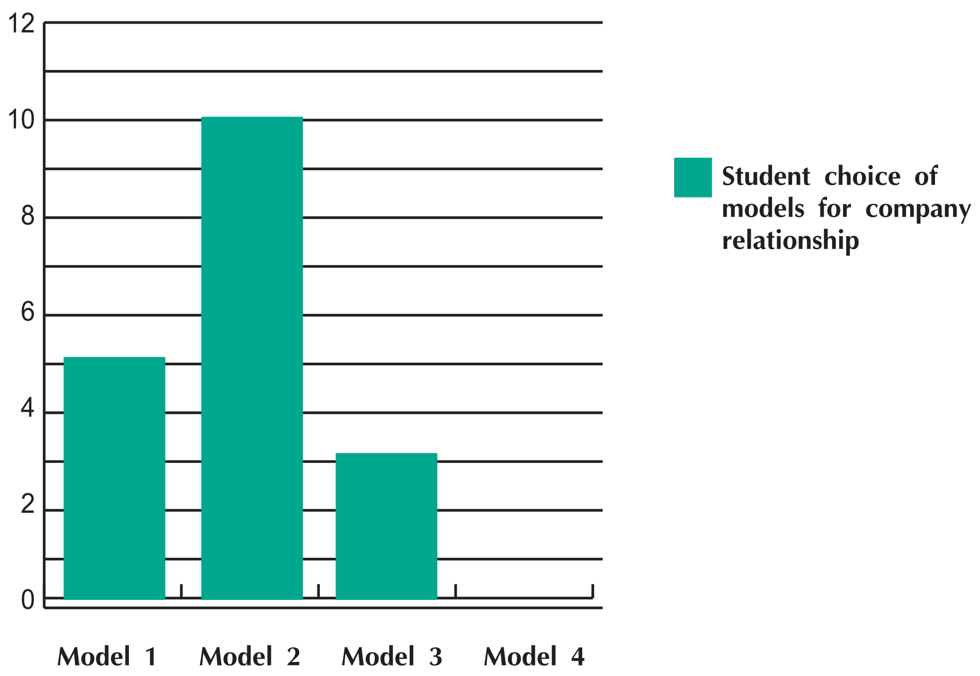
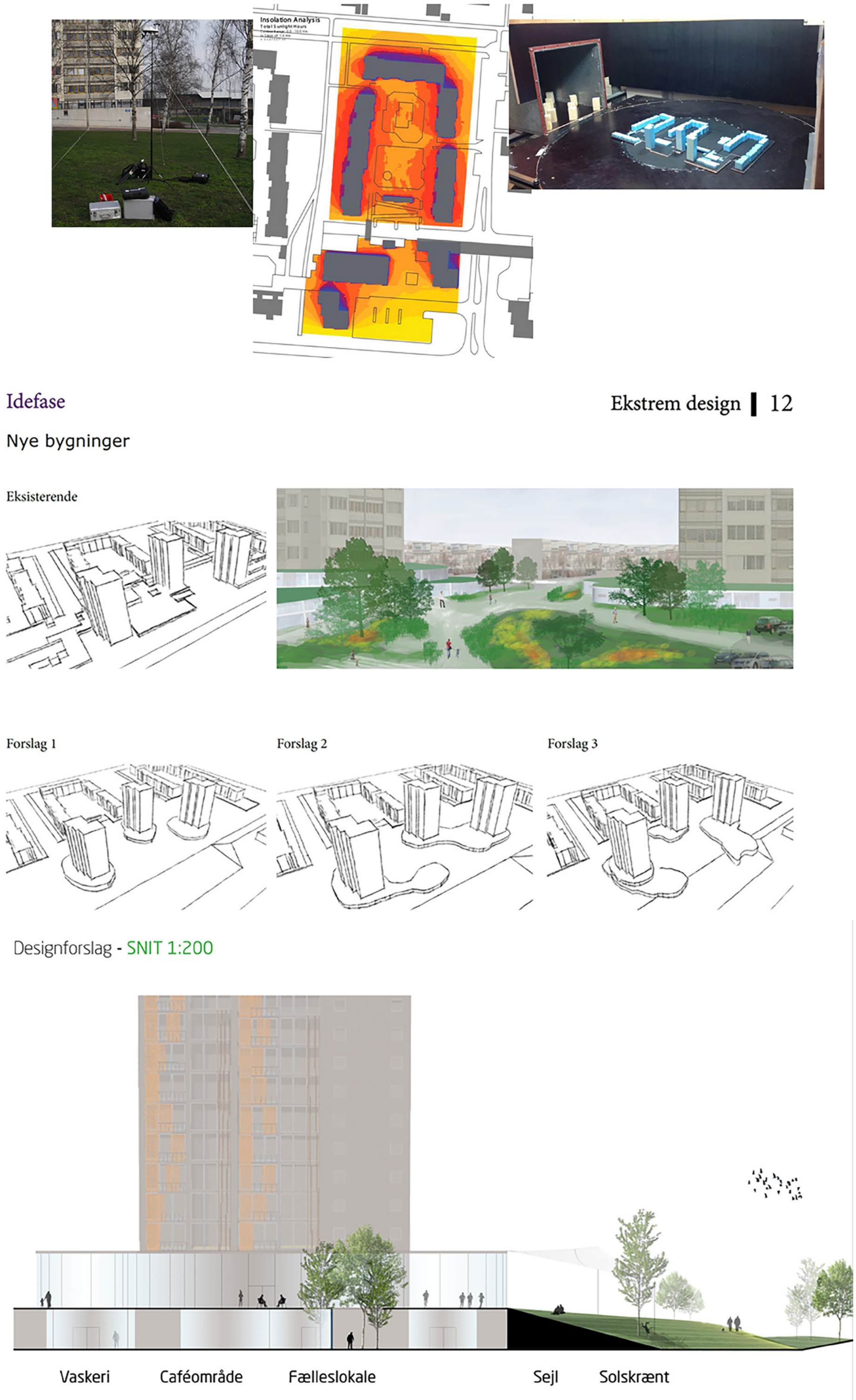


Fig. 10. 'Holistic Refurbishment'.



engineers (the structure of the lower floors are altered to allow more transparency and public facilities) and the wind specialists have added a glass pavilion and a solar sail where the turbulence is most severe.

CONCLUSION

The 2 topics that were chosen were not in the faculty made pamphlet of suggestions for projects. There was a refurbishment project proposal but not with the multidisciplinary urban approach attached.

The Health Care topic was new to faculty.

The strategy of letting students perform the role as agents for both coming up with relevant new project topics for the CDIO Integrated learning experience and for developing a project process proved to work.

Topics of high relevance for the industry had completely been overlooked by faculty researchers. The multidisciplinary character of the topics was also aligned with the demands in the industry and new to faculty.

The costs for supervision will probably increase because a number of supervisors are needed to cover the topic. Interestingly, the supervisors have to be called in not only from the Department of Civil Engineering but from other departments on campus. However it might turn out that the supervisors are needed for a shorter time and the students can profit from each other and work more independently or can make use of industry supervisors.

The 2 project topics developed in the process met the target of system design (CDIO syllabus 4.4.).

It was possible to create industry partners for students' post internship, real design and development projects by making use of the knowledge student gain of the potential of the enterprises, during their internship period.

DISCUSSION

Hopefully, the view to real innovation and development projects might create interest amongst faculty for engaging directly in the internship program in terms for visits to the companies. The motivation of university researchers to work with the practical realm of internship programs is a challenge. However, there are new winds blowing in terms of research funding programs that demand close collaboration with industry and favor multidisciplinary approaches. This is for instance the case with the EU horizon 2020 program. (3)

Viewed in this perspective internship visits might be an eye opener to faculty and help them create the necessary industry contacts in order to apply for horizon 2020 etc.

Most national policies tend to focus on innovation as a central platform for future societal development in Europe, and this might also motivate researches. The linkage between internship companies by means of the 6th semester CDIO integrated learning experience might be a hub for real innovation projects and thus attract the attention of faculty researchers.

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UDC 378

Project Activities in the Development of Engineering Thinking

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The article discusses the problem of educating a next generation engineer, who is able to think in terms of process. The particularities of engineering thinking being analyzed, the project activities are considered relevant to develop engineering thinking. The discipline «Introduction to Engineering Design» is proposed as an element within the system of project-based education provided at the Siberian Federal University in accordance with CDIO international initiative.

Key words: engineering thinking, project, project-based education, CDIO.

The emergence of new work types causes the need for specialists who are able to think in terms of process, set the goals and then shift them when several alternatives should be considered or when the circumstances have changed. From year to year, the character of changes in engineer's responsibilities becomes more and more distinct: from solving certain professional tasks to solving the problems and managing the projects.

Today, a successful engineer is an engineer with systemic thinking, which allows the specialist to view a problem from different perspectives thus identifying it in general and to determine the ties between the problem elements [1].

Within the process of project management, one not only solves actual problems but also develops individual qualities such as engineering thinking. To detail the term of "engineering thinking", it is necessary to determine the notion of "thinking" which is an umbrella term here.

Thinking is the highest stage of cognition and comprehension of the world through theories, ideas, and human goals. Being based on feelings and perceptions, thinking overcomes their boundaries and gets into the sphere of supersensible and intrinsic world ties, in other words, in the sphere of world laws. We substantiate the claim of the scientists that thinking reflects invisible ties due to practical activities, which are tools of thinking. Thinking is connected with the brain work but the ability of the brain to operate abstract ideas is developed through gaining practical skills, studying language, logics, and culture. Thinking is embodied in different forms of supersensible and practical activities which summarize and keep the cognitive experience of people. Being the object of different scientific research, thinking is studied by almost all sciences. Thinking is the source and the tool of intrinsic human existence.

Many philosophers determined thinking as an essential characteristic of a human being. Thus, Descartes affirmed: "I think, therefore, I exist". As a method of cognition Descartes suggested the method of doubt that means that we should doubt everything whether it seems to be natural or supernatural. However, Descartes insisted that the method of doubt is applicable to find out the scientific truth while to understand the matter of thing or events in every day life, it is enough to use true or probable knowledge.

Spinoza determines thinking as a way the thinking substance acts and consequently interprets the notion of "thinking" as follows: to define thinking, it is necessary to explore the way the thinking substance acts and then compare and contrast it to the way unthinking substance does (exists and moves) [2].

Practical experience obtained from human activities contributes to emergence of different types of thinking.

For instance, logical thinking is a historical type of thinking based on the laws of identity and the consistency of arguments [3].

Technical thinking is stipulated by technical knowledge, speculation on activities results and endeavor to simplify the process of production.

Strategic thinking is directed to the goal of thinking, which is based on the forecast of the future. "I rush to the place where the puck will be but not to the place where it was several instants ago" – said Wayne Gretzky, a famous hockey player, and this was a motto of Steve Jobs as well. According to Kenichi Ohmae, strategic thinking is creative and active, it is an ability to produce dynamic ideas and goals. Strategic thinking is systemic observation plus the ability to detail the goal plus opportunity to get trustworthy and sufficient information.

Creative thinking is an ability to identify the problems and solve them using unconventional methods, therefore, one obtains something new, original and unique in terms of history and society [4].

As for "engineering thinking", we agree with the opinion of scientists, who define this phenomenon as a special type of thinking developed and revealed in solving engineering tasks. Engineering thinking allows finding quick, accurate, and original decisions for the tasks which are caused by needs for technical knowledge, methods, and skills and aimed at the design of new technical facilities and the development of new technologies. Engineering thinking is structured as follows:

- technical thinking, that is an ability to analyze content, structure, configuration and operation principles of technical objects under varied conditions;
- constructive thinking, that is designing the model of task solution, which is based on ability to combine theoretical and practical knowledge; exploratory thinking, that is a set of abilities, such as to identify a new constituent within the task, to compare the task with those of distinguished types, to give reasons for one's actions, interpret results, and make conclusions;
- economic thinking, that is reflection on quality of process and activities results in terms of market demands, so, an engineer is supposed not only to possess profound knowledge of the specialty but also to be able to present his or her potential and implement the activities results [5].

The problem of engineering thinking development stipulates the necessity to explore the particularities of engineering thinking.

The phenomenon of "engineering thinking" is the object of exploration in many sciences: philosophy, psychology, pedagogy, humanities and technical sciences.

The solutions of creative engineering tasks have been analyzed, it is possible to claim that the foundation of engineering thinking rests on creative imagination and fantasy, "multiscreen" systemic reflection on knowledge, technical creativity, which allows operating the process of ideas generation.

What should engineering thinking be like? Which types of thinking should it comprise? Engineering thinking should be based on highly-developed imagination and include various types of thinking: logical, creative, theoretical, technical, special, as well as practical reasoning and eye-mindedness. The most important ones are creative thinking, technical thinking and eye-mindedness.

Previous researches conducted by psychologists and educationalists (E. de Bono, S.M. Vasileysky, N.P. Linkova, V.A. Molyako, N.M. Peysakhov, K.K. Platonov, Ya.A. Ponomaryov, A.F. Esaulov, G.S.

Altshuler, M.M. Zinovkina) showed that the most important characteristic of creative engineering thinking is its consistency.

Engineering thinking is systemic technical thinking which allows viewing the problem from different perspectives and analyzing the ties between its elements. Engineering thinking makes it possible to observe the system, the supersystem and the sub-system, the connections between and inside of them, moreover, to see past, present and future of all three systems. In other words, engineering thinking should be "multiscreen": the more "screens" a student observes, the more original and simpler solution will be suggested. The characteristic feature of "multiscreen" observation is the ability to identify and overcome technical contradictions as well as physical contradictions hidden inside, and intentionally generate ideas, which are paradoxical and heretical in terms of formal logics.

The following abilities are considered characteristic for engineering thinking: the ability to identify technical contradiction and initially direct one's mind to the ideal solution, when the basic function of the object is performed, so to say, on its own, without any expenses on energy or resources; the ability to specify such a direction of the thought that is the most promising in terms of technical system development; the ability to cope with psychological factors and deliberately intensify creative imagination [1].

Another characteristic feature of engineering thinking is the intention to submit the idea, which has been intentionally generated, to engineering study, i.e. to implement the idea into a real project on technologies development, facilities design etc.

As a result, the global task of a technical institute is to develop systemic creative engineering thinking in order to use the bulk of scientific and professional knowledge on different technological processes in the most efficient way.

One of the most promising ways to solve this task is to introduce project-based learning aimed at internal and professional development of personality through intensive involvement into the planned activities.

Firstly, project activity is a link between the theory and practice in education. Secondly, this type of activity allows operating the whole technological cycle of production.

Project is an original process comprising a complex of activities with the effective and termination dates being coordinated and operated to reach the goal which meets definite requirements such as terms, costs and resource limits.

Any project possesses a set of characteristics. These characteristic features have been identified, one can define this or that type of activity as a project one:

- temporariness: any project is limited in time, which does not refer to its results though; so, if there are no effective and termination dates, the activity is considered an operation and may last any time;
- original products, services, results: the results of any project are original outcomes (results, achievements, products); otherwise, the enterprise becomes serial production;
- consistent development: any project develops in time and passes through definite stages planned in advance, while the design of project specification is restricted to its initial content.

The technology of project education is a complex of methods, processes, and educational materials, which are used to organize project education, as well as a set of activities, operations, and methods to get the project results which meet definite quality, content, and expenses requirements (term of implementation, facilities rent etc.). The requirements, in their turn, are stipulated by the stages of science, technology and society development in general.

Project activities are considered

important in terms of pedagogy if their aims are:

- to get profound technical knowledge and practical skills in definite specialty;
- to develop the skills of designing and operating new products and systems;
- to understand the importance and strategic significance of scientific and technological development of the society;
- to acquire the knowledge on the chosen profile/specialty.

Students' interest in project activities is stipulated by project feasibility and its importance for particular individuals: the project matter should be connected with solving a realistic task which results in clear and tangible outcomes, whatever the degree of complexity and level of education are.

Development of engineering thinking is stimulated by mastering technologies which are in demand and which are successfully applied in modern companies. Another promotive factor is the possibility to explore project technologies at different stages of the whole cycle: reflection and identification of the task, possible solutions overview and analysis, suggestion of original solution, implementation, testing, preparation of report documentation, defense of results, and, if possible, application of the results, with raising the requirements from project to project.

High qualification of project managers (teachers and academic staff), who are experienced in real projects, as well as mutual work with companies, which, if possible, participate in projects, and employment assistance for graduates are the factors to motivate all participants of project activities. The motivation is caused by mutual interests.

Teamwork as well as short-term practical research or application tasks in the process of education develop the project skills which can be applied in hands-on production projects.

The results of the project are represented in the project design passports, analytical reports and public defense of projects to which the third party interested is invited.

Every student can participate in a project due to different degrees of complexity for the student to choose:

- Basic level projects. During the first and second years of bachelor's program projects are supposed to provide students with basic knowledge and to develop basic cultural competences such as project work technologies, project activities management and self-management, conventional ways of performing results, project results documentation in accordance with applicable laws and regulations. The most important requirement to projects is for the results to be applicable to solving engineering problems or tasks.
- Advanced level project. Here there are SSRPs (Student Scientific Research Projects), in which the degree of complexity is increased, scientific research is considered to be an essential part, scientific novelty is an important requirement and the solution is to be original.
- Practical training and work experience internship for most of the specialties may also be project-based. They may become either a project or a part of the project, for example, a stage of collecting data, studying technologies or exploration of work environment.
- Graduate qualification work. The result of the project is the solution of an engineering problem which should undergo external evaluation (reviewing).

Project-based learning has been successfully introduced in "Metallurgy" education program provided at Siberian Federal University in accordance with CDIO international initiative [6]. From the first year of studies students participate in projects of different complexity degree.

To give an example of project-based activity, let us turn to the project within the discipline «Introduction to Engineering Design». The project includes different stages which can be passed through either in the classroom or as self-study work. The term of the project is one semester and to complete the project successfully, one should get basic knowledge prescribed by the course syllabus.

The working title of the project is "Designing a Mechanical Element". Students are suggested to design a mechanical element from several (from two to four) assembly parts with the help of the program of three-dimension design.

The project includes two stages: the first one is texting and calculating, the second one is graphic. At the first stage the student gets the task for design (or suggests the task and discusses it with the teacher) and then describes the project stages in the terms of references. After that, the student calculates geometric and other technical parameters of the element and in the result makes a traveler for manufacturing procedures. At the second stage, the student using the obtained parameters designs a three-dimension model of the element and provides virtual assemblage. The result of this stage is an animated render-element. At the last stage the student makes a technical drawing and specifies it in accordance with the united system of design documentation. All the documents including the terms of references, traveler for manufacturing procedures, technical drawing, specification, calculations and the model, are discussed during public defense.

While working on a project the student obtains the skills of using basic and specialized computer programs, gets the knowledge prescribed by «Introduction to Engineering Design» syllabus. It is possible to increase the complexity degree of the project, which depends only on the student's wish and ability to design more complicated, technically-based and diversified stuff.

The student in the process of project work passes all stages including planning, analyzing, and synthesizing, etc. Project activities can be provided not only by individuals but also by groups, which makes it possible to develop communicative skills. Identifying tasks and solving problems increase motivation to project activities and stipulate goal setting, concreteness, initiative, originality in solving cognitive tasks, ingenuity of approaches, intensive brainwork, and exploration experience.

The majority of experts admit that the development of engineering thinking is caused by problems involving manufacturing operations and technical processes, i.e. solving engineering tasks through different options.

Thus, passing through all project stages the student not only obtains practical skills but also develops engineering thinking.

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UDC 378.14.015.62

Implementation of Practice-Oriented Training at Northern (Arctic) Federal University. IT Professional Standards as a Factor Influencing the Syllabus of IT Training Courses


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The paper covers education program development according to Russian and international professional standard requirements, development of IT specialist competency model, choice of training paths and learning outcomes with regard to international recommendations.

Key words: training of IT-professionals, engineering education, professional standards, international professional standards, learning outcomes.

Informational technology is the most intensively developing industry both in Russia and in the world. This is the industry that always faces the lack of qualified human resources. Besides, IT is instrumental in implementing any interdisciplinary research projects. Nowadays, the Russian education setting is confronted by the necessity to train highly qualified and highly demanded engineers including IT-specialists. Russian IT companies were among the first companies that elaborated the professional standards that should be taken into account while developing a competency model for graduates. Taking into account the global informational society expansion, special attention should also be paid to international IT professional requirements.

According to international IT training standards Computing Curricula 2005 (CC2005) there are 5 disciplines that are basic for the corresponding professional activities [1]:

- Computer Science;
- Computer Engineering;
- Software Engineering;
- Information Systems;
- Information Technology.

The combination of professional standards requirements and FSES ensures multidisciplinary professional training in the frame of a one degree program.

Education program development for a degree program according to FSES makes it possible to preserve the fundamental basis of the academic education aiming to achieve long-term educational objectives on the one hand; on the other hand, a variative program component provides freedom for the Universities to meet the current demand of a regional labor market. So, it is more important to analyze professional competences that ensure successful training of graduates [2].

Let us study IT-specialist training, a degree program "Applied mathematics and informatics" being taken as an example. IT professional standards developed by the Information & Computer Technologies Industry Association (APKIT) can help to define professional competencies for this degree program. These standards identify job responsibilities, professional competencies, educational level, work experience and certification according to qualification levels [3].

Education standards take into account

Table 1. Correlation of professional training according to Russian Federal State Educational Standards (FSES) with CC2005 degree programs

CC2005 degree programs	Russian degree programs
Computer Science	02.03.01/ 02.04.01Mathematics and computer science 02.03.02/ 02.04.02/ Fundamental informatics and informational technologies 01.03.02/01.04.02 Applied mathematics and informatics
Computer Engineering	09.03.01/ 09.04.01 Informatics and computer engineering
Software Engineering	02.03.03/02.04.03 Mathematical support and information system control 09.03.04/09.04.04 Software Engineering
Information Systems	09.03.02/09.04.02 Information systems and technologies 09.03.03/09.04.03 Applied informatics 11.03.02/11.04.02 Infocommunication technologies and communication systems 38.03.05/38.04.05 Business-informatics
Information Technology	09.03.01/09.04.01 Informatics and computer engineering 09.03.02/09.04.02 Information systems and technologies 10.03.01/10.04.01 IT security 11.03.02/11.04.02 Infocommunication technologies and communication systems 10.05.01 Computer security 10.05.02 Information security of communication systems 10.05.03 Information security of automated systems 10.05.04 Information-analytical security systems 10.05.05 IT security in law enforcement

both general education and fundamental training requirements. In these conditions, several professional standards can correspond to one FSES. For example, such professional standards as "programmer", "system architect" and "information security specialist" correspond to the education standard for the degree program "Applied mathematics and informatics".

Professional standards reflect current labor market demands and ensure successful performance of job responsibilities implied by a particular qualification level. Thus, the professional standard model (Fig. 1) is simpler than that of an education standard (Fig.2).

Each qualification level (from 1 to 8) is specified by professional activities described by FSES and such requirements as work experience, certification, grade level, training and the list of positions as well.

For example, the requirements for the professional standard "programmer" are specified according to four qualification levels with regard to educational attainment

Fig. 1. Professional standard model

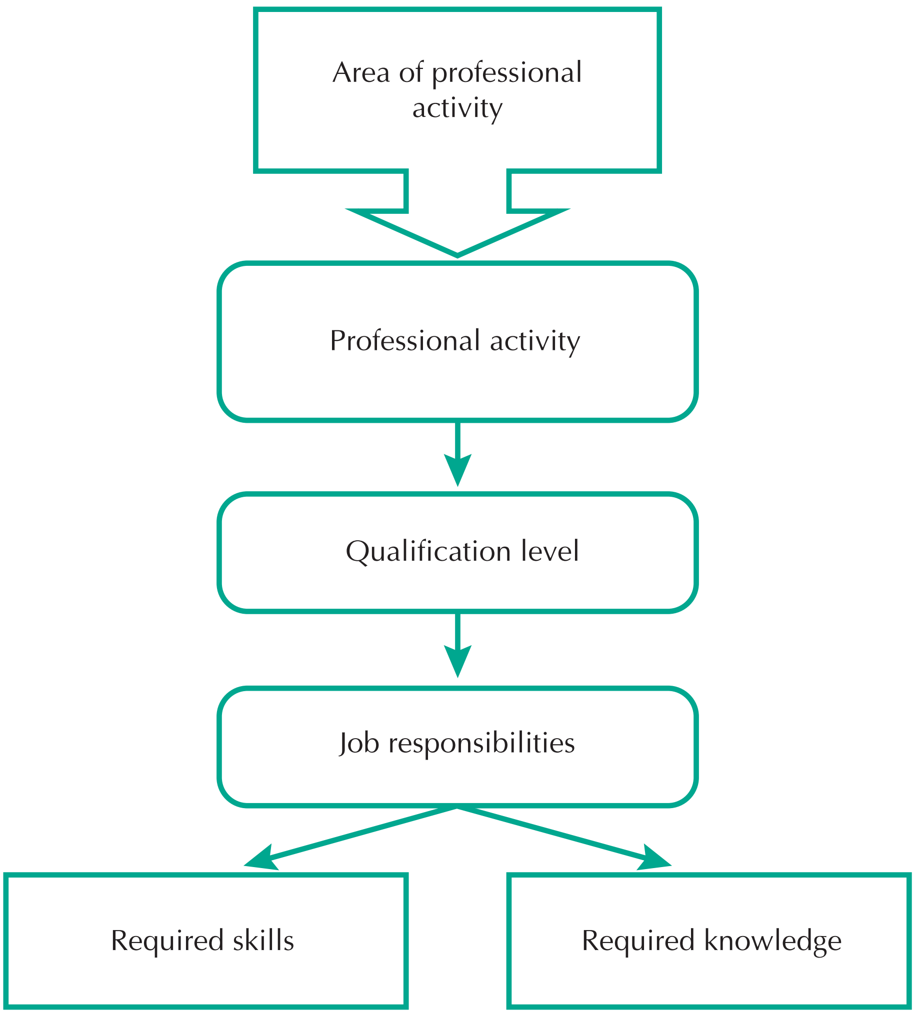

Fig.1. Federal State Standard model

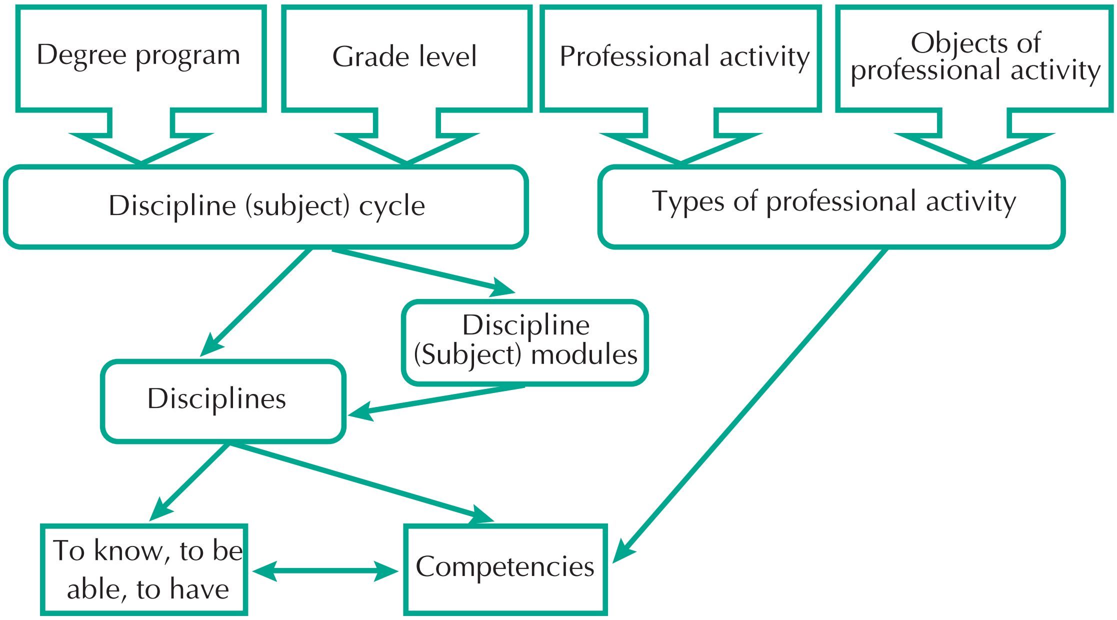

Table 2.

Grade level	Positions	Qualification level
Bachelor's degree «Certified specialist»	Programmer Development engineer Engineer	2^{nd} level
Master's degree «Certified specialist»	Engineer Senior development engineer Senior programmer	3^{rd} level
Master's degree «Certified specialist»	Senior engineer Senior specialist Chief programmer	4^{th} level

and estimated positions (Table 2).

Each qualification level determines a set of particular job responsibilities. Each job responsibility implies a set of particular skills and knowledge. While comparing professional and educational standards, it is possible to present job responsibilities as specified objectives and competences of educational standards (Table 3 as an example). At the same time, the required skills and knowledge of the professional standards can be correlated with the disciplines of the educational standards.

This is the first experience for Russian IT business in developing recommendations for the educational community, whereas the international IT business headed by the Association for Computing Machinery (ACM) has been actively involved in this activity for many years [4].

Currently, the recommendations available at www.acm.org/education/curricula-recommendations cover the following disciplines: computer engineering, computer science, information systems, information technology, software engineering, with the update period no longer than five years.

The recommendations include a list of topics, like in Russian FSES for the disciplines of the basic part, as well as student learning objectives achieved by studying these topics.

For example, the learning objectives for the subject "Object Oriented Programming", knowledge area "Programming languages", discipline "Computer science" are recommended to be as follows: to introduce the philosophy of object oriented programming, to define such notions as encapsulation, abstraction, inheritance and polymorphism; to study the issues of program design, implementation, testing and adjusting by using the languages of object oriented programming [4].

Russian higher education internationalization is a relevant issue nowadays. Development of integrated education programs is one of the forms of the process. In this respect, while designing

Table 3.

Professional competencies of degree program "Applied mathematics and informatics" introduced at NArFU	Job responsibilities of a programmer defined by IT professional standards
Ability to draw up regulatory and technical documentation as well as reports on a project	to collect and analyze requirements and to create scenarios of product application; to develop different types of software program requirements; to reconstruct requirements with a code during re-engineering; to develop detailed specifications based on high-level specifications according to the obtained requirements; to formalize and control the correctness of the requirements and/or specifications expressed by informal language

Ability to work with multiprocessor computing systems (clusters)	to develop and adjust concentrated, distributed and multithreaded applications
Ability to apply parallel programming by using MPI	
Ability to assess computational complexity and efficiency of parallel solutions	
Ability to test and review code and project documentation to control the project outputs such as quality and functionality	to analyze and optimize code by using tools to enhance product quality and operation performance; to plan testing and to develop testing sets and procedures; to develop and adjust test automation tools for a project; to elaborate and record project and technical documentation in accordance with the assigned task; to review technical documentation
Ability to use basic methods and techniques of software development process	to develop a code of software product basing on given specifications; to adjust the code at module level, inter-module level and the level of interaction with external environment
Ability to use project management tools	to measure software product parameters; to analyze project tools efficiency
Ability to interact with customer representatives or experts in specific subjects	to train and consult the staff
Ability to specify stages and methods of software product development quality management during the entire life cycle of the production	to integrate software components; to test software

the education program of specialty "Applied mathematics and informatics" in the Institute of Mathematics, Information and Space Technologies, NArFU, the following international recommendations (Table 4) were taken into consideration.

Having more intensive interaction with educational institutions, professional communities give their recommendations to the learning outcomes through professional standards, which makes educational programs more open for external evaluation and increases University's responsibility for training quality.

Table 4.

Knowledge areas of ACM	Curriculum subjects of specialty "Applied mathematics and informatics"
Discrete Structures (DS)	Discrete mathematics Theory of graphs Finite fields and polynomials Theory of Probability and Mathematical Statistics
Programming Fundamentals (PF)	Informatics fundamentals Programming languages and translation methods Computer Practicum
Algorithms and Complexity (AL)	Algorithms and data structures Basics of cryptography Error control codes Modern crypto-algorithms
Architecture and Organization (AR)	Computer architecture
Operating Systems (OS)	Operating systems Application support in operating systems Systems programming and information security of OS
Net Centric Computing (NC)	Computer network Computer network and network security Parallel programming Parallel programming and information security of distributed information systems
Programming Languages (PL)	Object oriented programming Office programming
Graphics and Visual Computing (GV)	Computer geometry Computer graphics Elements of abstract and computer algebra
Information Management (IM)	Database design and management Databases and their security

Social and Professional Issues (SP)	Business communication Business planning Law Basics of management Business ethics and psychology Psychology of successful career Risk theory
Software Engineering (SE)	Software development technology Software quality management, certification and standardization Project practicum Model and program verification Software testing System and applied software
Computational Science (CN)	Theory of parallel processes Computer modeling Optimization and mathematical methods of decision-taking Linear, discrete and network programming Game theory

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UDC 378.147.88

Practice-Oriented Education at Northern (Arctic) Federal University

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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

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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

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.

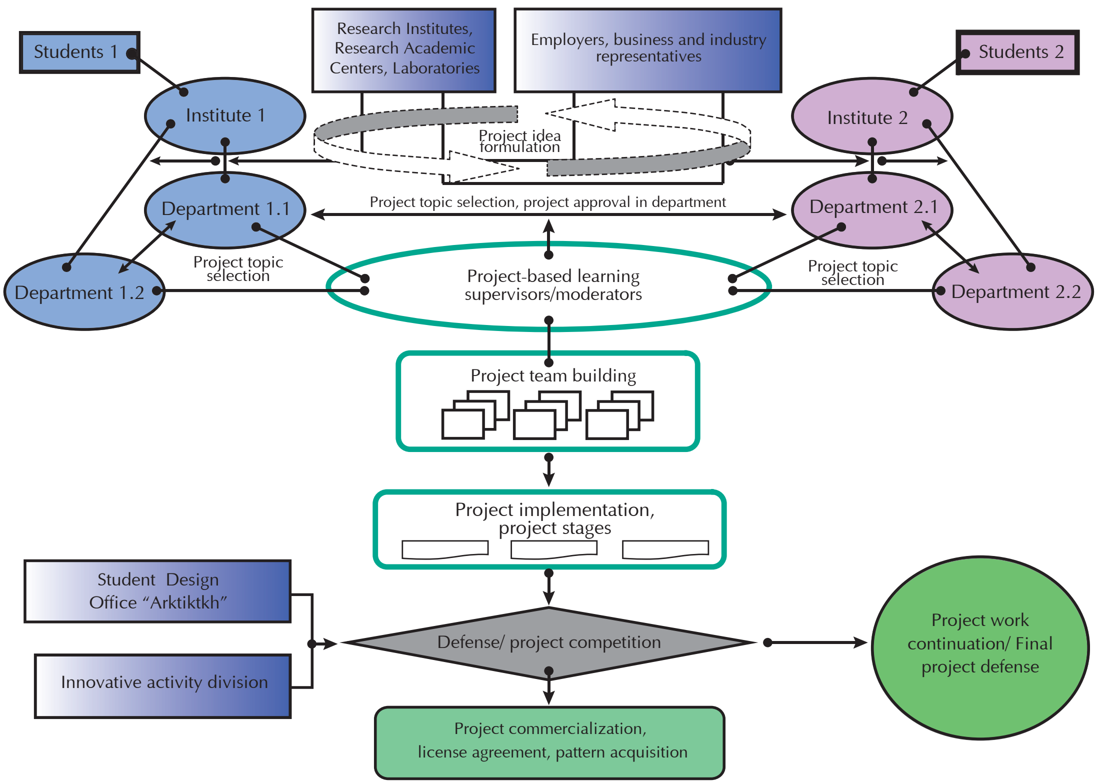
The members of design team are assigned special functional areas and specific responsibilities for which they are accountable. The project is intended to allow students to engage in a real professional environment and foster the development of engineering-design skills by introducing mutually supporting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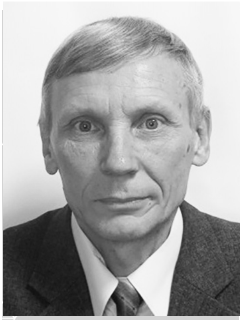

V.M. Fedoseev

UDC 378.001+51

Mathematics in Engineering Education within the Framework of CDIO Standards: Methodological Aspect

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"In studying science, examples are more important than rules"
Issac Newton

The article describes the CDIO standard effect on the teaching methods of mathematics in technical institutions and focuses on the integration tools in mathematical and engineering training. Teaching tools in designing learning activities to implement the integration objectives and recommendation for their application during the teaching process have been examined based on a specific example.

Key words: : engineering education, CDIO standards, integration of engineering and mathematical training, teaching methods in mathematics, technical universities.

Since engineering (technical) education has embraced definite learning tools and has become an independent domain, mathematics, as a science, could be considered practical in training future engineers. Moreover, mathematics is a fundamental discipline in engineering and, for more than 200 years, student selection during entrance exams has been based on their mathematical skills. The basic contradictions arise from the content of mathematical education of future engineers and, even more, from the teaching to be applied.

Within the framework of the engineering education there exist two competitive theoretic-methodological approaches in the didactics of teaching mathematics. The first approach is based on the fact that mathematics itself has its own internal structure and logic to understand, assimilate and facilitate its regular application. Applied mathematics does not exist independently. It is an integrated science and, as such, teaching mathematics for engineers should not be considerably diverged from other university courses [1, pp. 88]. The second approach includes that the objectives of mathematics teaching and academic interests of engineers are quite different from those of the mathematicians. Thus, mathematics within the framework of engineering education is something special, i.e. "engineering mathematics." And, in this case, it is necessary to teach it in a different way, incorporating the professional requirements, as well as characteristics of engineering mentality [2, pp. 285-289].

Based on the international CDIO Initiatives, teaching mathematics is considered obviously related to the second theoretic-methodological approach, asserting the fact of professional-oriented teaching. According to Standard 1 (version 2.0), CDIO facilitates the required CDIO engineering environment, within which, theoretical knowledge and practical skills are taught, assimilated and applied [3, pp. 5]; Standard 3-focuses on the integrated curricula promoting teaching systematization, involves interdisciplinary development and determines the maintenance of discipline integration into the teaching process via university academic staff [3, pp. 7, 8]; and Standard 5 in achieving stated tasks methodological learning activities are provided to develop student skills in applying theoretical knowledge throughout their engineering practice [3, pp. 9].

Regarding the content of CDIO standards and education programs, it can be stated that, in this case, methodologically, this is project-oriented education technology (EdTech), focused on the integration of both theoretical and practical training of technical university students.The application of the project method in domestic engineering education is not novel. In the 20's and 30's of the last century this method was promising and was widely integrated, including as a part of the mathematical prerequisite of future engineers. However, this method became irrrelevant, as its application often resulted in the degradation of the mathematical knowledge and roused unfavorable criticism from profile departments. From the point of view of modern pedagogics, the project method was unsuccessful due to the following: "The concept seemed to have been logical, i.e. to establish learning (cognitive) process, involving face-to-face learning. However, one factor was excluded- the more the immediacy elements (experiments, research, uncertainity) are included in the learning process, the more indirect supporting elements should be provided" [4, pp. 40].

Historically, a successful education project is already identified in the conceptual phase itself. In the case of specific academic courses, the implementation of the CDIO base, defined by the standards and programs, should be supported by relevant methodological support tools, i.e those tools designed in terms of philosophy and the conceptual CDIO orientation -their application in the learning process. As the teaching methodology of mathematics in engineering universities has been developing and upgrading during the last few centuries, the proposed methodological support of CDIO standards can not be developed "overnight". According to the opinion of university mathematical instructors, the reform of engineering education within the framework of one specific discipline is based on the requirement of explaining the mathematical examples in order to convey the meaning fully. In this case, the instructor is not considered with the question; "what to do?", but how to achieve this (what tools should be used)?"

New philosophy elements of education, modern standards, upgraded curricula and the international CDIO Initiatives are being more frequently implemented into the Russian engineering education. Based on regulatory documents, the above-mentioned items have already been integrated into the content of new education standard versions within different engineering profiles, therefore, the content of mathematics, as a discipline, itself, has been directly and significantly influenced also. In the context of CDIO standards, mathematics in a technical university should be integrated into the engineering education system. In this case, an excellent integrative methodological tool could be individual learning activities (i.e. projects), involving content-based interdisciplinary subjects. As the departmental teaching content remains unchanged and the mathematical aspect is actually the priority of most mathematical teachers, then the methodological problem-how to compile such assignments-emerges. This is rather a new aspect, and, moreover, quite difficult as its implementation involves not only mathematical but also engineering content. As Alfrйd Rйnyi wrote: " Those, who want to apply mathematics are like warriors in a two-horse chariot.......One should know something about both the chariot, and, of course, about the horses."[5, pp. 62].

According to CDIO Initiatives, the integrating learning activities, concerning mathematics, should be engineering projects and should combine both engineering problem-solving and mathematical research methods. The author states that the problem-solving of typical tasks invokes considerable difficulties for students. Based on didatic principles it is recommended to divide such tasks into two sections: the first-propaedeutic (preparatory instruction), where the teacher only instructs the student involved in the mathematical problem statement, selects the problem-solving method, comments and step-by-step controls the problem-solving process itself; the second-creativity, where the student independently solves equivalent tasks either through the application of the methodological tools from section one or could reasonably improve the methods in section one, which, in its turn, functionally assigns required mathematical tools and further becomes the pilot project. This is described in the following task-example (1-year students of Penza State Technical University).

Engineering task statement:

Engineering design of a device with face cam which ensures the pusher reciprocal motion (in-out movement) from the starting position to the end position and visa versa. Specified kinematics of pusher motion results in the cam profile shape, including two Archimedean spiral branches (fig. 1). The disadvantage of proposed engineering design is angular points in spiral branch joints (points A and B in fig. 1). This results in the failure of smooth device performance and further vibration of the machine itself, which, in its turn, causes undesirable technical problems. The engineering problem-design the cam profile shape which would rivet kinematic criteria and dynamics of device performance.

Section 1 Propaedeutic (preparatory instruction). The student receives a ready-made solution-cam profile shape as a disk cam (fig. 2) and should only perform the required of-design operation. In this case, the following mathematical problems are formulated:

1) determine radius R and position of circle center, corresponding to cam profile and compile the equation of this circle in polar coordinate system with displacement of pole in respect to the center by ε: (answer: $r = r_{\text{э}}(\varphi) = \sqrt{r_0(R+\varepsilon)+\varepsilon^2\cos^2\varphi} - \varepsilon\cos\varphi$);

2) investigate the radius direction of the disk cam deviation $\delta_{\text{э}}(\varphi)$ from the compound curve of Archimedean spiral branches so as to determine its asymptotic (maximum) value $R \to \infty$, and further determine the extremal value of obtained equation: (answer:

$$\delta_{\text{э}}(\varphi) = \sqrt{\left(r_0 + \frac{2\varepsilon\varphi}{\pi} + \varepsilon\cos\varphi\right)^2 + \varepsilon^2\sin^2\varphi} - R,$$

$$\delta_{\text{э}}(\varphi) \approx \varepsilon\left(\frac{2\varphi}{\pi} + \cos\varphi - 1\right),\ \left|\delta_{\text{э}}\right|_{\max} = 0{,}210514\varepsilon\ );$$

3) deduce the quality of engineering problem-solving, demonstrating its mathematical research results.

Attaining smooth device performance definite alterations in the engineering design were made. However, such questions emerge -how did these alterations affect the kinematic characteristics of the device itself? Is the disk cam deviation value acceptable to the theoretical profile? Could this be decreased if alterations are included? These questions further the possible research and the definition of the second section.

Section 2 Creativity. The task includes a cam profile as a smooth closed line reproducing the cam shape better than the disk cam, i.e. it involves less deviation than in the case of the theoretical profile. The obtained result should be explained and critically evaluated.

The creative task element is determined by the design solution freedom. However, this could be limited by the application of mathematical tools, and, this principally induces the possible standard set of curves: ellipse, hyperbolic, parabolic and other curves. It should be noted that the solution of this task could be an elliptic spline: closed curve of two semi-ellipses: $r_1(\varphi)$ and $r_2(\varphi)$, depicted in fig. 3. Mathematical research is conducted according to the methodology stated in section 1.

The described elliptic spline is a smooth convex curve. In the polar coordinate system if the polar is centralized, then the elliptic spline branches have the form of the following equation:

$$r_{\text{эс}}(\varphi)=\begin{cases} r_1=\dfrac{r_0(r_0+\varepsilon)}{\sqrt{r_0^{\,2}+\varepsilon(2r_0+\varepsilon)\cos^2\varphi}}, -\dfrac{\pi}{2}<\varphi\le\dfrac{\pi}{2}, \\ r_2=\dfrac{(r_0+\varepsilon)(r_0+2\varepsilon)}{\sqrt{(r_0+\varepsilon)^2+\varepsilon(2r_0+3\varepsilon)\sin^2\varphi}}, \dfrac{\pi}{2}<\varphi\le\dfrac{3\pi}{2} \end{cases}$$

The above-mentioned curve is depicted in Cartesian (coordinate) system $(r;\varphi)$ (fig. 4). The limited spline deviation from Archimedean spiral branches is investigated as in the first section and, if parameter r_0 is increased, then it is estimated in the following asymptotic equation:

$$\delta_{\text{эс}}(\varphi)\approx\begin{cases} \varepsilon\left(\dfrac{2\varphi}{\pi}-\sin^2\varphi\right), -\dfrac{\pi}{2}\le\varphi<\dfrac{\pi}{2}, \\ \varepsilon\left(\dfrac{2\varphi}{\pi}-2+\sin^2\varphi\right), \dfrac{\pi}{2}\le\varphi<\dfrac{3\pi}{2} \end{cases}.$$

Fig. 1.

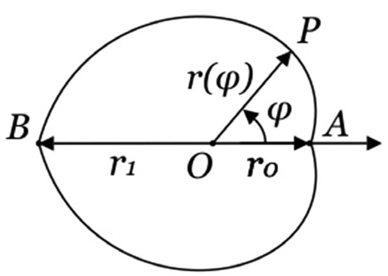
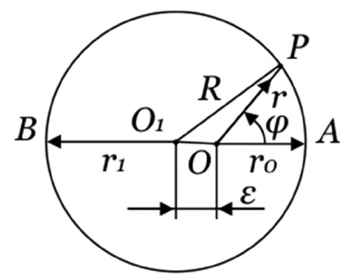


Fig. 2.



Determining the extremal values of the function $\delta_{\text{эс}}(\varphi)$ for the maximum deviation of the proposed engineering design of cam profile to the theoretical one the following asymptotic assessed value is obtained $|\delta_{\text{эс}}|_{\max}=0{,}105257\varepsilon$. In comparing this to analogous assessed value for disk cam the fact indicates in the case of an elliptic spline the error magnitude is two-fold less, i.e. the kinematic characteristics of the device are improved. This is the practical project result.

The above-described example gave a detailed explanation of the application principles of CDIO standards with regard to the mathematical education of engineers: 1) mathematical training of university students should be integrated

Fig. 3.

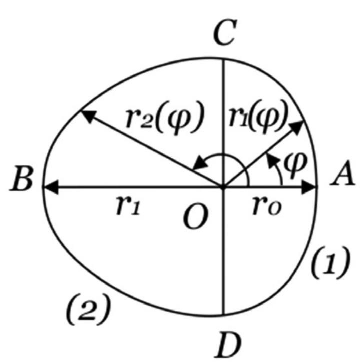
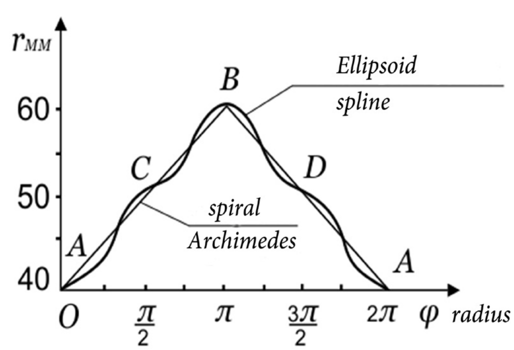


Fig. 4.



into the engineering education system; 2) achieving the discussed objective is through integrated curricula (IC); 3) engineering task involves the objective, content and further mathematical research within the framework of IC; 4) selecting an engineering task initially depends on the teaching requirements of mathematics and then professional interests, i.e. the engineering task is based on the mathematical tools, which, in its turn, should be rather "saturated" and informative in accordance with the learning outcomes; 5) engineering task should be simple and understandable for a 1-2 year student, while the results of the mathematical research-illustrative, assuming conceptual interpretation and possible empirical verification; 6) questions in didactics should also be included, for example, application of problem-based learning technology or other of active learning methods; 7) the author recommends the described task division into propaedeutic (preparatory instruction) and creativity, indicating different elements of student self-assessement.

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UDC 378.046.4

Competences of Management and Engineering Staff in the Sphere of Energy Conservation as a Base for Retraining Program Design

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Demand for personnel capable of making innovative decisions and designing innovative facilities conditions the necessity for training managerial and engineering staff. The offered programs of three types based on the energy conservation competence models of managerial and engineering staff contribute to the solution of professional problems and development of competences in planning, design, production, and implementation in the conditions simulating professional activity.

Key words: competencies of energy conservation, management and engineering personnel, requirements, retraining programs, design.

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Energy use and conservation problems are urgent all over the world. Experts have noticed the common regularities: less energy use in comparison with the predicted one, dependence of energy use on the rate of production development, continuous growth of energy resource utilization, in the developed countries – low usage of renewable energy sources. Energy consumption tends to decrease, which indicates high rate in energy conservation. In Russia energy conservation problems were not so urgent due to availability of great amount of resources, low population density in some regions, an increase in the energy intensity of the gross product in the first half of the 20-th century, which has had consequences so far [1].

Nevertheless, economic, ecologic, moral and other factors condition the specific character of energy conservation problem and urgency to solve it in Russia. To solve this problem one needs to take a number of engineering and management decisions that would require corresponding qualification of both managerial and engineering staff. It updates the issue of managerial and engineering staff retraining in terms of their energy conservation competence development. The given problem is one of the crucial ones which has to be solved in the course of the CDIO international project.

The foundation of the managerial and engineering staff retraining program rests on a competence-based approach. The competences present both a foundation and a goal (expected outcomes) of retraining syllabus implementation.

Traditional competence models of managerial and engineering staff are based on classical foundations: requirements of the Federal State Educational Standards (FSES), job description, research in competences and their empirical study [2 – 10].

To examine the competences the standards of the majors 140400 – Electric Power and Electrical Engineering and 140100 Thermal Power and Thermal Engineering were studied [7-10]. According to the standards and a survey among engineers the developed traditional competence model of managerial and engineering staff in energy conservation includes the following competence units grouped in terms of similar activity types:

- state and local policy implementation in the sphere of energy conservation and energy efficiency enhancement;
- thermal technology and thermal facilities service;
- thermal and electric energy generation;
- energy audit and certification at the public sector and housing-municipal sector enterprises;
- energy management;
- energy conservation in the heat and water supply systems;
- energy conservation in the energy supply and lighting systems;
- electric energy consumption records;
- energy resource consumption management;
- energy consumption measurement devices and methods;
- energy consumption, record keeping, and distribution systems service.

Hence, only competences of traditional energy source operation were revealed from the regulatory documents. In addition to them, for the purpose of energy conservation the competences of design and alternative energy system utilization has become in demand. Use of alternative sources are accompanied by a great deal of risks as they involve real processes and phe-nomena that do not depend on a human being: periodicity of energy supply, irregularities of process that can result in, for instance, global warming, absences of legal foundation for the use of alternative energy sources, risks of macroeconomic imbalance and limited resources.

Some risks can be overcome if hybrid sources are used. Utilization of hybrid sources is conditioned by the fact that many alternative sources are significantly limited in use. To remove the disadvantages, one needs to com-bine them achieving a synergetic effect. The use of hybrid sources is also connected with the fact that the energy supply of a unit is often convenient by utilizing not one, but several energy types. Besides, hybrid complexes are capable of controlling an energy supply providing energy in different volumes, for example, in different time of a day-and-night. Hybrid systems facilitate duplication of operations when one of the systems does not provide enough energy.

The analysis of alternative energy sources and traditional competence models allowed us to distinguish the following groups of innovative energy conservation competences that are not available enough for managerial and engineering staff in different branches of industry.

First, let us consider the competence related to the use of simple alternative energy sources. Here we can distinguish the same competences as for traditional sources of energy. The corresponding groups can be renamed as the:

- competences of state and local policy implementation in the sphere of alternative source utilization;
- facility operation and maintenance (collectors, mini-hydropower sta-tions, tidal, wave, waterfall power stations, etc. – depending on a type of alternative energy);
- generation of alternative energy;
- energy audit and certification at the public and housing-municipal en-terprises;
- energy management;
- energy conservation in the systems of alternative supply;
- electric energy consumption records;
- energy consumption management;
- energy consumption measurement devices and methods;
- energy consumption, record keeping, and distribution systems service.

Crucially new competences are developed in the hybrid systems which are intended for the optimal synthesizing of different sources in the most efficient way from the point of view of energy conservation. Among them there are the following competences:

- plotting schemes and hybrid systems meeting the requirements of complete facility functioning in the condition of maximum energy conservation;

- design of relevant hybrid systems;
- certification and energy audit of hybrid systems;
- application of hybrid systems;
- operation of measurement devices and methods of energy consumption;
- energy consumption records in hybrid systems – both in general and by elements.

In the sphere of energy management in a hybrid energy supply there appear the competences of interaction with intelligence hybrid systems. Intelligence hybrid systems can provide «self-analysis» of possibilities, limitations, interdependence of elements and units.

Intelligence hybrid systems (IHS) can reveal the necessity of changes in the scheme, desirable sequence of elements, their interchangeability and dependence. The engineer (bachelor or master) has to acquire the corresponding competences. One might group the competences as follows: IHS design, IHS development, IHS functioning service, analysis of functioning and proposed decisions, assessment of changes introduced and improvement measures.

Special attention should be paid to formation of research competences to work with IHS, since development, design, and testing of hybrid systems requires research at each operation and every stage of performance.

In fact, application of IHS means functioning anergatic intelligence system where the potentials of human intelligence and «the intelligence» of equipment and software are combined. The managerial and engineering staff should be ready for being incorporated into this supersophisticated system.

Due to its high complexity – the given competence can serve as a basis for development of not only separate module of the retraining syllabus but also the whole program for managerial and engineering staff.

Competence model built on scientific foundations, i.e. using four bases (FSES, duty regulations (or something similar), research in competences, empirical research in competences), is a key prerequisite for design, performance, and assessment of learning outcomes (quality) of managerial and engineering staff retraining.

When designing the syllabus – it is necessary to take into account that Further Professional Education (FPE) syllabuses are to be flexible and dynamic. Their flexibility is conditioned by a great number of factors: local, technological, economic, cultural, psychological, scientific etc. Hence, it is not reasonable to suggest compulsory syllabuses promoting competence development of managerial and engineering staff in the sphere of energy conservation.

It makes sense to design a generalized retraining syllabus, preferably in modules, to have an opportunity of its changing to different extent depending on the above mentioned factors.

We suggest three versions of generalized programs: traditional; for development of innovative competences in operations with the alternative and hybrid sources and development of innovative competences in energy conservation in hybrid intelligence systems.

Traditional syllabus «Professional retraining and qualification upgrade of the specialists in the sphere of energy conservation and energy efficiency» was developed and tested by us at South-Ural State University (SUSU) on the basis of the Common Use Center.

According to the competence groups there distinguished the retraining syllabus modules of alternative and hybrid power issues.

The syllabus «Hybrid power intelligence systems» is intended for experienced and highly qualified managerial and engineering staff, preferably with an engineer's qualification or a master degree.

The programs have the following peculiarities.

The syllabus modules correspond to the competence groups revealed by us. For instance, module «Devices and methods of energy consumption measurement. Engineering systems of energy record, distribution, and consumption» is developed for fostering the energy consumption measurement competences listed above.

Among the modules there are compulsory modules for everyone (invariant part), for instance, module «State and local policy in the sphere of energy conservation and energy efficiency», and variable ones which are chosen by employers for their workers in case of insufficient development of corresponding competences.

The outcomes of retraining courses depend significantly on how the syllabus is implemented in practice, i.e. forms and methods of its performance. At present the fact that one should apply interactive techniques, as well as methods simulating professional problem solutions have been recognized and specified at legal-regulatory level.

Hence, we recommend arranging academic environment based on the requirements even stricter than to those for arrangement of the principle academic process to realize FPE syllabuses.

The first necessary requirement is for teaching staff. In FPE syllabuses the most highly qualified staff has to participate, they also have to take upgrading courses on issues of innovative teaching techniques.

The second necessary requirement refers to forms and techniques of FPE academic process. To implement these syllabuses we suggest using special «practice grounds» – academic and research and «natural» centers like at SUSU and other universities including foreign ones.

The third requirement is subject-subject technique of teachers' and students' interaction in the retraining (or upgrading) syllabus at which students do not perceive information given by a teacher inactively, but gain it by themselves actively, thus solving real professional problems.

Such a way of designing and realizing retraining and upgrading syllabus for managerial and engineering staff allows introducing the potential of staff preparation for competences of «conceiving», «designing», «implementing», «operating» all together, but not separately. It permits us to consider the suggested approach as a modern one meeting the CDIO program requirements.

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Application and Development of CDIO Engineering Education Mode in Undergraduate Science Program

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Enlightened by successful implementation CDIO (Conceive, Design, Implement, and Operate) in Engineering Program, CDIO is applied to undergraduate science program in Chengdu University of Information Technology. In this work, CDIO is adapted into science program as a systematic framework including setting explicit professional training standards, reconstructing curriculum system, optimizing theoretical and experimental teaching mode, and intensifying process assessment. The results show that the adaptation of CDIO can inspire the interests of study as well as the practical ability of students in undergraduate science program.

Key words: CDIO, Undergraduate science program, Training standard, Curriculum system, Course designation, Process assessment.

1. Introduction

Established in 2004, engineering education mode of CDIO (Conceive, Design, Implement, and Operate) was based on the philosophy of product life cycle. In CDIO mode, the students learn engineering and obtain engineering ability in the way of initiative, practice, and courses with effective connection [1, pp. 1-4]. Thus make CDIO mode suitable for cultivating engineering talents of engineering majors.

Since 2008, Chengdu University of Information Technology (CUIT) has taken the lead in implementing the CDIO engineering education mode in China, which was involved in all engineering majors in the aspects of teaching theory, teaching plan, curriculum system, teaching method and assessment method. The reform process and results have gained the recognition of domestic and international peer.

Besides the undergraduate engineering program such as Electronic Engineering, Computer Science and Optical Engineering, multi science programs are taught in CUIT such as meteorological science, applied physics and applied mathematics. The education mode carried on in the past is focusing on the theoretical knowledge which ignores the knowledge application. The modification and development of this old education model is crucial for better ability of scientific thinking, knowledge application, problem solving as well as creation.

In 2011, enlightened by CDIO engineering education reform, CUIT introduced the educational theory focusing on the raise of comprehensive ability of students combined with knowledge, ability and quality together in the science major cultivation program, learned from the ability cultivation standard out of the engineering education standard to creatively apply CDIO teaching method into science major education and implement assessment module of equal stress on both taught knowledge and practical ability. Based on those reforms, CUIT proposed and propelled the integrated education and teaching reform in science majors [2].

2. Curriculum for undergraduate science program in CDIO

2.1 Setting explicit professional training standards

According to the professional knowledge and ability requirements of the Ministry of Education and the ability and quality demand of science talent from society, industry and enterprise, we set the training standards for knowledge, ability and quality of science talent. The standards are the basic training goals. The standard syllabus is divided into three professional levels and four ability levels of professional knowledge, personal and team skills, science and humanities. Table I demonstrates the training standards of Applied Physics.

(1) Professional training indicators

As shown in table 1, there are three levels of ability indicators from left to right. Four first level indicators represent four kinds of general capability of science talents, and every ability field is divided into many second level indicators which represent ability categories with professional characteristics. And then

Table 1. Training Standards of Applied Physics

First level	Second level	Third level
1. Professional knowledge and the humanities	1.1 Mathematical and physical fundamental knowledge	1.1.1 Higher mathematics, linear algebra and probability theory
		1.1.2 Basic theory and experimental method of college physics
	1.2 Engineering fundamental knowledge	1.2.1 Engineering introduction and basic theory of engineering drawing
		1.2.2 Basic knowledge of computer
		1.2.3 Circuit and electronic application technology
	1.3 Professional fundamental knowledge	1.3.1 Basic theory and method of theoretical physics
		1.3.2 Structure, composition, preparation and properties of solid materials
		1.3.3 Semiconductor optoelectronic materials and the properties
		1.3.4 Physical basis, design and manufacture of photoelectric device
	1.4 Humanistic literacy ability	1.4.1 Basic knowledge and ability of the humanities
		1.4.2 Humanistic spirit and character
		1.4.3 Historical and cultural environment
		1.4.4 Contemporary issues and values

2. Technical ability, professional skills and attitude	2.1 Experimentation and knowledge discovery	2.1.1 Ability to access to scientific literature and information
		2.1.2 Preparation of optoelectronic materials and optoelectronic devices according to the experimental scheme
		2.1.3 Testing and evaluation of experimental results
	2.2 Design and implementation of the comprehensive experiments	2.2.1 Put forward and express the problems of optoelectronic materials and devices
		2.2.2 Design and preparation of photoelectric material
		2.2.3 Design, simulation and making of photoelectric devices
		2.2.4 Testing, analysis optimization of material device performance
	2.3 Design, implementation and innovation of systems	2.3.1 Conceive, design and preparation of new photoelectric functional materials
		2.3.2 Design and implementation of optoelectronic devices and systems
		2.3.3 Judging the constraints of material devices and systems
		2.3.4 Pursuit of innovative attitude and awareness
	2.4 Professional skills and attitude	2.4.1 Keep pace with the development of world engineering technology
		2.4.2 Occupation morality and sense of responsibility
		2.4.3 Active planning of personal occupation development goals
		2.4.4 Keep the lifelong learning with physical and mental health
3. Interpersonal skills: teamwork and communication	3.1 Teamwork	3.1.1 Building effective team
		3.1.2 Keep team operation
		3.1.3 Team work
	3.2 Communications	3.2.1 Basic communication ability and skills
		3.2.2 Written communication
		3.2.3 Multimedia (data, chart) communication
		3.2.4 Oral expression skills
	3.3 Communications in foreign languages	3.3.1 Certain English ability in listening, speaking, reading and writing

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4. Conceiving, designing, implementing and operating systems in the enterprise and societal context	4.1 Society and industry	4.1.1 Know the culture industry, objectives and planning
		4.1.2 Social entrepreneurship
	4.2 Design and production ability	4.2.1 Set the performance goals of photoelectric devices and the system's
		4.2.2 Decomposition of design of photoelectric device system
		4.2.3 Production of materials, components, modules and systems
		4.2.4 Testing, verification and certification

the third level indicators are the specific abilities which are developed in the courses. The decomposition of indicators realizes the transformation of the training standards from macro to micro.

(2) Ability level

As shown in the table, there are four ability levels from top to bottom. The first level is professional knowledge and the humanities, the second is technical ability, professional skills, the third is the ability of communication and cooperation, and the fourth is the ability to adapt to industry. The four levels reflect the comprehensive training of students' knowledge, ability and quality.

2.2. Reconstruction of curriculum system

Based on the professional training standards, the courses are divided into four categories which include public basic courses, basic disciplinary courses, professional courses and practice. We reconstruct the curriculum system according to the process of decomposing the standards, optimizing the basics, integrating courses content, and penetrating projects. The implementation of training standards are decomposed to every course, meanwhile, practice projects in three levels which include course, course group, and profession penetrate the entire training process. The knowledge modules are organically linked, and the curriculum system with knowledge, ability, and quality is formed.

Students' key abilities are gradually cultivated in the practical projects and related courses. Innovative experiments and cross, comprehensive design innovation experiments combined with professional basic theories broaden students' horizons and innovative thinking, and the individual needs of students are met in diversified innovation practice and entrepreneurship training projects.

3. Course designation based on CDIO in undergraduate science program

CDIO emphasizes on the ideas of Conceive, Design, Implement, and Operate to cultivate comprehensive ability of students in order to effectively promote the student learning ability as well as personal skills. In order to make student fully command the knowledge and promote their personal skills, we adopted CDIO active learning method on the science major education to enforce students to learn knowledge actively and forge them to put the knowledge into practice actively.

3.1. Active theory of teaching

We succeed in realizing the transformation of the single teaching way that focus on teacher's explanation of knowledge together with student's listening to the class into the active and multiple-interaction teaching way. We adopted diverse teaching methods to use applied exemplification to guide teachers and supervise students to take part in the theory teaching as well as extracurricular special training, the purpose of this is to cultivate student's skills into implement.

3.2. Independent experimental teaching method

In experimental teaching, we take the single experimental project as the basic teaching unit to set up the index of project capacity as well as student's independent experimental project. During teaching process, teachers will change the role of speaker into guide; students will change the role of involver into active experimental actor in the experimental project in order to enforce their experimental skills and comprehensive ability.

The student's independent experimental process implements the idea of CDIO including the design of independent experiment, completion of independent experiment process, analysis of experimental results, access personalized experimental results and promotion of personal skills. That process will fully manifest the open experiment contents, process and results. Under the supervision of teachers on the experimental design and process, students will experience the whole view of CDIO training process, which will further enhance the cultivation of student's experimental skill as well as comprehensive ability.

3.3. PBL training

Project Based Learning (PBL) is one of the key approaches to carry out comprehensive engineering training. The students take the initiative to be involved in the whole process of PBL and experience the gradually changing problems in the process. The students are divided into several teams and carry out the project simultaneously [3, pp.17]. How to manage the teams effectively at the same time? Self-management is the answer. This is our idea of integrating teamwork into PBL in order to foster the skills of inner-team. Furthermore, the competition is introduced into PBL. The student's teams can compete with each other in learning process. This is helpful to the active implement of the project.

4. The assessment of knowledge and ability in the frame of CDIO ability standard

4.1. Processed assessment

We adopted multiple assessment method to supervise real time knowledge and skill cultivation process, increase usual process assessment and improve score of ratio in the usual assessment. It includes three categories:

(1) Conventional investigation: it focuses on the assessment of student's class discipline, learning attitude, regular homework completion. This assessment will occur in different teaching process in order to ensure the normal teaching order and emphasize on the assessment of student's knowledge learning.

(2) Special assessment: it focuses on the assessment of student's completion of specific task during learning process, mainly occurs in the second or third levels of teaching process. According to requirements of different teaching methods, the assessment will be based on the specific task or the learning results to examine the student's understanding of knowledge as well as the application of knowledge into practice in different teaching process.

(3) Ability assessment: it focuses on the assessment of student's personal skills manifested in the completion of specific task and the assessment of expected teaching goals by using different teaching methods.

4.2. Diversification of final exam

We made reform on the proposition exam paper, trying to reduce the assessment only on the memory of knowledge from books and increase the exam types of knowledge understanding and application. It requires students not only command correct concepts, principles,rules and methods but also requiring students to solve practical problems by using qualitative analysis and quantitative estimation. We used double assessments on student's knowledge and ability through exam of applied case analysis and applied design.

5. Conclusion

Based on the comprehensive promotion and sufficient practice of CDIO education model in our engineering majors, we reformed cultivating mode of science majors from the education idea, training standards, curriculum, teaching methods, and assessment methods. The application and development of CDIO model make educational goals of knowledge, ability, and qualities more specific for educational subjects, and then the educational process is more effective. Teaching practice has achieved initial results which demonstrates positive results of implementing CDIO education model in undergraduate science programs.

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UDC 811.111'378.662.147 (571.16)

Active Teaching Methods in Professional Content-based English Language Learning as an Important Component of CDIO Concepts
(profile/specialization 12.03.01 "Instrument Engineering")

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The article describes the possible quality provision of engineering training in profile (specialization) 12.03.01 "Instrument Engineering" via developing creative environment. Examples of applying active teaching methods in compliance with CDIO Initiatives are discussed.

Key words: CDIO, active learning methods, professional training, co – management of cognitive activity, competence.

Introducing multi-level education system, integrating unified education space, implementing CDIO concepts (initiatives) into National Research Tomsk Polytechnic University specified the relevant organization of practice-oriented-based teaching process. The instructors are not knowledge "translators", but are "selectors" of the optimal teaching strategy by applying modern education technologies and "thinkers" of creative education process environment. In this case, activities are characterized as partnership and co-management of subject-subject relationship between student and instructor.

It should be noted that active student cognitive activity is the psycho-pedagogic principle of practice-oriented based teaching approach, whereas the student applies attained skills, abilities, experience and knowledge during the process activities, which, in its turn, furthers the development of creative thinking skills.

Besides, modern education orientation in competence shaping as a result of organized didatic and psychological conditions promotes and develops possible intelligent cognitive and active life philosophy and professional attitude, which, in its turn, identifies the individuality of the subject. In most cases, the student is engaged in a dialogue with the instructor, executing creative, research and problem-solving tasks, oriented on the cognitive process development. Another aspect is the pair-group activities in task performance in accordance with this or that discipline. Above-mentioned aspects are effective if they are based on Standard 8- international CDIO Initiative: "Active teaching methods" [1].

We shall consider in detail the active teaching methods within the framework of the discipline "Professional Content-based English Language" in module "Intro in Engineering" (Bachelor degree program: profile / specialization – 12.03.01 "Instrument Engineering"), executed in the 5th semester:

- teaching domain: shaping professional foreign language communication competence, i.e. oral and written communication skills, as well as a good command of engineering terminology;
- mentoring domain: effective individual and/or team performance, demonstrating professional skills and abilities and personal development;
- development domain: training students for future professional (engineering) activities, involving

professional English language, assimilation and transfer of new knowledge, new experience acquisition and self-education.

Above-mentioned goals could be achieved only in the case of applying active teaching methods within the framework of a discipline [2].

One tutorial method, demonstrating high student activity level, is seminar-conference where students deliver different reports with further instructor-conference participant discussion. Within the sphere of studied discipline the students prepare reports describing leading engineers and scientists and their contribution in the development of instrument engineering. In this case, one specific requirement is that the students should use only authentic materials, while another important aspect is the grading system for students. Total grade is the average sum of the instructor and student grades as well as self-assessment. According to the authors, the estimated grade is rather objective. In addition, the student enhances his/her responsibility for the performance results provided that the assessment of this activity includes the assessment of other groupmate performance.

The second tutorial type – seminar-discussion. The classes are conducted as (scholar) debates. The primary focus is on the fact that a student executes material research and actively participates in the debate (discussion). It is important that diversified information source embraces different approaches to the problem-solving, while the debate (discussion) is conducted by means of student-instructor interaction. For example, within the framework of the module "Intro to Engineering" the students conduct a discussion (debate) devoted to the topic "Future-oriented engineering spheres in today's world".

Another tutorial type – seminar-extended colloguy (dialogue), which is conducted in the process of mastery challenging materials. In this case, the initiator is the instructor. The instructor elaborates the colloguy – plan in advance. During the dialogue the students express their opinion through relevant planned ready-to reports. This teaching technique focuses on the problem issues in the study and acquisition of the discipline, develops comprehension and listening skills, as well as skills in preparing concise and short presentations. The students are able to follow the relevance of a groupmate presentation to the seminar-plan, and then further review it. Within the framework of the module "Intro to Engineering" the above-described method could be implemented into the subject-topic "Development and successful commercialization of a new device".

Tutorials based on such a technique as problem-solving seminar via discussion includes a combination of "brain-storming" and "creative discussion", individual and teamwork not only at the initial preparatory stage but also throughout the discussion itself. Students are free to express their critical comments and questions. The principle of the problem-solving seminar is to produce a problem situation which could be elaborated in advance (7-10 days beforehand). A plan indicating the further results is outlined, which, in its turn, introduces the research concept and tasks. The students independently navigate for necessary information concerning the subject-topic, examine different versions and proposals in its problem-solving. In the above-mentioned module the students create an ideal portrait of an instrument-engineer with an extended description of competencies.

Seminar-role game objective is the commercialization of a new device and drawing investors into its production. The student-group is divided into six sub-groups: industrialists, bankers (economists), elective administrators, design engineers, ecologists and consumers. The goal of the design engineers is to provoke the interest of potential investors in a new device or its technological concept and providing not only its specifications, but also its resource efficiency. The device name with a brief description can be proposed by the instructor or invented by the students. The goal of the bankers and elective administrators – select the device that would guarantee maximum profit. The ecologists should verify the proposed device environmental safety. The consumers can be either students or instructors from other groups.

Active teaching methods could include watching English videos. For example, the students have a list of questions which he/ she should answer during and / or after watching the video. The students review a set of questions, then exchange questions between each other, checking the correct answers and adding necessary information.

Oral test involves debates devoted to such topic as "Who generates the development of a society – an engineer or a scientist?" [3].

It should be noted that the students compile a glossary, i.e. they write down 5-10 words in each class throughout the semester. The written test involves writing an essay based on a topic associated with the student's future profession and including as many glossary words as possible.

The students highly praised the application of above-mentioned active methods in the teaching process. The questionnaire survey showed that the students actively and thoroughly prepared their study assignments. According to the student-respondents, such active methods as debates, discussion, seminar-confetences have two advantages: (1) monitoring one's communicative skills and (2) depth-in understanding of specific topics associated with the student's future profession.

Thus, the following methods applied in teaching the discipline "Professional Content-based English Language" embrace such skills and abilities as:

- activation of thinking and behavior;
- motivation -promotion in learning, teaching process management and personal engineering activities;
- administrative response to teaching process;
- understanding technological processes, engineering problem – solving and their promotion;
- experience exchange (personal and professional);
- motivated interest in studying engineering;
- material acquisition and consolidation (in Russian);
- development of individual, intellectual and behavioral skills and abilities under non-standard conditions;
- english proficiency for graduates;
- implementation of CDIO standards;
- enhancement of engineering education.

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UDC 001.14(1).132

Application of International CDIO Standard and Innovative Approach in the Methodology of Scientific Creativity

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Innovative methods of scientific work combined with the international CDIO initiative criteria are a new approach to engineering education. The article presents the assessment tools and evaluation techniques which can be applied during various master's thesis project stages, with main focus being paid to "production" in parts «testing» and «validation». The present article is the continuation of the work done previously.

Keywords: innovation in higher engineering education, methodology of scientific research on the particular algorithm.

Engineering education of the previous period consisted in the development of the following chain: «learning – engineering knowledge development – skill acquisition - practice». The essence and spirit of the CDIO International Program are focused on development of features of engineering education relevant to the contemporary state of society, science, and technology. Thereby, academic process implies the following elements: «learning – practice – engineering knowledge development – practice – skill acquisition – practice – outcome correlation – practical application of the whole knowledge volume». Further education under the slogan «lifelong education» forms an individual «learning trajectory».

Competence approach to higher engineering education sets the task of tool development for future master's competence formation and corresponding innovative methodical supplement for their realization. CDIO program sets a through goal: «Graduates are to be ready for complex engineering activity: Conceive, Design, Implement, and Operate engineering products, processes, and systems of the contemporary environment based on team work of specialists» [3, p.5].

CDIO standards are focused on «eliminating the contradictions between theory and practice in engineering education» through «enhancement of practice-oriented learning process as well as introduction of problem and project learning techniques» [3, c.2]. The given contradictions include a gap between theory and practice, irrelevence of educational practice to the level of contemporary scientific theory development also predetermined by such an unprecedented achievement as IT-technologies. According to the researcher's statement, cofounder of Concept Labs CA, chief engineer of BT Labs P. Cochrane: «Imagine this school with children that can read and write, but with teachers who cannot, and you have a metaphor of the information age in which we live» [4, 5]. It is referred to school, but this feature is also relevant to the stage of higher education.

At Tyumen State Oil and Gas University a propaedeutic course of «Methodology of scientific work» was introduced for masters of major «Electrical Power and Electrical Engineering». Its key task is preparation for master's dissertation. It is performed by means of innovative developments in the sphere of scientific creativity methodology combined with the focus on masters' knowledge formation about the key stages of international standard of CDIO engineering education (program «4P»). An essential part of learning-teaching process is monitoring-testing materials (didactic), and monitoring-assessment means, since tests are of low efficiency due to the variety of research themes. Formal part of research in the form of Master dissertation is checked for consistency to GOST standards by a code manager. The question is how to arrange an objective assessment of the projects? How to overcome subjectivity? What are the assessment criteria? Can they be strictly specified?

Suggested technology implies application of such methods as annotation, definition of key words, abstracting, reviewing as innovative elements forming evaluation of the developed project both in general and in parts. In this case the essence, idea, assignment of annotation and report are not mystery for master students, as a result masters attain the idea of difference of maser's dissertation as a research project from a report overcoming an annoying erroneous approach typical for the previous stages of self-learning.

The situation with assessment of mater dissertation content is more complex and interesting (testing, validity checking). Suggested technology suggests consistent and interconnected performance of mutual monitoring allowing for «feedback» between researchers, basic forms of mutual monitoring being formalized as well, performed by using a number of monitoring-assessment tools in the form of tables completed by students. For example, the task is given to mutually annotate the materials of dissertation obtained at the intermediate stage. At the lecture it is explained what annotation is, how sections «summary» and «keywords» should be written, as well as what goals, tasks, and principles of reviewing material are, what the difference of formats is, correlation of annotation/reviewing/note-taking procedures with the elements of personal research work in the course of an engineering project. A review is a brief version of three or more sources following author's logic. In contrast to annotation a review contains comments for the key statements of the text, suggests «a reader's thoughts on the margins», note-taking suggests a thorough quotation etc. Then, the task is briefly set in three stages: 1. individual 2. pair 3. group. At the first stage «the task for independent work is given individually»: students write a mini-review (volume of 3 pages) based on the material of notes from three and more articles, the review text being connected with quotations, and the quotations – with the references. The 2-nd stage of «pair work» is to check the content of review working in pairs, perform error correction. In this case «Task for coordinator (monitor)»: distribute the tasks, follow the course of performance, answer the questions, collect the results, arrange checking in pairs, collect the results, check the quality of performance selectively. Such technique provides the interaction of future engineers in a team, a chance to ask each other questions, to give advice, mutually clear up the general problems and search for their solutions. The 3-d stage is «group discussion», when the «latter» developments are presented orally; master-students are to listen, ask questions, and give advice to a presenter on error correction.

Checking validity of the project performed at the stage of research feasibility study («Implementation» in terms of CDIO) can be made by means of scientific methods of annotation or reviewing. Mutual annotation (recital and unbiased), abstracting (descriptive and evaluating) and, particularly, reviewing (evaluating and discussing) of the research materials serve as techniques of students' mutual monitoring. For example, three times within the academic course master -students perform «a task of independent work in pairs: exchange the cases with materials of master dissertation, check their content, present the written analysis according to the offered scheme (form) or in a free format, put a checker's signature (in case of non-critical attitude the results are selectively checked again, the cause may be absence of comments, remarks, questions etc.). A checker fills in the column «correcting actions» - «error correction», or answer the questions defending the parts of research. The monitor's task is to arrange «pairs» of reviewed-reviewer using the principles «strong student-weak student», «strong student-strong student», or randomly; hand out the forms, collect, check out their completion, countersign with the words «checked, meets the requirements», «checked, should be revised (with reason)».

This algorithm made great impression on male master-students as, in the course of the first business game they could, apart from the expected knowledge enrichment, compare their level of skills-competence-qualification with that of other group members brining the elements of competitiveness. Female master-students showed higher degree of loyalty, inclination to assign «hidden» strengths to an opponent. Hence, at the first class «Selection of research theme» during 5 minutes of the business game «Hello, what do you do?» a group of 20 students selected: 1. The most topical (interesting) theme of master dissertation, 2. The most extraordinary theme, 3. themes - «doubles». There was even so to say «side effect» as soon as students solved some super-problem that had not been set by the teacher – they managed to guess who of master-students joined after bachelor graduation of similar major «automatization of power systems» from Tyumen State University of Civil Engineering and who came from classical Tyumen State University. Results served as a particular placement test permitting for definition of the level of initial skills and competences and using the intellectual potential of every student. As a rule, the level of master-students from foreign countries (Turkey, China, Kazakhstan) is not lower than that of the bachelors-graduates of Russian regional universities.

The major task defined by the section «Standard 1 – CDIO as a context of engineering education» suggests «accepting the principle according to which development and realization of products', processes', systems' life cycle takes place in the course of «conceive – design – implement – operate» model. The model defines the content of engineering education» [3, p. 5]. The applied task of engineering education resulting from the idea of CDIO is development of monitoring-assessment means as well as formation of ability to self-evaluate in accordance with objective criteria, including testing and validation of the project at the Implement stage. To develop steady skills of evaluating research, engineering products, schemes, processes, algorithms, solutions of industrial and production problems, a conditional-formalized technique of reviewing based on filling-in the form is used in addition to direct informal discussion, analysis, criticism. A fragment is shown in Table 1.

In the form fragment is given as an example, criteria and sections of assessment being at the development stage with regard to channels of «feedback». Thus, statements formulated by the master-students in the course of independent work are preferable as they reveal: 1) database for the development of general criteria of evaluation applicable for their engineering activity, 2) new ideas and approaches, 3) new problems for practical classes 4) challenges that should be managed at the nearest class 5) the form of training. Formalized form of review can serve as a «supporting document» that reflects the state of engineering project at this or that stage of research.

The parts for final assessment analysis at mutual reviewing the materials of master dissertation also include: title page, plan of dissertation, and the following parts – relevance, degree of problem development, theoretical background, methodical background, subject, goal, objectives of research, problem statement,

Table 1. Fragment of Review for Master Dissertation

Review of research project by Master __Name, Surname, group_

№	Name of dissertation section, volume, design	Relevance to the requirements of design, GOST, CDIO international standard 1, industry documents and requirements	Logic of narration, its forms	Scientific validation or corresponding supporting documents	Evaluating judgments: (8 positive and 2 negative notes), tips for error correction	Corrective actions
1	2	3	4	5	6	7
1	Theme of research	Approved /not approved by the department	Relevant/ irrelevant (explain why)	For example: «included in assigned for the department commercial agreement, approved by the department order », «presented at V. I. Potanin's contest» etc.	For example: «reduce the number of words», «specify»	Enclose the abstract of the order

current hypothesis, program of research performance.

According to CDIO International Standard development of engineering education «is to have the form of continuous enhancement and integration into the international education environment» [3, p. 2]. Engineering developments of international level and significance are impossible without access to the world achievements of engineering education, technology, and methodology. The presented methodology of the discipline «Methodology of Scientific Creativity» is focused on implementation of CDIO standards. The intermediate results of testing were published in the materials of conferences held in Tomsk State University, Tomsk Polytechnic University [1], Tyumen State Oil and Gas University. They were also represented at the events held with the support of Association of Engineering Education of RF [2].

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UDC 378

CDIO Initiative and Problems of Active Learning Implementation in Engineering Education

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The article considers recommendations of CDIO Standards on active learning methods and their application to the problems in the system of engineering education. Contradictions between the organization of educational process and conditions for active and effective learning (interactive, practice-oriented, problem-based and project-based learning) are discussed as the main reason of the above stated problems. To overcome the contradictions it is important to make significant changes in the planning and organization of training, as well as in the requirements for qualifications of teachers, that are critical for teachers' ability to use modern methods and techniques to ensure students' involvement in the learning process.

Key words: educational technologies, engagement, learning outcomes, Worldwide CDIO Initiative.

One of the progressive approaches to designing and implementing engineering undergraduate education is an international project that was introduced to the international academic community in 2000 as Worldwide CDIO Initiative. The abbreviation CDIO stands for Conceive – Design – Implement – Operate. CDIO concept is aimed at bridging the gap between theory and practice in engineering education, strengthening the practical values of training using problem and project-based learning.

As a part of the CDIO Initiative 12 standards were adopted, where Standard 8 addresses Active learning methods. Teaching and learning based on active experiential learning methods engage students directly in thinking and problem solving activities within the training process, including process management, ideas analysis and evaluation, experimentation and knowledge discovery.

According to the standards developers, active learning is considered experiential when students take on roles that simulate professional engineering practice, for example, design-implement projects, simulations. The reason highlighting the rationale for setting this standard is given in the thesis that «by engaging students in thinking about concepts, particularly new ideas, and requiring them to make an overt response, students not only learn more, they recognize for themselves what and how they learn. This process helps to increase students' motivation to achieve program learning outcomes and form habits of lifelong learning» [1].

Teaching methods and techniques used in the implementation of educational technology should motivate and encourage students to cognitive activity. The learning process should be organized so that students have the desire to participate more actively in the learning process, to take the initiative, and not just follow the prescribed rules. According to the research study of student involvement there are three types of engagement:

- academic, characterizes students' mental investment, expended effort in the learning process. Criteria for measuring this type of involvement include preparation for classes, homework, participation in classroom discussions, academic achievements;

- social/behavioral, emphasizes students actions and participation in university life outside learning process. Mainly focuses on students' interactions with other students and student communities;
- emotional, encompasses students' feelings of connection to their university, general attitude of students to the university level of support students perceive from members of the university community and their place in this community [2, 3].

Talking about engagement, we cannot ignore the role of faculty, that is expected to use active teaching methods aimed at developing the students' interest, the need for constant self-improvement, self-education, independent research and discovery of new knowledge needed when searching for solutions to the problem. One of the barriers to the adoption of new approaches and technologies in the training of future specialists is the conservatism of university community, and low motivation of teachers to apply modern interactive teaching methods. In response to this challenge the CDIO Initiative provided Standard 10 – Enhancement of Faculty Teaching Competence. If teachers are expected to implement new methods for active experiential learning and learning outcomes assessment, it is important to provide them opportunities to improve relevant competencies by supporting internal and external qualification development programs, forums to share ideas and best practices [1].

Ideas and principles of the CDIO Initiative, addressing identified problems, can be adapted and implemented in various universities taking into account specifics of the educational programs. Today, 117 universities from around the world, including Russia, have joined the CDIO Initiative. Reforming of the educational process in accordance with the CDIO requirements assists in improving the quality of engineering training, also by ensuring involvement of students in the learning process.

Wider implementation of problem-based learning could be one of the possible changes on the way of improving the educational process. Table 1 shows those features that in our opinion distinguish traditional forms of learning from the problem-based ones.

Guided by the Federal State Educational Standard (FSES) for training future engineers, universities define a set of core competencies (professional and general), that students should acquire upon successful graduation from the educational program in the filed of engineering and technology. However, the definition of a set of core competencies is just one of the steps that has to be fulfilled, but not enough for successful achievement of intended learning outcomes by the students. Providing high quality professional training mainly depends on the choice of educational technologies. Learning outcomes may be different at the same educational program and depend on the chosen educational technology. The learning process should ensure active participation of students that allows developing required professional attributes faster and efficiently. Undoubtedly faculty qualification in engineering and pedagogical fields is the essential element to achieve the objectives of the educational process.

According to the Federal State Educational Standards (FSES) the outcome-based approach requires «...vast implementation of **interactive forms** of training (workshops, discussions, computer simulations, business and role-games, case studies, psychological and other trainings) combined with extracurricular activities with the purpose of **students' professional skills** development. The training process should include meetings with representatives of Russian and foreign companies, state and public organizations, workshops provided by experts and high

Table 1. Specific characteristics of traditional and problem-based learning

	Traditional training	**Problem-based learning**
1	A large number of lectures, providing the basic content of the discipline (module)	A small number of lectures, integrating a number of topics related to the problem being solved and place students in the context of the real-world problems
2	Passive learning in large groups (25-30 people)	Active self study and teamwork in small groups (6-8 people)
3	Discipline (module) is divided into separate topics	The content of the discipline (module) integrated in problem-oriented case studies within interdisciplinary context
4	The leading role of the teacher, passive knowledge translation	The educational process is aimed at students independent search of information and new knowledge. The teacher acts as a mentor, consultant
5	Form of control of learning outcomes achievement: assessment of knowledge on the subject at the end of training	Degree of graduates' competencies development evaluated within the learning process. Integrated assessment

qualified specialists» [4]. In fact, practice-oriented, problem-based and project based learning are based on interactive forms of training.

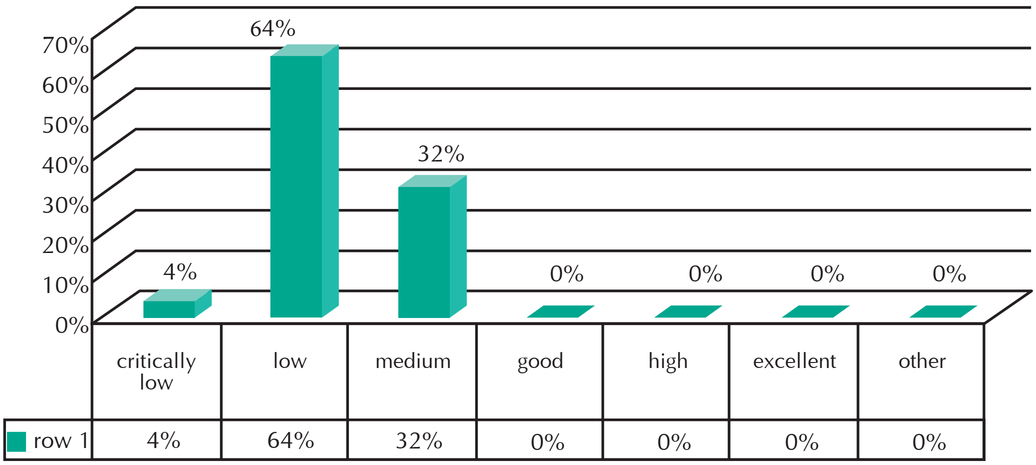
Despite the fact that FSES requires at least 20% of interactive learning in bachelor degree programs and at least 40% in master degree programs, the actual level of interactive practice-oriented teaching methods implementation in Russian universities remains dramatically low (based on the results of study conducted by the Association foe Engineering Education of Russia) [5].

The real implementation of interactive training often faces difficulties and contradicts the system of educational process planning that remains committed to the traditional teaching methods and forms of educational activities.

Experience of Russian universities shows that educational technologies required to ensure the achievement of intended learning outcomes are addressed only at the final stage of educational program designing, after the curriculum structure and academic hours for each discipline are defined. This indicates a sequence of actions confirming the priority of curricula for specific disciplines over teaching methods in educational programs implementation. It also leads to domination of knowledge-based approach over the activity approach in future engineers competence development.

Unfortunately, popular in technical universities traditional approach focused on lesson training system, does not allow achieving expected learning outcomes. Students just require ability to listen and write down instead of active independent work. The most common forms of educational activity are lectures and workshops that do not provide one of the main conditions of motivation for learning – engagement of each student in the learning process. The need for improving changes becomes obvious, primarily aimed at the selection of adequate educational technologies and teaching methods, enhancing their

Fig. 1. Expert evaluation of practice-oriented learning methods implementation in Russian HEI



effectiveness for the development of creative thinking, through transition from teaching to learning, from passive to active methods, from the reproductive activity of students to independent and creative activities [6].

High level of students' motivation and engagement in the educational process, of course, depends on the faculty competence in the field of interactive teaching methods, their ability to organize the learning process, using such techniques as brainstorming, expert seminars, trainings, case study, etc.

Professional qualification of university teachers is also determined by the frequency and duration of their internship at real engineering companies. This also assists in getting more contacts with industry representatives, who later could be invited as experts to give master classes for students on challenging engineering problems of today. A significant role can play business contracts for conducting research permitting to involve students in solving real industrial problems.

Committed to training competitive specialists, leaders and developers of educational programs should pay particular attention to the content and forms of organization of educational activities. The learning process should have such characteristics as outcome based approach, interdisciplinary content, modular and student-oriented structure with possibility to follow individual curricula. The above stated elements should be given sufficient attention at the stage of educational program development.

The implemented educational technologies and methods should contribute to achievement of intended learning outcomes, providing interactive learning, engagement and independence of students, flexibility to the challenges of the external environment, transforming students from passive listeners into active participants in the educational process.

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UDC 378.126

Activity of The Engineering Teachers Association to Implement CDIO Concepts

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The article examines a new approach to higher engineering education based on the introduction of the CDIO concept. The possibilities to implement the world CDIO initiative standards which enable university faculty to design educational process in the modern way so that students' motivation to learn is constantly outlined. The experience of the Ural Engineering Teachers Association in implementing CDIO concepts to improve educational process is presented.

Keywords: engineering education, CDIO concept, project activity, association of teachers.

Today, Russia has made fast progress in developing international relations, strengthening business activity, globalization aspects that become challenging for the system of higher vocational education associated with appropriate changes to be made. In this regard, there are some dramatic changes in engineering education concerning transition to the team project-based learning.

A new approach to higher engineering education is intended to increase practical training, as well as problem and project-based learning. These aspects are presented in the worldwide CDIO initiative aimed at reforming engineering education [6 -9].

The basis of CDIO initiative was conceived at the Massachusetts Institute of Technology (MIT) in the late 1990s. In 2000, MIT in collaboration with three Swedish universities - Chalmers University of Technology, Linkuping University and the Royal Institute of Technology - founded Worldwide CDIO Initiative [7]. Today CDIO Initiative consists of more than 100 universities around the world (30 countries). In Russia, the following universities became CDIO members:

- Moscow Aviation Institute (National Research University);
- Moscow Institute of Physics and Technology;
- Tomsk State University of Control Systems and Radioelectronics;
- National Research Tomsk Polytechnic University;
- Skolkovo Institute for Science and Technology
- Astrakhan State University;
- Siberian Federal University.

In September 2013 pilot implementation of CDIO approach was launched in the Siberian Federal University (SFU). SFU was given the status of CDIO initiative member on 16-17 January 2014 within the Regional CDIO Meeting in Chalmers University of Technology (Sweden).

The framework provides students with an education stressing engineering fundamentals in the context of Conceiving – Designing – Implementing – Operating (CDIO) real-world systems and products in the international market. This international project concentrates efforts to close the gap between theory and practice in engineering education. The new approach enhances hands-on training also by introducing problem and project-based learning [6; 8].

CDIO creates the necessary context for professional education, address program and curriculum philosophy, involves active methods of teaching and learning that engage students to solve practice-oriented tasks, focuses on faculty development including pedagogical competencies and skills in implementing operating systems and products, as well as program evaluation and students' learning assessment.

The CDIO Standards serve as a guideline to educational program design based on continuous activation of students' learning activity. Within the training process engineering fundamentals and social content of professional engineering activity are formed that allow to transform learning activity of students into real professional activity.

Creation of an Association of teachers of engineering universities of the Ural region is one of the steps that contributes to promoting practice-oriented training and project-based learning. This fact is rather actual taking into account that nowadays university teachers should be active and mobile, should monitor developments and achievements of colleagues and share their experience, participate in research, even in a distance mode [1; 2; 5]. Our experience has proven that it is more convenient and more efficient to act as a part of professional association, uniting enthusiastic and motivated teachers [4].

It should be noted that it is more reasonable and advantageous to form the Association of teachers, who work in the same specific field of training or have the same profile of educational program or department. For example, the Association of Teachers of specific engineering disciplines which brings together several universities in Russia: South Ural State University, Siberian Federal University, Perm National Research Polytechnic University, Ural State University, Chelyabinsk State Academy of Agricultural Engineering. The activities of this association are regulated by the following documents: Regulations on the Association, Code of Ethics for teachers – members of the Association and others.

To become a member of the Association a university teacher must apply for the membership, that is realized at different hierarchical levels: intern, provisional member, member or an honorary member of the association. Obtaining a certain status is based on the analysis and evaluation of scientific and pedagogical achievements of the candidate in the research, methodological and innovation fields.

Initially candidates were approved under recommendation or introduction made by deans or heads of departments of participating universities. Thus the pool of members was created. Other teachers when applying had to introduce their scientific and methodological works, conduct a master class or submit a research report, that were evaluated and served as a basis to give a candidate a certain level of membership within the Association.

Teachers, members of the Association, interact in different ways, including active work in sessional period (usually 4 sessions a year), as well as continuous cooperation between sessions.

There are different types of activities foreseen for teachers during on-site sessions usually based in one of the participating universities, like workshops, training sessions, business games, presentations of teaching materials and scientific achievements and other. Between sessions the most popular forms of interacting are media lectures, online discussions, webinars, etc.

Such forms of activities organized for members of the Associations have some positive impact in terms of training teachers to apply team-work learning methods and project-based learning for students.

In particular, master class is one of the most effective forms of sharing teaching experience [3]. Therefore, within one session 3-4 master classes are held:

a) Analytical – «Analysis of the labor market needs for engineering graduates in the Urals», «Trends in engineering education development in Russia», «Regional specific features of engineering education» etc.

b) Teaching – «The concept of the course Fundamentals of Civil Engineering», «The concept of the course Production logistics», «Developing engineering and economic modules for the MBA program» etc.

c) Psychological – «Time-management for teachers and students», «Stalking the energy», «Effective solution of pedagogical task» and others.

Training activities not only focus on acquiring skills of problem and project-based learning, but also contribute to the development of personal skills and attributes of a teacher. These types of activities are especially accepted with pleasure by young teachers beginning their carrier, professors usually treat them skeptically and operate formally. Therefore, such classes are more successful among young (beginning) teachers. The highest ratings are given to the reflexive procedures «Tree», «Give a name to yourself» and «Advertising clip»; project drawing «I am the way I am», activities like «Carousel», «Teaching observations», «I've been lucky in my life» and «Hero of our time.»

A hosting university prepares a business game for each on-site session. For example, a business game «Who are our competitors,» showing the nature, mechanisms, pros and cons of competition; business game «Press Conference», focuses on professional self-development of participants, effective ways of planning professional activity of the university teacher, ability to implement reflection of difficulties and obstacles in the process of professional growth; game «Choice» assisting teachers who find themselves in a situation of professional crisis, making the right choice for the further growth and development in the profession.

Presentation of scientific papers and teaching materials is very important and quite effective form of implementation. There is no secret that many universities have their own printing houses and publish educational, methodological and scientific literature. These publications are often «local» in nature and are not available for a wide pedagogical community. An opportunity to make presentation at the Association sessions allows teachers to be evaluated by colleagues from other universities and provides new market for disseminating their results.

During the inter sessional period, members participate in the Association activities through virtual departments, such as «Heat Power Engineering», «Metallurgy», «Software Engineering», «Computer Science and Engineering». It is important to note that each participating university is leading one of the areas, in other words, each university is responsible for one of the virtual departments. For example, the South Ural State University heads the virtual department «Heat Power Engineering». Each virtual department has its work plan, which is based on a survey of all members of this department on current issues in higher engineering education. According to the collected data the plan is developed and responsible members are appointed. As a result a special field of virtual department work was created called «Master lectures». These lectures are broadcasted live in the Internet. The topics of such media lectures are connected with those disciplines covered by department. As a rule, these are the topics that students have particular difficulties when learning and teachers share their experience of preparing and presenting such a complicated material.

Especially popular are the virtual master classes where teachers share their own features about workshops with students (in relevant disciplines) and how to better implement project and problem-based learning.

After the virtual lectures and master classes there is time for discussions which contribute to the development of ability of self-reflection, analysis of the possible ways for personal growth, increase confidence in their own abilities, help to express themselves in various aspects of teaching and development of positive thinking, setting perspective and other professional objectives.

A new form of virtual work of the department deals with holding public lectures or practical (workshops, laboratory) classes. This form assumes an open broadcast in real time. From the Association members' point of view this form of professional experience should be extended.

It is noteworthy that online disputes as another type of activity for interaction of teachers was born quite spontaneously. At the website of the Association often new forum topics are started where teachers discuss various issues related to professional activities and exchange their views. Active discussions revealed the need for virtual online discussions through the media bridge. Among the most frequently discussed topics are the following: «Preparation and execution of grant applications in engineering fields», «Monitoring on», «Development of network educational and methodological complex of engineering disciplines» and others.

Effective form of the Association activity aimed at promoting the professional development of teachers in terms of introducing the CDIO approach is based on reviewing learning and teaching materials, research studies of colleagues from other universities. This is a mutually beneficial cooperation: the author promptly receives an external review, participants get critical thinking skills to review the concept presented by the author also comparing with their own achievements and successes stories. Of course, many members of the Association are seeking approval of their achievements by the expert community within the virtual departments.

It is also important to focus efforts of the Association on bringing active learning methods in the framework of integration and closing the gap between various humanitarian and technical disciplines while making project work, modeling engineering processes, solving problems as in the real-world engineering practice. This integration is based on modeling real work situation within the training process, highlighting the key issues, searching possible solutions using knowledge and skills from different fields. Adoption of the principle that product and system life cycle (conceive, design, implement, operate) are the context for engineering ensure the most effective use of active learning methods in engineering universities.

Thus, teachers, members of the Association, are able to maintain the highest level of competence in their work; take into account modern society requirements and quality standards; continuously improve their professional skills; conduct research, using modern scientific tools and developments, what undoubtedly contribute to the quality of higher vocational education.

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UDC 378.1

Team-building for Implementing Innovative Basic Education Program within CDIO Ideology

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It have been revealed that to improve the quality of engineering education it is required to build a creative team of teachers for developing innovative framework which guarantees adaptation and implementation of CDIO ideas. The article presents the experience in team-building including selection criteria. The task to create the unified team of teachers, students, employers and University authorities is set.

Key words: innovative process, CDIO ideas, criteria for selecting team members, team-building.

CDIO ideology implementation in engineering training is an innovative complex process which implies adaption, development, assimilation, application of CDIO concept, as well as dissemination of the innovations aiming at improving the quality of engineering education [1, 2, 3].

Conceptual principals of the engineering education in CDIO ideology are the following:

1. Basic Education Program (BEP) addresses learning outcomes (LOs) that are developed in collaboration with employers to meet the needs of particular industry, and defined as graduate's competences with taking into account international and domestic educational experience, as well as CDIO concept, and manifested through problem solving activities.
2. Phased implementation of skill development as a technological and methodological process of engineering skills enhancement, as well as personal, communicative and professional skills development based on active learning, integrated educational content, and project activity.
3. Practice-oriented educational process that is ensured by increasing number of internships and training in real industrial environment.
4. Evaluation and monitoring of learning outcomes achievement by measuring competence constituents.
5. LOs in the form of competences are specific and measurable.

This process implies principle changes in BEP content and educational technologies. It is focused on graduate's competences as the form of LOs, and implemented according to the following steps:

- adapting CDIO concepts;
- developing innovative BEP;
- implementing BEP in educational process;
- spreading the proposed concept and implementing it in social and educational environment.

The innovative process described above is logical and relevant to CDIO ideology: Conceive –Design – Implement – Operate.

While implementing CDIO ideology at School of Non-Ferrous Metals and Material Science, Siberian Federal University, it was found out that this process, like all educational innovations, caused some resistance of teachers, since they have to adjust themselves to new educational environment. This pushback was manifested through various forms: persistent disregard of innovation; demonstrative adherence to the traditional and established ways; criticism of innovation without understanding its essence; obvious unwillingness to change their activity. The intensity of such resistance depends on a number of factors with the main one being teacher's matching the impending changes with his/her personal benefits and self-determination in a new educational environment. It was necessary to take away the teachers' fear and anxiety of unknown, which set a number of objectives for the initiators of CDIO innovation. Firstly, the teaching staff were to be widely informed about the key provisions of worldwide CDIO initiative, goals, objectives, and learning outcomes of the innovative educational process, which could be achieved by ensuring access to information about CDIO, as well as launching a website to convey information about a project "Local system of continuous multi-level engineering education, specialty "Metallurgy", in CDIO ideology. Secondly, it was necessary to develop a training and consulting system in the frame of staff professional development for those who might be willing to be involved in innovative activity.

Professional development of teachers for innovative BEP is not to teach something new, but to change the traditional knowledge approach to training process to the activity approach which is less acquired. In fact, it is required to train teachers to teach other things (priority to activity) in a completely different manner.

However, BEP implementation in CDIO ideology made it necessary to build a team of creative like-minded persons united by the aim to develop and implement an innovative educational process. Engineering education quality improvement can be achieved through the development of effective teamwork. It is a new complicated task that needs much time to be solved. Team building for innovative BEP implementation in CDIO ideology is a big challenge for engineering education due to the following factors. Firstly, teacher team building has not been well studied yet both in theoretical and practical aspects. Secondly, while implementing a competence approach with competences being viewed as learning outcomes, it is necessary to develop BEP with regards to professional competences being developed during a whole course, thus ensuring their interconnection and interdependence, as well as their evaluation. Being a forecasted aim of engineering training, the learning outcomes determine the content of engineering education and the number of credits for each discipline. All the mentioned above allows us to say that the learning outcomes are the base of the learning content for a whole education period, which differs from the traditional approach with the curriculum cut into separate disciplines and teaching staff of non-graduating department being unaware of final results.

The integration process is implemented through a teaching staff that ensures the learning content to be connected with learning outcomes, which makes stronger interdisciplinary connections.

Such team of teachers is a collective unit with different forms of group behavior, interconnection in activity and intensive relations between group members [4]. Regarding team building as a targeted process, one should answer the following questions:

- How can the teaching staff be involved in innovative activity?
- How can teachers be supported in difficult situations forcing them to change themselves?
- What requirements should the group members meet?
- How many members should be the group comprise of?

The answers to the questions are given further.

The team building process identifies the following stages:

- focus on CDIO ideology values;
- adherence to CDIO ideology values through collaborative design if BEP;
- consolidation as a team while implementing BEP.

The key factor of the first stage is to

promote faculty awareness on advantages of innovative concepts. This stage resulted in teachers' making decision on whether to participate in the innovation or not. The decision was motivated by numerous factors including those that are significant for being involved in innovation, such as psychological disturbance, interest in positive experience of other universities.

The second stage involved building a team of teaching members who were willing to implement CDIO ideology in the educational process. During 2013-2014 academic year, the team with participation of the administration office developed an innovative BEP in accordance with the concepts mentioned above. On the one hand, it was a cooperative activity contributing to team building, on the other hand, different members of the team worked individually or in small groups fulfilling different functions (distribution of roles):

- teaching staff of graduating departments, administration office of the School, and industry stakeholders/employers were jointly working to agree the significance of each BEP competence as a key learning outcome;
- faculty members who were in charge of theoretical analysis examined the data submitted by industry stakeholders/employers to define whether they were in compliance with FSES and CDIO standards. Based on the analysis results, the graduate's competence model was developed;
- being the result of a joint effort (stakeholders/employers and university), the competence model was justified, discussed and revised at various problem-based learning seminars, which made it possible not only to analyze the work done, but also to comprehend the common goal of the team and the ways to achieve it;
- competence model design in accordance with BEP sections, the need to agree them with the subject areas stipulated building the team comprised of teaching staff from different departments;
- the new-build team was consolidated alongside BEP implementation, and in order to ensure the final goal achievement, it involved teaching process monitoring, joint action in identification and analysis of possible challenges with a view to making recommendations.

The main criteria which we used in team member selecting are as follows [5]:

1. ability to adapt to change;
2. high degree of professionalism;
3. adaption of and adherence to CDIO values, clear identification and division of objectives and responsibilities for innovative BEP implementation;
4. communicative skills.

The number of team members was defined on the basis of reasonable sufficiency enabling, when necessary, the substitution or replacement of a team member.

The ability to adapt to change allows a faculty member to implement innovative approaches into teaching process, i.e. one of the components of CDIO ideology team work. It manifests through continuous development and renovation of professional activity in compliance with the project specifications agreed by all team members. Team building is facilitated by specially developed information support to handle and promote engagement, collaboration and dialogue among the team members.

High degree of teaching staff professionalism enables to implement more innovations in the teaching process due to more creative responses to emerging challenges.

The communicative skills that govern the interaction between teaching staff provide them with every opportunity to discover their creative and professional potential which, in its turn, contributes to achieving the common goal of the team.

Understanding the importance of adapting the goal of innovative changes by all teaching staff, we decided to organize the weekly problem-based learning seminar series. The experience showed that such form of problem discussion stimulates self-reflection of team members, contributes to finding a common ground for their views, beliefs, and values forming a specific subculture of the team. Today, School of Non-Ferrous Metals and Material Science (SibFU) has initiated the implementation of innovative education program "Metallurgy". The experimental student group comprises 25 persons. In 2014-2015 academic year, the program involves 27 faculty members who have adapted CDIO standards. The number of faculty members having candidate (PhD) and doctor degrees is 75 %. The team consists of rather young specialists (average age is 44) who were engaged in developing new education program within one year. The team is still being developed. At this stage, one of the tasks to be addressed is to instill in each team member the responsibility not only for the results of their activity, but also for implementation of the entire project. This can be achieved by introducing monitoring activities developed and agreed by all project participants.

As students are the main constituents of the teaching process, it is reasonable to provide them with the conditions which will help them adhere to team work ideas and consolidate the image "We". When students perceive themselves as parts of this image, they can work as one team regarding CDIO values; demonstrate a genuine will to implement CDIO standards collaborating with each other or faculty members. Student team is consolidated through joint activities in preparation for meetings with teaching staff and industry stakeholders/employers, development of "visit cards", participation in collaborative work-shops and training seminars.

We strongly believe that the creation of an integrated team involving teaching staff, students, University administration, and industry stakeholders/employers is a logical result of team building as a part of CDIO ideology implementation in the innovative BEP. Practical activities aimed at finding a common ground for innovative teaching and its implementation by the stakeholders continues: the role of employers both in traditional classroom learning and internships including advanced training has been specified; the schedule and content of intermutual professional development programs for teaching staff (in enterprises) and employers (at university) have been adjusted and improved; the issues that are faced by real industry have been identified, and the ways to address them in bachelor training have been proposed; a number of meetings involving students and the leaders of industry have been held.

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UDC 378.1

Human Resource Management for Developing Basic Education Program in CDIO Ideology

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The article highlights the issue of human resource training for CDIO ideology implementation. The issue is addressed by reviewing human resource management that involves all the stakeholders of the program: teaching staff, university managers, university applicants, students and business and industry representatives.

Key words: human resource of Basic Educational Program (BEP), University applicants, students, teachers, project managers.

Defining human resources (HR) groups is an essential element of preparatory stage of any new project implementation. Therefore, at Siberian Federal University (SFU), while developing education programs that meet CDIO initiatives, the following HR groups have been involved: teaching staff, university managers of different levels, university applicants, students and business and industry representatives that are responsible for further staff training and improvement.

At the beginning of the work we studied basic challenges each of the group is faced with. For example, employers traditionally spend some resources on retraining or further training of young specialists. Therefore, those teachers who keep in touch with the graduates, professional community and employers are often dissatisfied with their professional results. University applicants when choosing an engineering course are typically unaware of their future professional activities and areas. University managers try to find points of growth and positive changes in educational system, on the one hand, and to optimize its resources, on the other hand. Thus, we did a good work by uniting representatives of all the groups into one project team to achieve new results in engineering education. This work is still being carried out to guarantee educational process to be within CDIO ideology [1, pp. 2-10]. The characteristic features of the proposed approach is highly used and developed pattern that allows us to implement separate elements of the educational process in a technological way, and being flexible and having a wide scope, the CDIO ideology can be effectively adopted to particular educational conditions.

Four specialties of SFU became an experimental base. They are: Thermotechnics and Heat Power Engineering, Metallurgy, Software Engineering and Informatics and Computing Technology.

The first stage was to determine (identify) the University staff that would be interested in further professional development and be ready to significant changes in their professional activity. This means that teachers and managers should be motivated by two factors: personal investments of time and efforts and dissatisfaction with their work results and student learning outcomes in general. It is impossible to solve this problem at a big University (there is a wide scope of engineering specialties in SFU) just by “giving an announcement” or holding a competition. The staff’s motivation should be supported by real demand for particular engineers and by productive interaction between a University and employers who tend to be involved in such educational process. Besides, critical approach as a base of CDIO ideology determines significant changes in educational process and brings about the following requirements to HR: creative thinking, freedom of thoughts, systematic thinking and work etc. In other words, these are the specialists capable of developing their professional activity to higher level. In fact, we have implemented recursion by using CDIO approach (Conceive – Design – Implement – Operate) through elaborating requirements to the staff. These criteria formed the basis for choosing four specialties and a staff team to implement CDIO Initiatives at the University. It allowed us to choose leaders and managers for each specialty as well as potential employers.

The project leaders had to seek for motivated teachers who could be interested in project design and development. Thus, each project organized a team that was familiar with CDIO Initiatives. The University administration did not control the selection of candidate for the project team. Though being selected in accordance with CDIO ideology, not all the leaders managed to apply this approach at the starting point of their activity. Nevertheless, they had to study CDIO ideology in detail in the course of project development to explain the main objectives to the teams. As a result, the process of project design concentrated necessary staff for further project implementation.

In accordance with CDIO, there are two staff training areas: pedagogical and engineering. In addition to that the staff took English courses to be more integrated in the international CDIO community and to apply the English language in the teaching process. Staff development is a continuous process that should be carried out throughout project duration, i.e. for not less than 5 years. Pedagogical was the first area to be suggested for the staff. The main objective was to implement the first standard that is to take CDIO ideology as a base of professional activity. The staff development was founded on the following principles: various forms of training, practice oriented tasks, public report on learning outcomes and expert assessment of learning outcomes. Our teachers took part in different courses and seminars in Russian and foreign universities (Tomsk, Moscow, Ekaterinburg, Chalmers, Barcelona etc.), taught their courses and public expert events (seminars, CDIO days) for better understanding of CDIO ideology and its implementation in teachers' professional activities. The University administration insisted that all the staff members of the project should study in detail the CDIO Initiatives and report on their professional achievements in terms of CDIO ideology, otherwise, the teachers have no rights to deliver courses in the frame of the project, which is recorded in the University regulations.

A number of public CDIO events were regarded as further professional development since they gave the opportunities for the teachers to report on their results, evaluate others, to identify new challenges and clear up some notions and ideas. It was a productive way to communicate with the University administration, to make a collective reflection that results in personal one. Such seminars and "CDIO days" always included reports on each education program, on particular CDIO issues, as well as "problem team" work focused on particular challenges to find different ways of solution. Experts' work was the other essential element of the seminars. They were to assess the reported results and to make the "problem team" achieve their goals. In addition, every seminar participant filled in questionnaires that reflected their readiness to work in CDIO ideology, which allowed the managers to capture a complete picture of the project development stage. Thus, these events fulfilled a monitoring function, as well.

The teachers should develop a curriculum in a discipline, implementation methods and teaching materials as a result of their annual work. While evaluating the teachers' work, we discovered the following: different levels of the ideology acceptance among the teachers, poor success in applying examples presented in the courses for their practical course development, low (elementary) reference level of pedagogic competences that are mostly based on practical work rather than theoretical knowledge of the teachers. It is explained by the fact that engineering disciplines are taught mostly by engineers and technical university graduates who are unaware of fundamentals of pedagogy and psychology of higher school, didactics, etc. Thus, the first year of staff training resulted in dividing the trained staff into two groups. The first group included those (mostly young ones) who are interested in the CDIO ideology, value and quite understand it, though having problems and making mistakes in its practical application. The second group of teachers did a lot formally but was not really interested in any changes having no inner motivation for that and being quite satisfied with the results of their professional activity. Furthermore, the administrative staff experiences deficiency of specialists qualified enough to do such kind of staff development, the situation being the same of other Russian universities.

Collaboration with employers gave us the ideas of the courses that have never been offered for traditional staff development but are necessary to prepare teachers for innovative education. They are the following:

- "Engineering project" as a discipline.
- Kaizen (continuous improvement).
- Advanced education (to teach in advance).
- Network education.
- Backbone and value-setting disciplines of engineering areas.
- Team competency.
- Productive management stimulation of individual work.
- Education fundamentalizing.
- Competence measurement.
- Assessment of teachers.
- Teaching process evaluation by students.
- Curriculum assessment by professional communities.
- Employers, their role in network teaching process.
- Methodology of modern engineering science.
- Development of new engineering idea and technological breakthrough.
- Effective business unit.

A special challenge we dealt with while implementing the first CDIO standard was to elaborate and approve a common concept on new learning outcomes. Most part of young participants and only few representatives of managers and teachers (those who concern with innovative activities) are ready to abandon traditional learning outcomes and professional activity. Most teachers feel stress and resist to development of new learning outcomes for particular discipline though formally accepting the idea. Some teachers substitute projects with lab tasks developed long ago and are strongly against employers delivering special courses. In these cases, it is reasonable to give the choice for the staff to "leave" the project and return to traditional teaching approach. Those who keep to CDIO ideology should be motivated both by material stimuli and higher status that allows them to participate in education development problem solving including implementation of CDIO education practice with its essential reflexion.

Other difficulty was collaboration with employers. University and employer's representative speak "different languages", which is explained by different production cultures. Thus, before negotiating new cooperative learning outcomes, it is necessary to construct a "field of mutual understanding". Consequently, it is impossible to start working in CDIO ideology with any employer. The results can be achieved only with the employers having close informal educational and scientific relations with the University. Besides, an enterprise should perceive the new collaborative project as a strategic line of staff development.

All the mentioned resulted in the following requirements to the employers to participate in CDIO ideology implementation. They are: regional employer; the product is demanded in the market; HR policy have been developed in collaboration with the University for many years and is expressed through informal contracts performance, active employment of the graduates, effective collaboration in internship, scientific activity and public relations. Not being sure of a long-term CDIO contract and not being able to ensure official contract relation at the starting stage of the project, we asked the employers for a written agreement on their participation in CDIO education project development with an indication of people responsible for implementation.

The next stage of collaboration with the employers was an iterative process to elaborate and range the learning outcomes. Different employers were ready to different levels of the work. The task was understandable and easily achieved for those who have their own professional standards or were working on them. But they were few. As for the others, we summarized the learning outcomes according to FSES and CDIO for them and asked them to add, exclude or specify the points to their mind. At the same time we compared the FSES and CDIO requirements with regard to four specialties and made sure that they do not contradict each other, though having different values for different points. As a result of iterations and mutual coordination, which was time consuming, the employers managed to write a list of requirements to the learning outcomes. Then, the employers were offered to range the elaborated requirements or to divide them into 3 groups according to their value. The results were added by interviews with graduates, staff of special departments and other stakeholders.

While elaborating CDIO syllabus and basic education program most teachers have had to review for the first time didactic units of the disciplines in terms of their importance and continuity. They had to overcome traditional approach to the scope of disciplines, their place in a curriculum and, what was the most difficult, to decide whether some parts of course or the whole course are necessary at all [2, pp. 1-3]. Thus, as we recognize that the first stage of the project was carried out by teachers, the objective of revolutionary changes in curriculum was not achieved. However, we put an objective for a teacher not to transfer knowledge but to make conditions for student's professional growth and to monitor it.

On elaborating the new curriculum and the education program we had to break down stereotypes that had been created for decades, to change the members of teams that are responsible for developing such documents, to make them coherent, logically and didactically justified for CDIO ideology. Curriculum should be constantly developed in the frame of the ideology as the staff develops their competences in this field.

For the most part of the teaching staff it was very difficult to elaborate methodical support of a discipline, having no experience in methodology. Being unaware of active training techniques, they didn't take into account some important points. So, in spite of the learning delivery, the key quality indicator will be implementation of study process in the frame of a discipline. Besides, to address managerial issues, we organized methodical support for a project work including interdisciplinary [3, pp. 155-156]. With the help of employers the topics, types and leaders of the projects were chosen. Thus, preparing methodical support, we also gave the possibilities of personal realization for every teacher in the frame of CDIO ideology. But the main scope of such work will be implemented at the next stage of the project.

A special task was to define approaches and requirements to University applicants and to find the ways to make the new education programs attractive for the students. [4, pp.48-50]. This aspect was not paid attention to until the Enrollment began. Consequently, this process was organized spontaneously: questionnaires, school diploma assessment etc. It is useless to resolve this task without taking into consideration the potential of the stakeholders. But this potential can be expressed only through the study process itself. The administration suggested the ways and had to motivate the staff to use them.

It took us one year to prepare the HR for CDIO ideology introduction into study process. As a result, the study process has been launched and the next stage of CDIO introduction has been started.

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UDC 378.141.4, 378.14.015.62

Experience and Further Reflections on Practice-Based Learning Development at Omsk State Technical University

Omsk State Technical University
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The article discusses experience and prospects of practice-based learning development at Omsk State Technical University (OmSTU) through the establishment of resource centers and basic academic departments in corresponding enterprises, as well as implementation of CDIO standards.

Key words: practice-based learning, resource center, base chair, CDIO, educational program.

Major Soviet Russia enterprises of many industries such as aerospace and aircraft engineering, transport machine building, precision tool engineering were accumulated in Omsk. Their high level of technological intensity is guaranteed by high-quality engineering staff, predominantly from Omsk Polytechnic University.

Fundamental knowledge gained in 5 years at the university was thereafter reinforced with practical skills which graduates "young specialists" obtained over first 3 years of working experience in a definite enterprise. It was this period when new employees gained practical skills, or as they say now "competences", under supervision and control of experienced workplace supervisors. That was the way for a "real" engineer to grow.

During 1994-2008, many industries of manufacturing sector, which were located in Omsk, faced serious stagnation. There was lack of cooperation between higher professional institutions and manufacturing enterprises. As a rule, such cooperation implies internships and involvement of specialists in student progress assessment. Having graduated from universities, majority of young engineers chose a different career path. Therefore, they have lost their theoretical knowledge and have not gained any practical skills. It means that they will never become "engineers".

Now comes a new period, when it is obvious that economy of the country should be based on manufacturing sector. Enterprises gradually started to recover and increase their potential within contemporary framework. Engineers having sufficient knowledge in new equipment and machinery are in high demand. However, due to new economic conditions, not all enterprises can employ graduates and patiently wait when she or he becomes a "real" engineer. The other challenge is that duration of higher professional education has been changed from 5 years (in fact, 8 years) to 4 years.

A serious problem has arisen – how to enhance the quality of engineering education under new conditions, i.e. to expand student practical training in limited duration.

At the first stage, Omsk State Technical University (OmSTU) focused on the establishment of resource (innovative) centers. A new quality level of educational process was provided by spending money on purchasing the most up-to-date equipment required to deliver training within definite education programmes. Such resource (innovative) centers facilitate student learning by engaging them into real production process and research. Besides, these centers offer various advance programs and refresh courses for the employees of manufacturing enterprises. A total of 12 resource (innovative) centers have been established at OmSTU (Table 1).

The most successful and effective resource centers are those which have already repaid the expenditures:

- Modern Techniques in Mechanical Engineering.
- Research Institute of Radio Electronics and Instrument Engineering.

100% of the graduates in the programmes supported by these centers are annually employed.

Table1. Resource (Innovative) Centers and OmSTU Basic Academic Departments in Enterprises

Resource center (name; profile/ specialization code*)	Basic academic departments (name, location, profile/specialization code*)
1. Modern techniques in mechanical engineering 15.03.05	1. Department “Aircraft Engineering“ in Production enterprise “Polyot” – branch of Khrunichev State Research and Production Space Center, 15.03.05; 24.03.01; 24.04.01; 24.05.01
	2. Department “Gas-Turbine Engine Manufacture” in OJSC “Omsk Engine Design Bureau” 15.03.05; 24.03.01; 24.04.01; 24.05.02
	3. Department “Production Facilities Operation” in OJSC “Vysokie tekhnologii” 15.03.05
2. Pressure metal treatment and foundry technologies 15.03.01	4. FSUE “P.I. Baranov OMO” branch of FSUE “MMPP “Salut” 15.03.01; 22.03.01; 22.04.01
3. Welding in civil engineering 15.03.01	
4. Research Academic Resource Center of Nanotechnologies 22.03.01; 22.04.01; 28.04.02	
5. Auto transport service 23.03.03; 23.05.02	5. Department “Hydromechanics and auto vehicles” in OJSC “Transport Machine Construction Plant” (OJSC “Machine-Building Design Bureau”) 13.03.03; 23.05.02

* *Profile/specialization codes are given in accordance with the order № 1061of the Ministry of Education and Science of the Russian Federation dated September 12, 2013 № 1061*

6. Power supply 7. Energy efficiency 13.03.01; 13.03.02; 13.05.01	6. Omsk branch of Quartz Group, Inc 13.03.01; 13.03.02
8. Research Institute for Radio Electronics and Instrument Engineering 11.03.01; 11.03.02; 11.03.03; 11.04.03; 11.03.04; 11.04.01; 11.04.04; 11.05.02; 12.03.01; 12.04.01	7. Department "Construction and Radio Electronic Equipment Technologies" in: PJSC «Omskiy Nauchno Issledovatelskiy Institut Priborostroeniya» (basic education programmes); Production Association «Irtysh» (advance programmes); Scientific Research Institute NII Neptun (advance programmes); JSC "Saturn" (advance programmes) 11.03.03; 11.04.03; 11.03.01; 11.04.01; 11.03.02
	8. JSC "Tsentral'noe konstruktorskoe byuro avtomatiki" 11.03.03; 11.04.03; 11.03.01; 11.04.01; 11.03.02
9. Information technologies 02.03.03; 09.03.01; 09.03.02; 09.03.03; 09.03.04; 10.03.01	9. "Satori-Partner", ltd. 09.03.03
	10. ISS "Art"
	11. limited company "Tele2-Omsk" 27.03.03
10. Hydrocarbon Pipeline and Tank Design 18.03.01; 21.03.01	12. "Gazpromneft-ONPZ" 15.03.02; 15.04.02;18.03.01; 18.04.01
	13. ONHP "Oil and Gas Engineering" 15.03.04; 18.03.01; 21.03.01; 27.03.04
11. OmSTU-FESTO 15.03.04; 27.03.04.	
12. Polytest 15.03.03	
	14. Scientific and technical complex «Cryogenic technique», Ltd. 15.03.02; 15.04.02; 16.03.03; 16.04.03
	15. JSC "Omsk Map Reproduction Plant" 29.03.03; 29.04.03

The next stage was to establish basic academic departments (workspaces) of OmSTU in corresponding enterprises. A total of 15 departments have been founded (Table 1). The idea was to attract industrial facilities and intellectual assets of the enterprises to teaching process during senior years.

It is a fruitful experience for students to become familiarized with the different aspects of real manufacturing, to do research on the specific topic assigned by enterprise's specialists, which in its turn significantly contributes to facilitating practical competence of OmSTU graduates and assists them in adapting to their new professional roles.

We also seek other ways and means.

Having analyzed the educational experience of leading Russian engineering universities [1, 2] and European Engineering Schools [3, 4], the decision to train specialists through practice-oriented learning technologies on the basis of CDIO standards (Conceive, Design, Implement, Operate) has been made.

One of the main reasons for choosing this particular approach to modernize engineering education is that CDIO standards can be easily adapted to the education programmes offered by OmSTU, which have been developed in accordance with the Federal State Educational Standards (FSES) of the Higher Professional Education. Besides, the experience that has been already gained could assist in implementing the above-mentioned standards.

The needs analysis of the military-and-industrial complex enterprises located in Omsk region, as well as examination of university facilities and analysis of university faculty have revealed that it is more effective to implement CDIO standards into master's degree programmes. It is this degree or level of education when it is possible to focus on developing practical skills relevant to inventive work, conceptual design and design-implement experience, which are the appropriate context for engineering education.

Since 2014-2015 academic year, several master's degree programmes offered by OmSTU have been delivered so that they could meet all of the CDIO standards, i.e. international educational project (Table 2).

These master's degree programmes have been developed by request of military-and-industrial complex enterprises located in Omsk.

Table 2. Master's degree programmes delivered in accordance with CDIO standards

№	Master's degree programme	Programme outline
1	Mechanics of small unmanned aircraft vehicles (15.04.03)	The programme is intended to train specialists and experts who will be capable of designing and operating small unmanned aircraft vehicles.
2	Design of machinery production fixtures and tools (15.04.05)	The programme is intended to train specialists and experts who will be capable of designing nonstandard fixtures and tools for modern machinery production.
3	Aircraft design (24.04.01)	The programme is intended to train specialists and experts who will be capable of developing, manufacturing, operating and modernizing rockets and rocket-space complexes with due regard to environmental safety.
4	Design and optimization of power-supply systems (13.04.02)	The programme is intended to train specialists and experts who will be capable of designing power-supply systems of different complexity, solving the problems related to power-supply system modernization and optimization.

The main focus of student training in the mentioned programmes lies within the profound theoretical knowledge and practice, in-depth study of profession-related courses which are aimed at design engineering and scientific experiment in accordance with enterprises' requirements within the framework of federal national project implementation. These federal national projects are among the ways to boost Omsk region development.

As OmSTU has no right to apply its own educational standards in teaching process, the master's programmes in question have been developed on the basis of FSES of the Higher Professional Education and international CDIO engineering education principles. There is no contradiction between the Federal State Educational Standards and CDIO principles.

Programme educational objectives and learning outcomes have been reviewed and validated by key stakeholders including university faculty, students, alumni and representatives of industrial enterprises for relevance to engineering practice (Standard 2).

Mutually supporting disciplinary courses are the basis of the master's programme curricula (Standard 3).

Alongside profession-related courses, the curricula of these master's programmes also include general courses which are delivered in all master's programmes: "Introduction to Engineering", "Economic Feasibility of Design Solution", "Mathematical Modelling and Information Technologies in Design". These courses are intended to develop personal and interpersonal skills knowledge, skills, and attitudes. The course "Introduction to Engineering" is compulsory in all master's programmes and provides a framework for engineering experience acquisition and essential personal and interpersonal skills development. The main focus is on the role and responsibilities of an engineer, oral and written communication, as well as design-implement experience (Standard 4).

The course "Economic Feasibility of Design Solution" is intended to provide understanding of the issues related to the principles of engineering systems economics and feasibility studies.

Active experiential learning methods are widely applied at OmSTU. The regulation 75.03-2012 "On application of active and interactive teaching and learning methods in education process" has been approved and put into execution (Standard 8).

Since 2013 the application of active and interactive teaching and learning methods are specified in course curricula. To reveal whether students are satisfied with learning outcomes, as well as introduction of active teaching and learning methods, OmSTU conducts student survey on a scheduled basis.

The learning process is supported by relevant resource centers and the potential of the basic academic departments (workspaces) established in the corresponding enterprises, which allows students to be engaged in practical work, collaborative discussion of the problems to be solved (Standard 6).

Master's students from the programmes in question build teams made up of about 3-5 people. These teams are supervised by scientific advisors who are leading scientists and researchers having their own scientific schools and associations in the corresponding sphere. Students who enroll in the master's programmes are expected to do at least two research projects aimed at acquiring experience in design-implement activity, with the level of complexity being increased. The second project is planned to be carried out as a part of research-and-development activity and on the basis of industrial enterprises (standard 5).

Funding of much of the work done mainly comes from the Program of OmSTU strategic development and extrabudgetary resources. Further funding is planned to be directed at purchasing required equipment, developing teaching materials, providing professional training of university faculty, etc.

The work that has been done at

OmSTU is just the beginning. In future, it is planned to revise and modernize all master's, bachelor's and specilist's degree programmes offered at OmSTU.

OmSTU, being a member of university-enterprise consortium, won a competition of European Union's programme for enhancing quality in higher education TEMPUS. The project title is "New model of the third cycle in engineering education due to Bologna Process in BY, RU, UA" (NETCENG)".

The project is aimed at developing a pilot model of the third cycle in engineering education (post-graduate programmes) in accordance with the regulations and up-to-date recommendations of Bologna Process.

The project objectives are:

1. to develop, implement and accredit basic and additional ECTS engineering education programmes including new principles of post-graduate programmes;
2. to develop innovative teaching methods and educational setting for prost-graduate programmes;
3. to bring universities of partner countries and labor market closer.

The duration of the project is 36 months.

Within the project, OmSTU is in charge of developing the course in design of robotic onboard systems of automatic maneuverable space vehicles in order to address the challenges in non-cooperative rendezvous in space, i.e. large-sized space rubbish, interorbital towing, space vehicle refueling, replacement of onboard equipment, disorbit, etc.

Conclusion:

Implementing practice-based learning at OmSTU on the ground of resource (innovative) centers, basic academic departments established in corresponding enterprises and CDIO standards will contribute to enhancing the quality of engineering training within bachelor's, master's and specialist's degree programmes and assist in resolving the issue of human resources in military-and-industrial complex enterprises. The proposed model of engineering education allows university to train such a specialist who does not need to be retrained after graduation in order to be fully engaged into professional activity.

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UDC 006.32:339.924:17.024.4

CDIO Standards Implementaion. TUSUR University Case Study

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The paper presents the TUSUR University case study in implementing CDIO Standards. The authors describe how TUSUR University manages to apply CDIO principles at different levels, from one discipline to the whole educational program.

Key words: Worldwide CDIO initiative, CDIO standards implementation, project-based learning, curriculum modernization, distance learning technologies.

According to the remark of President Vladimir Putin, that has been made during his speech at the extended session of the State Council on February 08, 2013, “the main problem of today’s Russian economy is its uttermost ineffectiveness. Workforce productivity in Russia stays unacceptably low…”. In our opinion one of the reasons for such ineffectiveness is an outdated system of future engineers’ training. It is natural that with the transition from industrialized national economy to a knowledge economy new economic fields and professions emerge, requiring miscellaneous training of specialists.

Unfortunately, due to a variety of causes many classical universities get involved in the process of adaptation with a stitch in time. Despite the active evolvement of innovative infrastructure and development of new research trends racing to create the most effective educational approaches, it is evident that educational curriculum as well as teaching methods is not undergoing significant alterations. It is common for Russia and many other countries that educational fields created during the industrialization era cannot keep up with the development of corresponding economic fields, therefore dooming its graduates to employment problems [1, pp. 233-240]. How often do Russian graduates hear when first entering the real production: ”Forget all that you have learned at the university, we will now teach you how to work the right way”? Education here contradicts with the social and economy context and seeks for reformation: the solution to the problem is the multidisciplinary projects and project-based learning, close cooperation with corresponding industry on early stages of curriculum development, and more flexible approach to modern competence formation.

In context of slow-speed advancement of national economy and with the aim of its stimulation it is necessary to change the attitude for engineers’ training. Liberal creative engineering requires specialists who above having fundamental knowledge are able to set and solve problems, see the whole picture and promote development of scientific and technical fields not only nationally, but on an international level as well. Let alone the fact that such education would raise considerably the competitive performance of Russian HEI graduates when applying for a job. To achieve the goal successfully and provide students with opportunity to advance competences from different fields of knowledge a thorough analysis followed by educational programs reformation is needed. It is also necessary to develop their skills of professional self-development and adaptation in the context of globalization.

However it is improper to believe that the problem of “fulsome fundamentality” is solemnly Russian. European and American scientists and employers became aware of this problem back in early 1990s. As an answer to the challenge a concept of practice-oriented learning, the so-called project-based CDIO Initiative, has been developed. Key elements of the CDIO Initiative replicate life cycle of real systems, processes and technologies, that progresses from idea through understanding and development to management and stabilization, allowing young specialists to have a try in different professional roles. Today over a 100 universities all over the world are united by this idea, 6 of these universities are the leading universities of the Russian Federation.

Historically Tomsk State University of Control Systems and Radioelectronics (TUSUR) has always stood out from the majority of Russian universities by virtue of its bold ideas and pioneering spirit; and it has been proved once again when TUSUR joined the CDIO Initiative in 2013. It was a seamless process due to the fact that back in 2006 TUSUR and its organizational staff has already developed and implemented in educational process structure a "Project-based Group Learning" technology that is to a great extent similar to the CDIO principles. Aiming to support this educational technology and other emerging projects and companies in the University, TUSUR has developed an essential innovative infrastructure: development laboratory, common use centers, student business incubator, technological parks, etc.

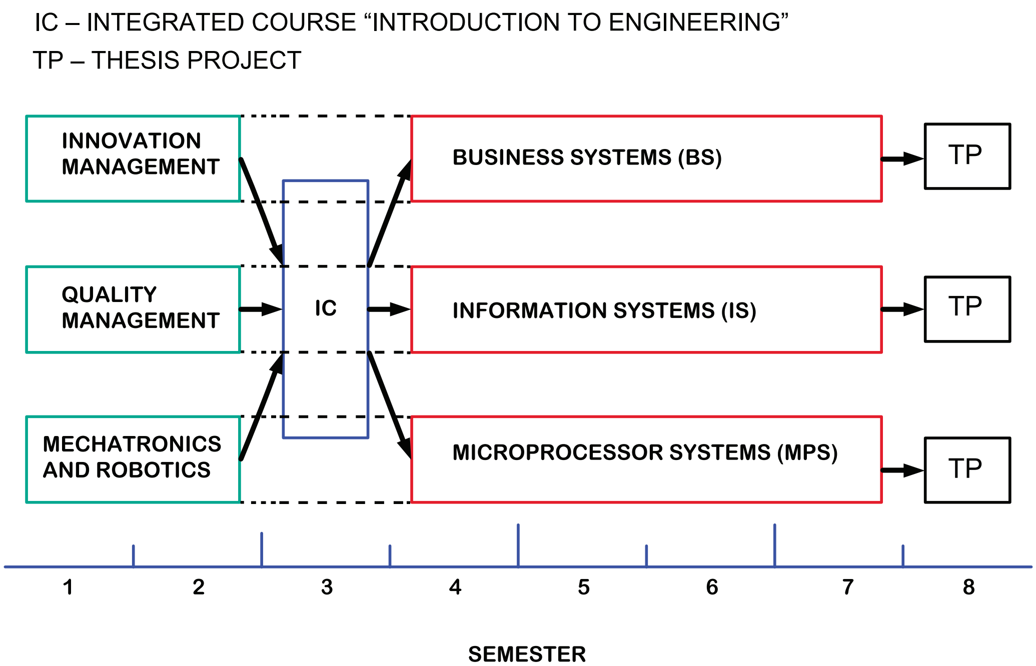
Becoming an official member of the CDIO Initiative university association has opened new opportunities for the University in terms of sharing best practices of taxonomy and more profound implementation of practice-oriented learning. Today CDIO Standards are implemented in three Bachelor majors of TUSUR's Institute of Innovation: 27.03.05.62 Innovation, 27.03.02.62 Quality Control and 15.03.060.62 Mechatronics and Robotics.

In accordance with the plan of CDIO Standards integration in University's educational curriculum, students of all three majors have a single educational program for the first 3 semesters complying with each major's standard. This standardization has two core advantages. First of all, joined lectures give a room for saving of educational resources – faculty work hours, classrooms, tutorial and maintenance facilities – without jeopardizing the quality of education on the first stage. This provides a stockpile of resources needed for the stage of specialist formation, when project activity will require extra courses and new disciplines creation, leading to a one-to-one training. Secondly, students have an opportunity for extra career guidance. As a common rule enrollees make a choice prematurely, basing their opinion on parents' views and bright advertisement. It may be quite complicated to make a change once students realized they have made a wrong choice. A unified curriculum during the first semesters provides students with an overview of all three majors and allows them to seamlessly choose a different one if needed. This enhances attractiveness of project areas for students and therefore creates a solid base for project-based learning.

According to the curriculum, Bachelors' project-based group learning starts at the fourth semester. In case it is related to the internships and thesis project such learning proceeds until graduation, i.e. slightly over 2 years. During this limited period a set of actions has to be carried out, i.e. set a problem, conduct research and development actions as well as trial experiments, document the results. This implies that students will get into action right away. However students are not ready for the project activity yet [2, pp. 44-46].

Integrated course "Introduction to Engineering" carried out in the third semester is designed to prepare students for the project-based group learning. Background for the course is provided by

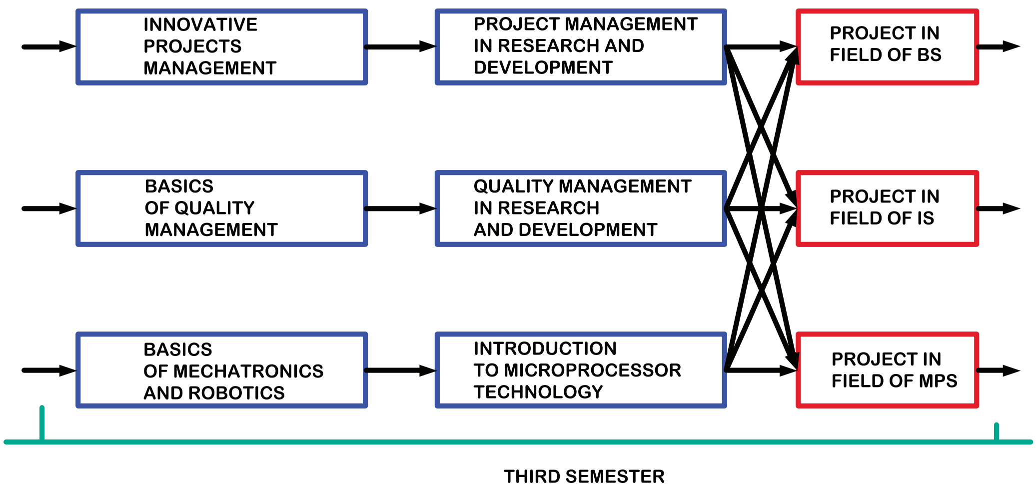
Fig. 1. Integrated Educational Program



three courses of the integrated curriculum: "Innovative Projects Management", "Basics of Mechatronics and Robotics" and "Basics of Quality Management". The first two are the courses of federal component for "Innovation" and "Mechatronics and Robotics" programs and therefore are the extension of a first-year course "Introduction to Profession". "Basics of Quality Management" is a part of the University educational programs component and serves for the same purpose for the "Quality Management" program. Implementation of an integrated project for all three courses enables specification (clarification) of the courses' content. Integrated course is built upon a project and comprises first stages of project execution – predesign research, project requirements development, draft evaluation of risks and project costs, and determination of the next stages (semesters) of the project [3, p. 189-194]. Besides, the course ensures a general overview from the position of project management, quality management and microprocessor systems development. In addition University organizes visits to industrial companies in Tomsk and invites practical engineers to give lectures.

Implementation of the Worldwide CDIO Initiative Standards and execution of an own Project-Based Group Learning fully corresponds to the modern trends in international engineering education development, where knowledge paradigm of education is replaced by the active-learning approach, putting TUSUR on one level with world educational leaders, such as Massachusetts University of Technology (USA), Chalmers University of Technology (Sweden) and others. However it is essential to keep in mind that world of engineering thinking does not have territorial boundaries, and international aspects of project-oriented learning should not be left out. At the moment a complex challenge is

Fig. 2. Integrated Course "Introduction to Engineering"



set for universities of the world, which is to train technically competent entrepreneurs, scientists and engineers, who focus their activities on global development and understand interdisciplinary and cross-cultural connections, as well as know at least one foreign language. TUSUR's answer to this challenge is presented in the Net Project-based Learning Concept. The aim of the project is to stimulate development of international creative teams within a framework of specific projects. The project implies existence of four key components:

- increase of practice study hours within specific projects;
- constantly enriching data base and methods of self-education;
- close ties between university and industry;
- development of a project within an international team.

TUSUR has already been conducting such projects for several years. A successful example of the Net Project-based Learning Concept realization is a joint educational course «Global Software Engineering» organized together with Ritsumeikan Asia Pacific University (APU) and dedicated to software development. In 2012 the project leader, developer and main lector, Professor Victor Kryissanov from Ritsumeikan University invited his colleagues from TUSUR to participate in the project with the aim to broaden course's content and make it more practice-oriented.

Aiming to carry out this educational project teams of Russian and Japanese students are formed each fall semester. Moderators define project theme for current semester collaboratively. The theme is given in a generalized manner, normally only the basic technologies are discussed, for example "neural interface" or "humanoid robot". Specific content of the projects will be formed by student teams during educational process.

Major part of the course consists of online courses on both distributed software development and specific technologies proposed for the semester. Lectures on technologies are led by guest specialists. Thus in fall semester of 2012-2013 lectures on social networking analyses were delivered by professor Uwe Serdьlt from

University of Zurich, in fall semester of 2013-2014 professor Tomasz Rutkowski from University of Tsukuba gave a speech on neural interfaces and Eugene Shandarov from TUSUR discussed NAO humanoid robot. However the core elements of the course are not the lectures, but rather collaborative student work on projects. Project execution is provided by two virtual teams; each of them consists of equal number of students from Kyoto and Tomsk. These teams have to accomplish the following tasks on a competitive basis:

- Prepare CVs for each participant.
- Outline roles in the team (programmer, designer, team leader, presenter, etc.)
- Choose subgroup leaders (Japan, Russia) for effective cooperation.
- Select communication channels (as a rule, the main communication channel is e-mail, however it could be Skype for collaborative software and hardware trials).
- Specify project's theme based on the proposed wider themes.
- Prepare project's presentation for midpoint project defense.
- Ensure collaborative project execution (software code writing, hardware preparation, detailing of each module's specifications, etc.)
- Conduct collaborative trial experiments.
- Prepare and make presentation and demonstration for project defense.

Thus attendees of the Global Software Engineering educational course not only get theoretically acquainted with distributed software development methodology, but conduct projects using this method by themselves. Owing to the roles outline within teams each student has an opportunity to actively and efficiently participate in the project. It is also essential that communication within teams as well as the education process is conducted in English language, which is a foreign language for both Russian and Japanese students. Real practical results that have to be shown at the final presentation of the project serve as an extra incentive for a more thorough work within the project.

During the 2013-2014 semester two projects on NAO humanoid robot management through neural interface have been conducted. One was designed for development of an application that provides aid for kids with "attention deficit disorder", the other one was aimed at development of robots' remote control system. One of the projects' unique features was that all work concerning neural interface has been done in Kyoto and the one with NAO robot has been conducted in Tomsk. All the trial experiments and developments presentations have been made via free access Internet channels in real-time mode. Projects results have been presented in three conference reports and one thesis paper.

Opportunity for participation in international projects is a strong motivation that leads students to their knowledge enhancement and, besides teamwork skills, provides students with such an important quality as a habit of self-education. It is insufficient to simply download information from the Internet and listen to a course of video lectures from a distinguished professor. It is necessary to have the ability to see aspects of practical knowledge implementation and understand which of the variety of courses will be useful within a specific project.

Owing to the existing educational system and educational methods of the TUSUR Distance-learning Institute students are able to obtain access to the University educational resources not depending on their location. This allows students to constantly improve their professional skills and broaden their professional horizons. Thus Net Project-based Learning leads to student's transformation from a listener to a man of action. Educational process is retargeted, emphasis are shifted from theory to practice. And most significantly the process of knowledge and skill assumption is deliberate and directly related to execution of real-life tasks [4, pp. 19-23].

Summarizing all of the above we can conclude that an intensive and effective modernization of educational curriculum in accordance with the Worldwide CDIO Initiative Standards takes place in TUSUR. The success of this experience is mainly based on historical prerequisites and both moral and infrastructural readiness to accept the changes: longstanding experience of Project-based Group Learning, distance learning technologies, equipped laboratories, innovative infrastructure, including student business incubator and center for engineering creativity. All of these ensures a more balanced pass to a new evolution level of University's educational practice and raises chances for TUSUR graduates' employment. Young engineers trained within this ideology will not be a burden for the enterprises during the adaptation period, but will rather be able to introduce a new vision and take part in optimization and modernization of the production process.

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Z.C. Chagra

UDC 378

Mobile Software Engineering Field: Innovation in Education to Shape the Engineer Profile

The Private High School of Engineering and Technologies Tunis, Tunisia
Z.C. Chagra

During 2011, the Private High School of Engineering and Technologies (ESPRIT) came to decide that modifications ought to take place in the study plan within the school. The mobile section is one of the main fields that were born after a global analysis of several profiles and engineering technologies. This paper addresses a model of mobile software engineering taught through the mobile section curriculum.

Key words: active learning, CDIO, educational programs modernization, education engineering, mobile software engineering.

I. INTRODUCTION

Reconceiving the study plan is a process that aims to shape the profile of an up-to-date engineering student. Most of the newly-conceived plans are focused on the CDIO standards, on the modernization of the actual courses and projects in order to follow the PBL approach: Project/Problem Based Learning.

Mobile Software Engineering is one of the recent fields that are acknowledged after analyzing the trending technologies and profiles on the market. This field consists of two years of studies during which the engineering student will essentially learn software development on the trending mobile OS: Android, iOS, BlackBerry, Windows Phone in addition to several other trending types of development as cross platform using HTML5. The study plan was entirely established according to the CDIO standards.

Mobile Software Engineering field at ESPRIT is implementing student-centered education approaches to join worldwide programs as the CDIO initiative. Therefore, this experience's outlines meet CDIO standards as learning outcomes, integrated curriculum, active learning and integrated learning practices.

This experience resulted in three generations of student engineers:

- 2011/2012 first generation: 1 class, 32 students.
- 2012/2013 second generation: 3 classes, 94 students.
- 2013/2014 third generation: 4 classes, 128 students.

The Mobile Software Engineering field has faced multiple challenges whilst achieving its objectives, if major and unpredictable changes in mobile development trends were to be taken into consideration. That is why partnerships were made with Samsung, Microsoft, BlackBerry and other key partners in the mobile development industry, to plan a decent and updated course support.

This paper will mainly present this educational experience as a potential solution for building ready-to-market engineers profiles.

II. THE OBJECTIVES

The main objectives of Mobile Software Engineering are made and reviewed according to the needs (CDIO Standard 2):

- Shaping ready-to-market engineer profiles.
- Participating in mobile development activities enhancement locally and globally.

- Expanding mentoring and development activities from classes to learning factories.

III. THE PROGRAM OUTLINES

Since 2011, faculty teaching model at ESPRIT was meant to be reconceived in a manner that meets the fixed objective: moving from the classical learning procedure to active learning. In this context, several alumni students were selected according to the targeted skills in order to integrate new pedagogic and research teams.

ESPRIT Mobile is the research team supervising all mobile development activities: teaching, developing as well as Research and Development activities.

Furthermore, ESPRIT Mobile is the pedagogic team mentoring the Mobile Software Engineering field from a basic creative stage.

The targeted mobile software engineer profile is pictured through an analysis of different feedbacks. Essentially the feedback of a graduate student's experiences in mobile development during his/her graduation project: a ready-to-market mobile engineer is a developer mastering the mobile operating systems: Android, iOS, Windows Phone, BlackBerry with a basic knowledge of cross platform development and trending mobile development activities.

The major key players in the mobile development activities offer different academic programs; this must be beneficial to reach the aimed objectives: working on the latest trends of technologies and being in a direct contact with the companies developing the appropriate mobile operating system, and thus, guarantee a distinguished quality of courses content.

IV. THE BASIC PRINCIPLES

The Mobile Software Engineering student has to develop an application per mobile OS and publish it to the appropriate store or marketplace in order to be graded. This is the main idea around Mobile Software engineering field. It is quite common that in every mobile OS, there are market places or stores in which the developer has to send his project so that it can be published and reviewed by the mobile OS users.

Once the project is sent, several teams from the targeted and the compatible store has to test each function in order to verify the compliance with the guideline principles and the decency of the project. Afterwards, the project can be granted the access to the worldwide market as a new mobile application or a report containing the errors made could be sent.

Mobile applications published in different stores have numerous benefits:

In the first hand, it is a proof of what the student is capable of during his learning process (using the technical knowledge, respecting the design and user interface guideline to produce a decent application on the market). On the other hand, the generated applications in each store are, as a matter of fact, genuine sources of incomes. This has been subject to several discussions: Where should the generated income go? Which business model to opt for? Knowing that this field is an adoption of producing and processing a lifecycle, subject of continuous improvement through Conceiving Developing Implementing and Operating (CDIO Standard 1), the mentoring team responsible of conceiving the Mobile Field took the decision to benefit from the incomes statically in order to teach the best practices and income generating practices/ subjects to the next generations. A part of the decision was to also be committed to the actual projects that are published in the Mobile Software Engineering Field stores owned by the mentoring team. The generated incomes are fully reserved to buy devices for the next generations. As a result, each generation learn and produce projects by re-using the devices coming from the last generation incomes.

V. THE MENTORING AND THE LEARNING PROCESS

Once the targeted profile was pictured, multiple measures were taken in order to reach the objectives:

- Retargeting the learning experience to be student-centered in a way that the student masters the mobile OS specifications through developing a meaningful project (CDIO Standard 3).
- Rebuilding the teacher-student relationship to mentor-apprentices following active learning concept: the teacher is no longer the main source of the information. In this case, the student becomes directly engaged into the courses' objectives through problem statements, usually taking shape as workshops covering the basic learning outcomes of the appropriate software mobile OS development. The mentor is a guide or a facilitator to the desired objective: solving the problem statements in a way to master the mobile OS development (CDIO Standard 8).

VI. ASSESSMENT AND EVALUATION

The key feature of the program is that assessment meets with learnings outcomes. Assessments are the way students measure their capabilities and the degree of their success to reach the learning outcomes.

In Mobile Software Engineering field, and following the fixed objectives, the student is rated according to a project made during the learning procedure and knowing the best practices of mobile development through publishing the project (the impact of design and user interface, business model followed and other concepts on the generated incomes). The student guarantees the validation of his grade once his application is published on the appropriate store. This procedure is a perfect measure of the educational product maturity level. Then, the additional assessments (oral, quiz, respect of deadlines) are added to the basic grade in order to finalize it.

It is necessary to update the learning outcomes, the teaching methods, as it is for the courses' content and the mobile OS version (CDIO Standard 12). It is a continuous process due to program evaluation by both teachers and students at the end of every course.

In addition to this evaluation, other means to measure student's success and teacher's expertise are offered to the mobile developers, which are the national and international development contests.

The students and mentors of the Mobile Software Engineering field at ESPRIT participated and won several developers contests. This task, along with Research and Development activities, is a way to enhance the faculty teaching competences (CDIO Standards 9, 10).This continuous challenge is the perfect opportunity to measure the success of the program and fix the next generation's aims.

VII. PERSPECTIVES: LEARNING FACTORIES

The Mobile Software Engineering field, in its fourth year, expands the activities from classes to learning factories: dedicated spaces for training, incubation and R&D activities. This space is basically offered by the Engineering school and equipped and branded from partners as Samsung Electronics and Orange Telecom who were the first partners to join this step of the program. Learning factories are the space in which the graduated student can get in touch with the professional world and evolve while maintaining a relationship with his educational ecosystem. This may facilitate the transition and guarantee the success of the aimed engineer profile.

VII. CONCLUSION

In this paper, we presented the experience of Mobile Software Engineering as one of the reconceived fields at The Private High School of Engineering and Technologies. This experience, joined with other software engineering fields' experiences, consequently had the acceptance of ESPRIT as a CDIO member in 2013. In order to insure the efficiency of this field, the basic concepts demonstrated are fundamental: actualized courses and published mobile applications, workshops based on active learning, continuous evaluations and so on. The perspectives that the mentoring team is working on depends mostly on the feedbacks and the continuous evaluation of each step. Studying the impact that these generations are making after graduation is the key to keep the productivity and the efficiency at its highest levels.

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I. Shimi

UDC 378

Super Courses – a Bridge Between University and Incubator

The Private High School of Engineering and Technologies Tunis, Tunisia
I. Shimi

Engineering studies are based mainly on projects and Implementing solutions and are the most required selection criteria in the industrial market, particularly during economic crisis where finding jobs isn't guaranteed anymore and only Operational engineers can become job creators. To help engineers become future entrepreneurs, super courses or accelerated undergraduate studies are becoming necessary to provide extracurricular experience in a short period of time. Here comes the important role of CDIO standards, which helps engineering students from designing patterns to integrate the professional significantly world.

Key words: teaching, learning, accelerated scheduling, implementing, operating.

Today's market has totally changed from a market where you search for a product or a service to a place where only innovators can survive.

To catch-up with this quick transformation, and with the exponential growth of IT and ubiquitous computing, many universities and engineering schools in Tunisia have faced a big challenge ensuring the employment of their graduates.

As a solution, ESPRIT, private school of engineering & technology, started since September 2012 a pedagogical reform that aims to transform some curricula into programs based on Projects Based Learning (PBL) [1].

The following table 1 summarizes the differences between the classical projects in ESPRIT before the reform and the adoption of the PBL pedagogy.

At the beginning this experience has encountered some difficulties but succeeded afterwards thanks to the investment of stakeholders.

Only 16% considered that it was a bad experience and17% of the team members have not been able to resolve internal misunderstanding or conflicts.

Table 1. Classical Projects Vs PBL Projects

	Classical Projects	**PBL**
Nbre of Projects/ Year	1	2
Nbre of Students/ Team	2	5 to 6
Nbre of proposed Projects	100	5+5
Validation	At the End of the Project Development Process	During the Development Process
Monitoring	1 Supervisor/binomial	2 to 3 tutors/ Group (Class)
Academic Projects in Parallel	Yes	No

This successful experience allowed ESPRIT in 2013, to become member of the CDIO initiative and proved that it is preparing a new generation of «operational» engineers rather than mere graduates. This experience has allowed ESPRIT to reach a percentage as high as 72% of its Alumni, being active in medium and big enterprises.

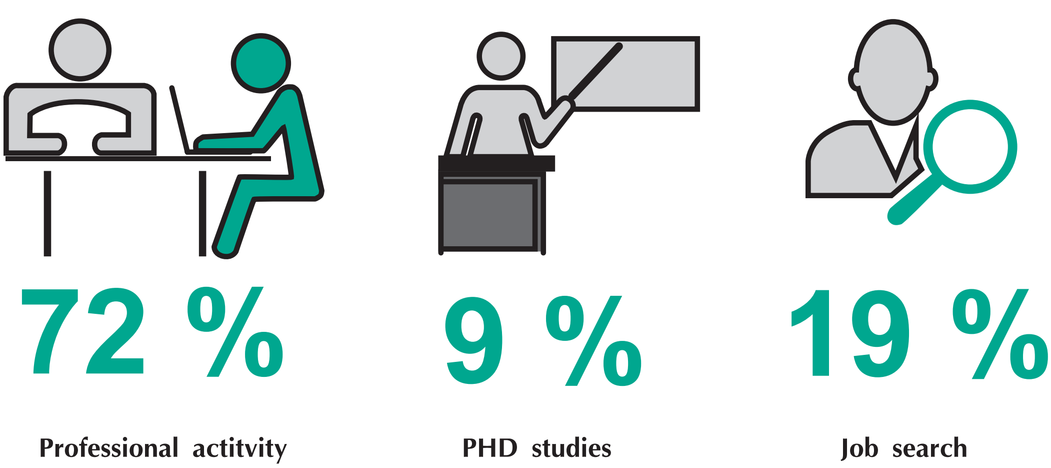
We've also noticed that there are effective smart graduates who are unemployed.

This contrast is maybe due to the economic crisis or the unstable political situation prevailing in Tunisia but ESPRIT didn't give up.

ESPRIT has kept reforming its curriculum by adopting a teaching strategy mostly entrepreneurship-driven. This approach has led the university to fit with the international standards [2] in the term of teaching soft skills like management and marketing using active pedagogy while respecting the number of credits (15% of the curriculum) required by French CTI (Commission des Titres d'Ingŭnieurs) which allowed ESPRIT to become officially accredited by EURACE this year. (June 2014).

Despite all these advantages among which a good international exposure, ESPRIT faced a problem with the proposed academic projects, especially the ones that have in their evaluation process «pitching projects», «presenting projects business plans», simulation of market studies or financial projections, yet their cases are not based on real ones reflecting market's situation. The reason behind this is that such projects are credit-driven choices (for credit) and modules are made in a purely academic context. Besides, having these projects as modules made them evaluated like any other module in the curriculum. Indeed problems such as absence or conflicts between team members working on these academic projects doesn't really allow teachers to select the best of their students and to encourage them getting involved in related international competitions and challenges. PBL courses are similar to the milestones projects adopted to follow up the CDIO standards and practice active learning. We have noticed that the majority of these integrated courses are given since the 1st year of the engineering studies (2 years before graduation), we consider at that level the taught soft skills and management practices can be forgotten easily once the

Fig. 1. Graduates' status



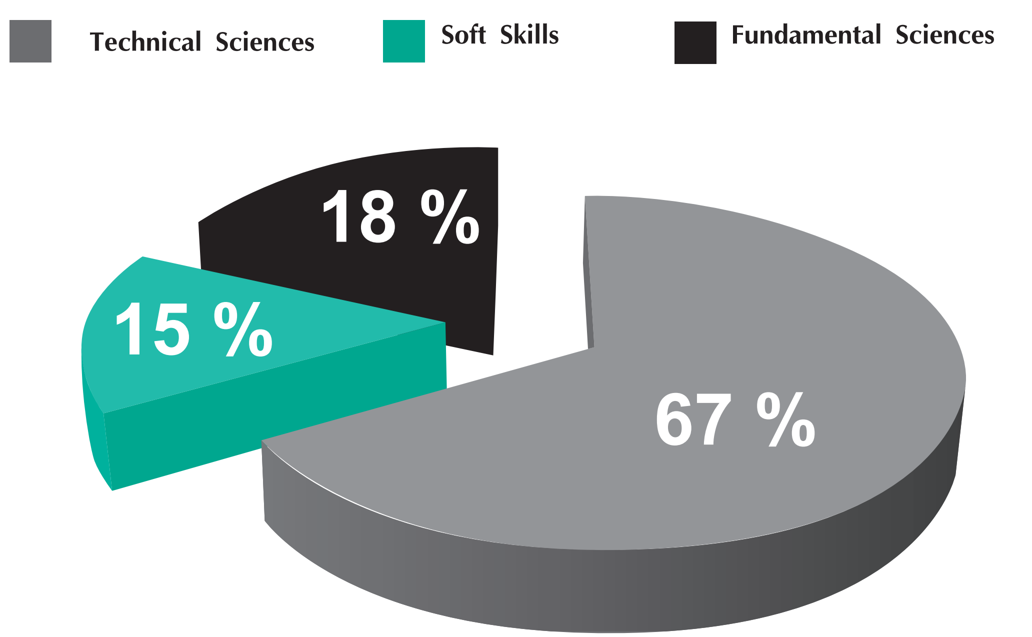
student moves to other modules without keeping practicing these important learning outcomes [3].

Here we can realize the importance of super courses, these extracurricular courses reminding the student these concepts and helping him/her building up his/her knowledge on entrepreneurship by empowering the competences, the engineering skills and also helping him/her thinking about exploiting these outcomes to move from the academic phase to the operating one in a professional manner which can even lead the student to the creation of his/her own start-up. Being aware of the importance of the technology entrepreneurship culture within the engineering curriculum, ESPRIT has worked for the last 14 months drawing the first steps of launching an "academic" incubator. This new and very important entity in the life cycle of the school, will add to the 11 years of shining image of ESPRIT as the First private school in Tunisia.

ESPRIT Incubator has already started its awareness campaign within the campus about its incubator's model and all the process of screening, incubating and graduating incubatees. Despite the fact it is not operational yet, Esprit-Incubator has already signed a partnership with SAMSUNG which is organizing very soon a one month training program similar to super courses teaching best practices managing technology Start-ups meant for potential candidates, which will start next January 2015. The latter will help 24 innovative students (6 teams of 4) and even faculties having brilliant ideas to compete and go through a screening process before integrating this super course and the incubator.

By creating several partnerships and such a professional environment the incubator will certainly help spreading the culture of entrepreneurship and bridging the market environment with its industrial needs to Esprit engineers to be their

Fig. 2. Modules by Category



solution finders certainly. To build this whole ecosystem, academic support has to be brought continuously and in parallel with classical for credit curricular modules. Super courses can prepare motivated students to make their ideas feasible and responding to the market need. In fact, it can be even part of the ideation phase before integrating the incubator [4, 5].

These super courses can be the solution for the discontinuity of the learning process which can cause memory lapse of the knowledge students only learn to have marks or validate credits. This idea is inspired from ESPRIT Incubator partner, Digital Media Zone (DMZ) the academic IT incubator of Ryerson University in Toronto, Canada, that uses these courses to prepare new generations of future entrepreneurs before leaving the school [6].

So ESPRIT is committed to ensure graduating «operational» engineers among whom few can create their own Start-ups and be Tunisian business leaders in a country where the need is burning.

These super courses are mainly divided into 70% of workshops, 25% of seminars and 5% of the time is about pitching ideas to evaluate communication and soft skills. The evaluating committees are composed of experts, coaches and businessmen who got a deep knowledge about the market needs and are able to guide students build their business models and plans.

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UDC 378.141.4

Implementing CDIO as a Tool for NArFU Programs

Northern (Arctic) Federal University named after M.V. Lomonosov (NArFU)
N.V. Chicherina, E.E. Ivanova, M.A. Korelskaya

This article describes the enhancement of upgraded engineering education programs based on international CDIO standards within the framework of Northern (Arctic) Federal University n.a. M. Lomonosov.

Key words: engineering education, CDIO Initiative, module-integrated curriculum.

In the last few decades the priority of RF socio-economic development has been constantly considered with reference to the exploration and development of the Arctic region itself. In view of the fact of the growing geopolitical and economic significance of the Arctic and its vast resources, the big challenge in engineering education redirects the thrust of engineering programs towards the personnel training and re-training to work in arctic conditions and solve the problems listed in "Development Strategy in RF Arctic Region and National Security Protection, through to 2020"[1]. The major tasks stated in this document involve the following: effective chrome, manganese, tin, aluminum silicate, uranium, titanium and zinc mining within the Arctic Ocean islands, Kola Peninsula, Polar Urals mountain massif; development of Timan Pechora petroleum province and hydrocarbon reservoirs in the continental shelf of Barents, Pechora and Kara Seas and Yamal and Gydan peninsulas; as well as the development of marine service complex, including marine geological exploration, application of fibre-optic and communication satellite systems and their monitoring and hydrometerological and ecological safety and security services; Arctic transportation infrastructure development, facilitating the Northern Sea Route as an integrated national transport route throughout the RF; improvement of Arctic ports and establishment of modern port-production complexes in the RF Arctic Region and other zones [1].

Under these circumstances the mission of the Northern (Arctic) Federal University n.a. M. Lomonosov (further NArFU) involves the training of highly-qualified personnel for the exploration and development of Russian European North and Arctic, which, in its turn, defines engineering education as the priority orientation included in its education policy.

Since 2012 NArFU has been implementing the project "Engineering Education" focused on university-wide education process improvement in different engineering majors via enhancement of international CDIO standards, which would shape the relevant engineering competencies in priority areas of the North Arctic Region, as well as perspectives of its development in view of the existing possibilities and regional demands.

To implement this project a charter was formulated which embraced the goals and tasks, domain and feasibility study, assumed results, risks and, finally, the project phases. According to the adopted charter there are three phases in the project implementation of improving the training system of engineering personnel: preparatory phase (September 2012 – August 2013), project phase (September 2013 – August 2014) and pilot phase (September 2014 – June 2018).

Preparatory phase included the

following: analysis of international CDIO Initiative materials [2; 3]; benchmarking of Bachelor curriculum in priority majors for further technological development of economics in North Arctic Region; benchmarking of convergent education in domestic and foreign universities; audit of engineering education programs in NArFU; and questionnaire survey in engineering training for stakeholders.

According to the final analysis of above-mentioned facts, it is obvious that there is no systematic interaction between the employers and the training program majors as an employer is involved only in the education process itself, i.e. in the initial phase of the program implementation, while further interaction in the project and assessment phases is rather insignificant. Other evident factors are that many instructors have no internal motivation to change not only the teaching content but also its technologies, and most instructors lack those necessary competencies in modern engineering didatics, in particular, project management. Consequently, even well-developed, sought-after education programs are of underdemand for employers.

Survey for employers conducted by the Department of Education Evaluation Monitoring (NArFU) showed that the relevant global trends are influencing NW Russian employers' demands and requirements to engineer-graduates. In employers' view the engineer-graduate cultural competencies (so-called "soft skills"), including system thinking, management, project, team-work, negotiation, leadership skills, as well as responsibility are rather insufficient. However, 89% of employer-respondents consider that the above-mentioned competencies are very important in job placement and in further professional activities.

Many employers indicate that universities should enhance training in the domain of professional occupation rights, as well as early introduction not only into the professional engineering domain, but also into production and technology spheres, especially, before planned internship. They also highlighted such important factors as updated teaching content and technology in terms of existing global trends.

Based on obtained and analyzed preparatory phase results the following issues were adopted: incorporating the device of regulatory, organizational, procedural and informative-consulting support for education-business partnership at the university level and implementing T&E activities (i.e. professional development) in engineering didactics for the university academic staff.

To implement the project the following pilot curricula were defined within the framework of five NArFU institutes:

- 23.03.03 Operation and Maintenance (O&M) of Transport-production Machines and Systems (Bachelor degree in Engineering), major – "Service of Transport and Production Machines and Timber Complex Facilities";
- 15.03.02 Technological Machines and Equipment (academic qualifications), major – "Engineering of Technological Machines and Equipment"
- 18.03.01 Chemical Technology (Bachelor degree in Engineering);
- 09.03.01 Computer and Information Sciences (Bachelor degree in Engineering), major – "CAD System" and "Integrated Automatic Systems";
- 09.03.02 Computer and Information Sciences (Bachelor degree in Engineering), major – "Design and Maintaining IT Systems";
- 08.03.01 Building and Construction, (Bachelor degree in Engineering), major – "Highways".

Project phase included the shaping of instructor CDIO competencies (Standard 9 – international CDIO Initiative). Within the NArFU institutes team groups were organized. The responsible executives of these groups were certified against the

"CDIO Initiative in Engineering Education" within the framework of the co-project "CDIO Academy: 21st Century Engineering Education" between SKOLKOVO Institute of Science and Technology and National Research Tomsk Polytechnic University.

The first session of the CDIO Academy was in January, 2014 in Chalmers University of Technology (Guteberg, Sweden), where the CDIO Initiative participants discussed the leading practical applications of CDIO concepts and standards in different Russian and foreign universities. The second session was in Tomsk Polytechnic University (Tomsk) in March, 2014, while the final session including the project review of the participants, was conducted in May, 2014, in SKOLKOVO Institute of Science and Technology (Moscow).

Project members became familiar with the training experience of engineering personnel (Bachelor engineering modules) in the Ural Federal University, as well as participated in relevant workshops, organized in Immanuel Kant Baltic Federal University (Kaliningrad).

Besides, the above-mentioned sessions in CDIO Academy, information dissemination and shaping CDIO competencies of University instructors were conducted through training workshops in pilot NArFU institutes.

Shaped competencies addressed the possible go-ahead decision of this phase- designing education programs in accordance with CDIO standards. Project members in co-operation with employers and under the supervision of the NArFU Academic Development Department, conducted re-engineering of the pilot education program. As a result, module-integrated curricula were designed (Fig. 1), in terms of the pilot education programs (Standard 3 – international CDIO Initiative).

These curricula included such a discipline as "Introduction to Engineering" (Standard 4 – international CDIO Initiative: Intro to Engineering), which, in its turn, embraced the fundamentals for accepted engineering practice in product, process and system development and shaping basic personal and interpersonal skills [3].

Based on the analysis of cultural and engineering competencies stated in the Federal Education Standards, as well as the employer-respondent questionnaire results, the modules of basic humanities, mathematic and natural sciences were defined.

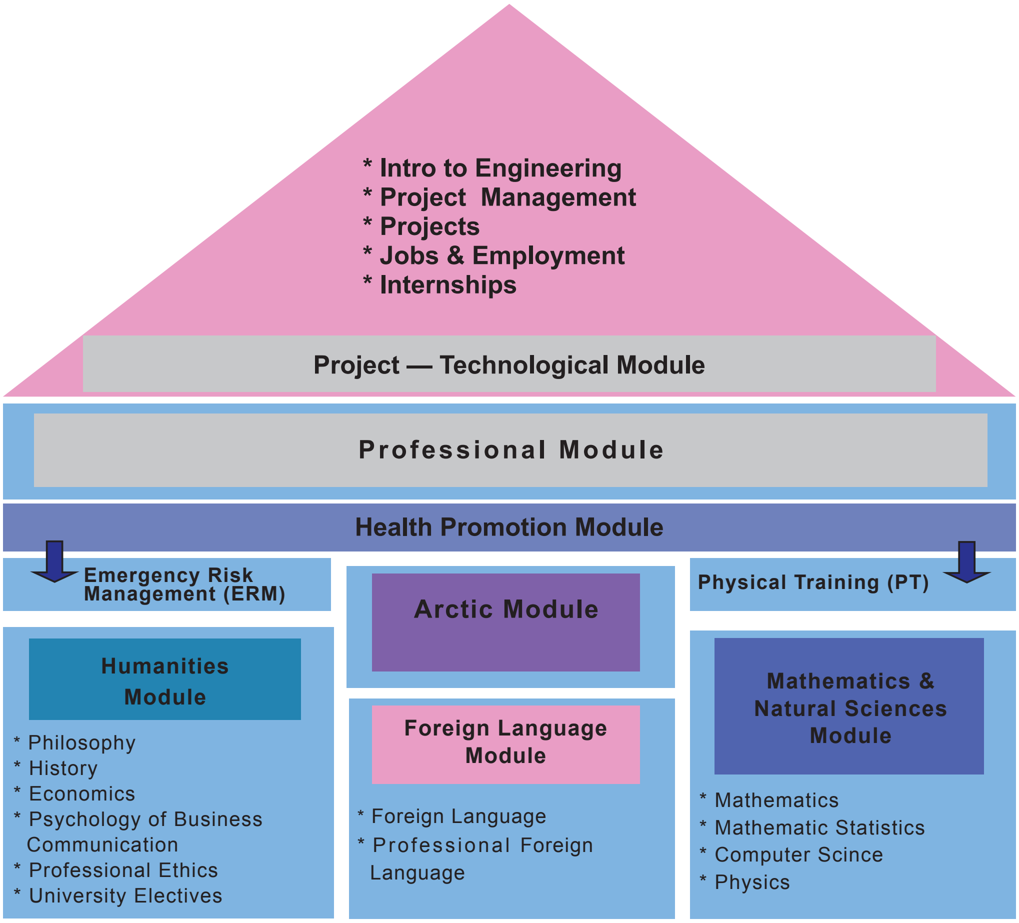
The humanities module included such disciplines as "Professional Ethics" and "Psychology of Business Communication" as tool subjects in developing integrated cultural competencies for further curriculum module studies (Standard 7 – international CDIO Initiative: integrated learning) [3].

To develop project-innovation competencies, the Project-Technological module was designed including "Intro to Engineering", "Project Management", execution of three projects within the framework of different 1-3 course year disciplines, as well as an engineering project as a part of the graduation paper (Standard 5 – international CDIO Initiative: implementation of project-innovation activities) [3].

In respect to the University mission the "Arctic" module was integrated into the curriculum, the content of which was determined by the domain specification and types of professional (engineering) activities of this or that education program. This module task was to identify the current issues in developing the RF Arctic Region and those professional (engineering) activities which are specific under the existing Arctic conditions. This module embraced the possibility of solving current problems and tasks defined by both the University and regional administration.

The pilot phase was launched in September, 2014. This phase included not only the implementation and problem-solving of the teaching process organization itself, but also the further advanced training of the academic staff, the interaction mechanism of stakeholders within the framework of the education program

Fig. 1. Model of module-integrated curriculum



via organization management of basic education departments, customization of education quality monitoring techniques to evaluate the education process and the results of curriculum implementation in compliance to CDIO standards (Standard 11 – international CDIO Initiative: learning evaluation), policy performance of preparing team-groups for project management (Standard 6- international CDIO Initiative: collaborative workplace for professional (engineering) activities and developing professional system management for graduates [3].

At present this phase is still in progress. Concepts, stated in international CDIO Initiative are being visualized in the developing curricula. It is obvious that the effective evaluation of the upgraded engineering education system could be conducted through longitudinal monitoring. However, during this phase, the project members have developed a solid understanding in the following: significance of systematic and continuous enhancement of the curricula, commitment in updating the module content, acquisition and implementation of favorable technologies, and demand in a constant interaction with stakeholders.

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UDC 378

Collaborative Projects Within «Student – Faculty – Enterprise» System as Means of Professional Competency Development

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Yu.B. Chervach

The article reviews student involvement in professional business project devel¬opment at HEI engineering department from the CDIO model perspective. The extent of student engagement in stages of conceiving, designing, implementing, and operating is analyzed. Possible roots for project activity development within the CDIO framework are proposed.

Key words: Project-Based Learning, business activities, project activities, CDIO model.

High level of CDIO Initiative dissemination in modern educational society and successful CDIO Standards implementation experience of world's leading technical universities makes it possible to state that "Conceive – Design – Implement – Operate" educational framework is one of the most efficient, if not the role model of educational activity structuring, set to nurture competent specialists. Leading technical universities of Russia are unanimous with the international society and provision high potential for development in the implementation of CDIO principles. At the moment, twelve Russian universities have joined the CDIO Initiative; the first one among them was National Research Tomsk Polytechnic University (TPU) [1].

An indefeasible feature of CDIO implementation at university is the support from the university management in terms of curriculum modernization, providing faculty with modern pedagogical methods, CDIO principles promotion, infrastructure development for all stages of project activity, etc. Since joining the CDIO Initiative, TPU has conducted a set of actions, providing partial or full compliance of the engineering curriculum with such standards as Standard 2 (Learning Outcomes), Standard 3 (Integrated Curriculum), Standard 4 (Introduction to Engineering), Standard 6 (Engineering Workspaces) [2, 3].

However, even if the university has a strategic goal to adapt CDIO principles, the implementation process inside the university can be carried out in different manners, sometimes unsystematically. Commonly, the university selects one or several (as in case of TPU) educational directions/specialties to modernize training in accordance with all CDIO Standards and CDIO Syllabus. The changes implemented in these specialties are centrally-controlled and embrace full scope of educational activities within the specialty [3].

At the same time, initiative for modernization in the university can originate from a particular department. In such a case, due to resource limitations, an overall project-based learning principle is supported, however, only some of the Standards are addressed. Thus, contractual development projects organized at engineering departments can be considered as one of the means for CDIO concept realization. Within the framework of contractual development activity faculty members contrive collaborative projects corresponding to the industrial needs. Students' work engagement at different stages of such projects substantially enhances their competency development and assures compliance with CDIO Standard 5 responsible for "development of product, process, and system building skills, as well as the ability to apply engineering science, in design-implement experiences" [2]. At the same time, this contractual development projects system can be viewed not only from a point of their compliance with one particular Standard, but rather as a system assuring elaboration of the very basic principle of the four-stage project activity: conceiving, designing, implementing and operating.

At National Research Tomsk Polytechnic University faculty members of the Department of Automated Engineering Technology (Institute of Cybernetics) have long-term experience of collaboration with industrial enterprises of Tomsk and Russia in the framework of state and private contractual development activity. It is common that students are involved in such projects. In spite of the regression in the mechanical engineering industry in Russia, the amount of real projects brought to the Department has grown notably within the past years, which led to a decision to build up an individual enterprise on basis of the Department. This structure allows for official employment of students, who are involved in the contractual activity, and enables a more rapid enhancement of facilities and infrastructure, both for the Department and for the enterprise, at the expense of the latter.

In comparison with the CDIO model, the contractual development activity does not unlock full potential of each project stage (each element of the model). Thus, the extent of student involvement differs at various project stages; and some of the project stages are conducted without students' participation. Whereas the educational process that is structured in a full compliance with CDIO Standards stipulates integrated learning and equal acquirement of conceiving, designing, implementing and operating skills.

In order to educe weak spots of the contractual development activity and to determine areas of growths for the individual enterprise as a system of students' competency formation within the educational process, an analysis of the enterprise's project activities has been conducted in the context of its compliance with the four semantic elements of the CDIO concept:

Conceive. Project idea identification and specification, project planning

Project ideas' conceiving is carried out within the key research areas of the Department of Automated Engineering Technology faculty, i.e. manufacturing process planning, development and investigation of cold working processes used to enhance performance characteristics of mechanical components, technology for worn parts reconditioning by various methods, etc.

Faculty members of the Department, being employees of the individual enterprise, are searching for customers interested in products and services provided by the enterprise. Project ideas also evolve from the external customers themselves. Such projects are taken only after a thorough consideration of each project stage and assessment of the possibility for its elaboration. Due to the lack of contacts with real production entities, students are rarely involved in the process of contracts search.

Students get involved in the projects elaboration at stage of engineering creativity, when research of new technical solutions is addressed and real industry challenges are tackled. At this stage work teams, responsible for planning and development of different project stages, are formed. The majority of project ideas and challenges is at the cross border of several disciplines, requiring faculty members to attract external contractors and form interdisciplinary teams. This permits students to gain experience not only in finding and executing optimum production solutions, but in complying them with allied project groups. Under the first-hand supervision of qualified specialists students have an opportunity to put forward their own technical proposals for problem solutions applying the knowledge gained on previous stages of their education. Team leaders, responsible for the final planning, develop project concept while explaining each technical decision taken to all the participants, thereby providing knowledge segment of the project activity.

Despite students' involvement in the process of project ideas conceiving, they are not initiating ideas themselves, due to the lack of professional experience and scarce technical imaging. From the perspective of CDIO Standards this stage is given deficient attention.

Design, including computer simulation

Design is conducted with use of all modern methods of computer simulation, including CAD/CAM systems. Once the project concept is confirmed, students get involved in designing of specific units and mechanisms of the whole project, and propose their feedback and remarks while different project subgroups align their parts of the integrated project.

On the design and simulation stage students develop components' and units' constructive elements taking into account their functional purpose, material behavior, mechanical strengths characteristics and technology for its future express operation. This permits students to test their simulation skills in practice.

Students perform their part of the project independently; however, the result of design/simulation is processed by team leaders, tutors for each area of activity, with the aim to make needed adjustments before the real implementation. Students are fully involved at the stage of design and acquire practical competences while studying.

Implement. Manufacturing of components, machines and mechanisms

Manufacturing of components for the designed project is conducted on premises of training workshops, fitted with modern cutting equipment. This equipment is purchased at the expense of either the individual enterprise, or the previous contact projects, or partly with help of partnering enterprises and organizations, and sometimes sponsors support.

Major part of the components' production is performed eminently by students, who first gain professional specialization with guidance from production foremen and faculty involved in the project.

During the project machinery equipment is constantly rotated between students to ensure production continuity and to acquire practical skills on different types of machinery: from universal to CNC machines requiring profound background of program development with use of different software programming languages. New coming students are taught to work on the machinery equipment by tutoring: an experienced student, who has already taken part in several projects, teaches young workers the basics of production cycle.

At this stage students gain practical understanding of the optimum production process for components development on various equipment from technological, metrological and economic points of view. The implementation stage is fully embraced by the contractual development activity; it gives students sense and skills of real production process.

Operate. Adaptation, project workpiece management

Educational process of the project workpiece operation is culminated with the analysis of the whole production cycle during the startup and adjustment operations and commissioning of the project. Structural and technological errors' analysis, as well as analysis of production process, technological tooling and other issues permits quality assessment of project planning proposed by the project team, including students, from the point of production process optimization. This is a valuable experience for future participation in the first stage of projects execution, namely, the idea conceiving and project's concept formation.

Students, who have participated in project development and elaboration, gain higher degree of freedom when working on the next project: they are able to take more complex technical decisions independently and teach new students basic practical tasks.

However, the project operation stage is still not implemented to a full extent, since students and even tutors/project supervisors do not have the opportunity to take part in real implementation of the project unit/component/mechanism to the production line, but terminate their work process at the stage of commissioning and basic testing.

In the context of educational process students' participation in project activity provides solid knowledge base and skills for development of practice-oriented thesis work based on a real-life project. Students' involvement in the project development from first study years gives faculty an opportunity to evaluate each student's performance from the perspective of his initiative, efficiency, basic and specific knowledge existence, ability to use this knowledge, and, most of all, degree of his inclination towards engineering creativity, inventiveness. Such assessment of student's technical incline allows defining his future role within projects.

An example of project elaboration according to the CDIO Standards is the development of a welding complex for welding zirconium tubes with end-plugs for fuel rods production requested by Novosibirsk Chemical Concentrates Plant (NCCP). This project had been carried out by faculty of the Department of Welding Engineering, Institute of Non-Destructive Testing (TPU), who developed new breed welding unit, together with faculty of the Department of Automated Engineering Technology, Institute of Cybernetics (TPU), who developed and produced automated complex for welding process. The project involved employees of the individual enterprise and a group of students from the Department of Automated Engineering Technology. Throughout the year more than 20 students of the Department have been involved in the project. All students were officially employed by the individual enterprise. Labor expenses were provided according to the index of labor distribution, work complexity and personal qualification; an average monthly salary for students varied from 5 to 9 average monthly student educational allowances. Students' work experience in the field, highlighted in the employment record book, is to be a valuable competitive advantage in future employers' sight.

The conducted analysis showed, that students' involvement in contractual development activity provides skills enhancement at different project stages unequally. Following the main aim of education proposed by CDIO: "engineer (university graduate) should be able to conceive new product or a new technical idea, perform all design-implement activities for its implementation (or give out proper instructions to those, who will perform the tasks), operate the production process", it appears that the analyzed example of the individual enterprise and the Department of Automated Engineering Technology executes only the design-implement activities to the full extent, namely the "Design" stage and the "Implement" stage. Whereas the ability to conceive technical ideas and new products ("Conceive" stage) and introduction of these products and technologies to the real industry ("Operate" stage) involve students only collaterally [4].

The analysis resulted in the following two areas of potential growth for the individual enterprise in the framework of the CDIO Initiative:

1. Students' attraction to participating in the "Conceive" stage through organization of creative engineering activities and development of engineering thinking. Full involvement of students at this stage of a project requires background of several real projects' elaboration that would provide experience and knowledge

base for invention and technical solutions' execution.

2. Organization of student involvement in the "Operate" stage through their employment by organizations that provide these real-life projects. It is essential to attract students to participate in the project activities from the early years of study. Thus, by the time they receive Bachelor's degree, they will gain experience of involvement in a big industrial project and go through an internship and/or get employed by the company that requested the project. Provided that, the most efficient educational model for Master's degree can be a block-modular education. Master students will be able to study without discontinuing their work, find problems and ideas within the company and work on their solutions during the educational process.

Students' involvement in conduction of real industrial projects in the context of contractual development activity provides enhancement of professional competences and forms students' engineering thinking. The system of integration with individual enterprise allows organizing discontinuous project activity for students and draws it closer to the CDIO model requirements. As a result, students, who take part in CDIO full cycle project work, enhance not only their specific professional skills, but develop professional competency that serves as a basis for future successful career in the field. The key result of students' involvement in enterprise's contractual development activities is the acquirement of manufacturing, engineering and managerial experience and, therefore, shortening or dissolution of the adaptation period once they get employed by industrial mechanical enterprises.

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Ye.O. Akchelov

UDC 378

Worldwide CDIO Initiative: Implementation Experience in Singapore

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This article is dedicated to analysis of CDIO standards implementation in Singapore Polytechnic curricula. This paper presents evidence of compliance of Singapore Polytechnic curricula with CDIO standards. It is considered that experience of CDIO implementation in Singapore Polytechnic is successful.

Key words: CDIO, Singapore Polytechnic, competence-based approach.

SIntroduction

Singapore Polytechnic was established in 1954 to prepare specialist in different fields – engineering, information technologies, building, business, finance, law etc. The aim was to ensure technological and economic development of the country [1, p. 1]. Singapore has been successfully developing over past 50 years and it has changed its status of the Third World country for that of the most developed one. Being one of the few national institutions, Singapore Polytechnic played a significant part in this process.

From 2004 Singapore Polytechnic began to implement new initiatives and approaches to improve the quality of education and to make their graduates competitive within modern economic environment. In pursuit of new teaching methods and technologies, systemic and interdisciplinary approaches to knowledge acquisition, integrated curriculum, and practice based education, Singapore Polytechnic joined Worldwide CDIO Initiative. The aim of the present article is to describe the experience of CDIO implementation into Singapore Polytechnic educational programs and to prove correspondence of the programs to 12 CDIO Standards [2].

Standard 1. CDIO as the context for engineering education.

To implement CDIO Initiative Singapore Polytechnic began to enhance educational programs giving particular emphasis on development of creativity, innovative and business thinking. Moreover, the educational process was organized as a system for students to pass all the stages of innovative process – from idea (concept) to implementation. The correspondence of Singapore Polytechnic educational programs to Standard 1 is proved by a number of factors. Firstly, there is cultural context, within which education, practice and knowledge acquisition are ensured [4, p. 29, 41, 43]. Secondly, there is a plan of educational programs enhancement [1, p. 2]. Moreover, the idea of program enhancement is shared and actively supported by the Board of Governors of Singapore Polytechnic[1], while scientific publications and presentation on CDIO topic [1, 3, 4] demonstrate the high level of teachers' involvement.

Standard 2. CDIO learning outcomes.

Singapore Polytechnic is the place where customized learning outcomes were designed on the basis of those of CDIO [6]. The outcomes are detailed in the document

[1] http://www.sp.edu.sg/wps/portal/vp-spws/!ut/p/c1/04_SB8K8xLLM9MSSzPy8xBz9CP0os_hQD1NXIzdTEwOLMEs3A09_xwB_F7cwRxNjA_2CbEdFABoCxrw!/?WCM_GLOBAL_CONTEXT=

that implies interdisciplinary knowledge and integration of required skills, personal values, and ethical priorities. Apart from fundamental knowledge and skills, the student should acquire additional competences, such as problem solving, leadership, teamwork, communication, professional ethics [1, p. 2]. The list of competences is validated with key program stakeholders. In particular, learning outcomes of educational program программы «Electrical and Electronic Engineering» were set [1, p. 10-11]. They include technical disciplinary knowledge, individual and communicative skills, as well as CDIO competences. The validity of documents, which describe set of learning outcomes in detail [1, p. 10-11; 4, p. 16, p. 23, 25] and define the knowledge and personal skills of the graduates, confirms effective implementation of Standard 2.

Standard 3. Integrated curriculum.

Standard 3 implementation in Singapore Polytechnic caused the enhancements of educational program structure [4, p. 27]. Singapore Polytechnic diploma program comprises three years: the first year is exposure of expected CDIO learning outcomes, the second year is development of CDIO skills, and the third year is practice and application of acquired CDIO skills. CDIO learning outcomes customized for Singapore Polytechnic [6] are those of discipline «Introduction to Engineering» [4, p. 41], which serves as a basis for discipline «Design Build Course» [4, p. 42] and the project on social innovations during the second year. Design Build Course as well as the project on social innovations allow students to work on the final project during the third year [4, p. 39]. However, not all the programs of Singapore Polytechnic include integrated curriculum, therefore, the level of conformity with Standard 3 might be assessed as satisfactory.

Standard 4. Introduction to Engineering.

At Singapore Polytechnic, discipline «Introduction to Engineering» is a component of integrated curriculum [4, p. 41]. It provides a framework for the practice of engineering and ensures product, process, and system building experiences as well as acquisition of personal and interpersonal skills. For example, the final task of «Introduction to Engineering» is to conceive, design and construct a springal. This corresponds to top ranks of implementation scale.

Standard 5. Design-Implement Experience.

Singapore Polytechnic pays particular attention to Standard 5 implementation. Standard 5 was first implemented into educational program «Electrical and Electronic Engineering», which caused changes in all curricula of Singapore Polytechnic: students should develop a project at the end of every academic year [1, p. 4]. During the first year students should study module «IDEA» (Innovation, Design and Enterprise in Action), the aim of which is to provide basic information on key aspects of innovative process. As a result, students assess the demand, make business plans and design prototypes [1, p. 4].

During the second year students should develop a group project based on knowledge acquired in preceding engineering courses. Project scopes are defined in accordance with the specialties: 1. Aerospace engineering. 2. Microcontrollers. 3. Biomedicine. The project aim is to provide students with the opportunity to put their ideas into life and apply their engineering skills within an involving project [1, p. 6]. Expected learning outcomes are detailed in educational programs of Singapore Polytechnic [1, p. 10-11].

During the third year students should implement an interdisciplinary project based on knowledge acquired in several preceding engineering courses. In other words, students from different institutions join to make a team for the project implementation. Project scope is broad enough – it might be bread vending machine or dehydrated milk distribution system.

In general, the level of Standard 5 implementation is high.

Standard 6. Engineering Workspaces.

Workspaces and laboratories which encourage hand-on learning of product, process, and system building skills deserve the high grade in Singapore in general and Singapore Polytechnic in particular[2]. This also refers to the workspaces that support disciplinary knowledge acquisition as well as social learning [1, p. 6; 4, p. 29, p. 42, p. 51, p. 57, p. 59, p. 61, p. 62].

Standard 7. Integrated Learning Experiences.

The integration level of expected CDIO learning outcomes and acquired skills is very high (refer to Standard 3). Moreover, according to educational programs, education is provided with due consideration of world experience and involves teaching by experienced industrial professionals [1, p. 2]. The level of Standard 7 implementation is high.

Standard 8. Active Learning.

Active learning is provided within design-implementation experiences [1]. However, these methods are not woven through the whole curriculum and the level of conformity with Standard 8 might be assessed as satisfactory.

Standards 9 and 10. Enhancement of Faculty CDIO-competence and Faculty Teaching Competence.

The level of Standards 9 and 10 implementation is quite high in Singapore Polytechnic. A lot of teachers participate in events, which upgrade their professional competence in active learning, learning assessment, and development of integrated curriculum. It is important to notice that teaching competence in educating and assessment are regularly tested and enhanced. Education specialists in Singapore are generally estimated to be the best in the world[3].

Standard 11. Learning Assessment.

Assessment of student learning in personal and interpersonal skills, and product, process, and system building skills, as well as in disciplinary knowledge is appropriate. Methods of assessment match to expected learning outcomes. Different methods are used to assess customized outcomes throughout the whole period of studying.

Standard 12. Program Evaluation.

In Singapore Polytechnic there is a system that evaluates programs against the twelve standards, and provides feedback to students, faculty, and other stakeholders for the purposes of continuous improvement [1, p. 8; 4, p. 47; 5, p. 8].

Conclusion

The experience of CDIO implementation in Singapore Polytechnic is undoubtedly successful and can serve as an example for Russian engineering institutions. Particular attention should be paid to the efficient use of facilities and rich design-implement experience revealed in hand-on projects.

[2] http://www.sp.edu.sg/wps/portal/vp-spws/spws.org.abtsp.vstsp.fac?utm_source=spws&utm_medium=facilities_banner&utm_campaign=spwsbanner

[3] http://www.topuniversities.com/university-rankings/university-subject-rankings/2013/education-and-training#sorting=rank+region=+country=+faculty=+stars=false+search=

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In Memoriam

BORIS LVOVICH AGRANOVICH, Vice-President of AEER, renowned Professor of Control Systems Optimization Department of Institute of Cybernetics of National Research Tomsk Polytechnic University, died August 12, 2014. He was 77.

He attended Tomsk Polytechnic University where he was graduated in 1962, specialization "Radio Engineering".

He was working as Associate Professor and Dean of Radio Engineering faculty at Tomsk Institute of Radioelectronics and Electronic Engineering up to 1981. However, he never failed in loyalty to his Alma Mater, to whose service his whole life was dedicated.

Since 1991 Boris Lvovich worked as Associate Professor in Control Systems Optimization Department, Tomsk Polytechnic University and director of West-Siberian Regional Center of New Information Technologies. Besides, he was appointed a deputy director of Cybernetics Center. Then, he was advanced to professor of Control Systems Optimization Department, Institute of Cybernetics, Tomsk Polytechnic University. In 1988-1995, he served as design manager in Automated University Management System of the Ministry of Higher Education of the RSFSR and Standard Automated Control System of Higher Education Institution. For 15 years Boris L. Agranovich was an active and influential member of the Association of Engineering Education of Russia (AEER). He was among the founders of and served as an executive editor of the journal "Engineering Education". As one of the distinguished managers and vice-presidents of AEER, he exerted a profound influence on the development of the association.

Professor Boris L. Agranovich was a person of high moral values, a distinguished scientist whose mind was of unusual brilliance and alert. He was well-known in his field, both in Russia and abroad, as an expert in innovative information technologies. As an outstanding academic and educator he was concerned with a wide scope of issues, such as methodological support for man-computer complex design, development of the automated control systems for industry, education, and economy.

His growing reputation as a scholar won him promotion to the rank of design manager of Automated University Management System of the Ministry of Higher Education of the RSFSR in1986 and design manager of Integrated Automated Ministry Management System, 1989. Under his leadership and guidance the first automated control system of the Ministry of Higher Education of Russia was designed and implemented.

Boris L. Agranovich achieved great results in solving issues related to higher engineering education. He was honored with the Russian Federation President Award in the field of education (1998). He was also the Laureate of Tomsk region Award in the field of education and science (1995) and Tomsk region Award "For development and implementation of precision instrument for phase measurement" (1970).

Agranovich B. L. was awarded with medal "For Valorous Labour" (1970), " For Merits to the Fatherland, 2nd grade" (1996), the title "Honored Worker of Higher Education of the Russian Federation" (2000), "Honored Worker of Higher Professional Education of the Russian Federation" (2005), silver medal "For Merits to Tomsk Polytechnic University" (1998), and medal "400 years to Tomsk" (2004).

Indeed, as an active member of AEER, he will be long remembered for his significant contribution to the advancement of engineering education, for his wide influence on the growth of engineering industry. In 2011, Boris L. Agranovich received the highest award from AEER, Medal of Peter I "For the development of engineering and education».

There is a great emptiness left by Boris L. Agranovich's passing. He was a man of great insight and personality, always faithful to his promises, colleagues and like-minded members of the team.

Boris L. Agranovich will always be remembered as an especially given person of great character, distinguished scientist, brilliant teacher, attentive colleague, and reliable companion.

AEER Administrative Board

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Summary

CDIO: OBJECTIVES AND MEANS OF ACHIEVEMENT

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The system of CDIO standards in terms of implementation in Russian engineering education is analyzed. Particular attention is paid to the scientific and methodological elaboration of «Conceive» stage. To increase the efficiency of this stage, domestic TRIZ methodology is considered. Relevant didactics, CAI programs and virtual environments of professional activity are proposed. It is indicated that international standards are more effective when they are implemented in educational-scientific-industrial (innovation) complexes.

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.

INTEGRATED CURRICULUM DEVELOPMENT IN INDUSTRIAL ENGINEERING PROGRAM USING CDIO FRAMEWORK

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This paper shares Thai industrial requirements on new graduates entering real-life workplace and the development of an integrated curriculum using CDIO framework. The result from a questionnaire survey showed high needs for personal and interpersonal skills with strong industrial engineering background. These skills were integrated into courses in 4-year program.

EXPERIENCE AND PRACTICE OF MANAGEMENT PROBLEM SOLUTION AT CDIO IMPLEMENTATION IN UNVERSITY EDUCATION

P.M. Vcherashniy, N.A. Kozel'
Siberian Federal University

There have appeared a great number of management problems at universities first introduced CDIO ideology. Taking into account the fact that the ideology itself leads to critical technologies development in the current education system, solution of management problems is to result in significant changes in a university. The article lists and describes the problems solved in a definite university and the results.

CDIO WITHIN THE SYSTEM OF CONTINUOUS EDUCATION "FROM SCHOOL TO HEI": STAGE "CONCEIVE" AT SCHOOL

O.V. Sidorkina, T.V. Pogrebnaya
Siberian Federal University

The article describes the system of methods to reveal potential intellectual giftedness of pupils. The system is designed by the authors and based on TRIZ-pedagogy. Within this system the pupils, who are regarded as future university applicants, are related to innovative HEI (high education institution) through innovative project activity. The authors have analyzed how appropriate the system is to introduce stage "Conceive" at school preparation for HEIs implementing CDIO system.

CONTENT AND AIM OF THE DISCIPLINE "INTRODUCTION TO ENGINEERING" WITHIN THE WORLDWIDE CDIO INITIATIVE

S.I. Osipova
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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 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.

STUDENTS AS AGENTS – CONNECTING FACULTY WITH INDUSTRY AND CREATING COLLABORATIVE PROJECTS

L.B. Jensen
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Collaborative projects between partners in the building industry and students constitute important means for addressing more advanced parts of the CDIO Syllabus 4. In this paper an existing internship program is revised in order to enhance collaboration between industry and faculty/students and perform as vehicle for addressing challenging parts of the CDIO syllabus.

PROJECT ACTIVITIES IN THE DEVELOPMENT OF ENGINEERING THINKING

T.V. Dontsova, A.D. Arnautov
Siberian Federal University

The article discusses the problem of educating a next generation engineer, who is able to think in terms of process. The particularities of engineering thinking being analyzed, the project activities are considered relevant to develop engineering thinking. The discipline «Introduction to Engineering Design» is proposed as an element within the system of project-based education provided at Siberian Federal University in accordance with CDIO international initiative.

IT PROFESSIONAL STANDARDS AS A FACTOR INFLUENCING THE SYLLABUS OF IT TRAINING COURSES. IMPLEMENTATION OF PRACTICE-ORIENTED LEARNING AT NARFU

N.V. Chicherina, O.D. Bugaenko, E.E. Ivanova, E.V. Rodionova
Northern (Arctic) Federal University named after M.V. Lomonosov

The paper covers education program development according to Russian and international professional standard requirements, development of IT specialist competency model, choice of training paths and learning outcomes with regard to international recommendations.

PRACTICE-ORIENTED EDUCATION AT NORTHERN (ARCTIC) FEDERAL UNIVERSITY

O.D. Bugaenko, E.E. Ivanova, E.V. Rodionova
Northern (Arctic) Federal University named after M.V. Lomonosov

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.

MATHEMATICS IN ENGINEERING EDUCATION WITHIN THE FRAMEWORK OF CDIO STANDARDS: METHODOLOGICAL ASPECT

V.M. Fedoseev
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The article describes the CDIO standard effect on the teaching methods of mathematics in technical institutions and focuses on the integration tools in mathematical and engineering training. Teaching tools in designing learning activities to implement the integration objectives and recommendation of their application during the teaching process have been examined based on a specific example.

COMPETENCES AND ENGINEERING STAFF IN THE SPHERE OF ENERGY CONSERVATION AS A BASE FOR RETRAINING PROGRAM DESIGN

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Demand for the personnel capable of taking innovative decisions and designing innovative facilities conditions the necessity for training managerial and engineering staff. The offered programs of three types based on the energy conservation competence models of managerial and engineering staff contribute to the solution of professional problems and development of competences in planning, design, production, implementation in the conditions simulating professional activity.

APPLICATION AND DEVELOPMENT OF CDIO ENGINEERING EDUCATION MODE IN UNDERGRADUATE SCIENCE PROGRAM

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Enlightened by successful implementation CDIO (Conceive, Design, Implement, and Operate) in Engineering Program, CDIO is applied to undergraduate science program in Chengdu University of Information Technology. In this work, CDIO is adapted into science program as a systematic framework including setting explicit professional training standards, reconstructing curriculum system, optimizing theoretical and experimental teaching mode, and intensifying process assessment. The results show that the adaptation of CDIO can inspire the interests of study as well as the practical ability of students in undergraduate science program.

ACTIVE TEACHING METHODS IN PROFESSIONAL CONTENT-BASED ENGLISH LANGUAGE LEARNING AS AN IMPORTANT COMPONENT OF CDIO CONCEPTS (PROFILE/SPECIALIZATION 12.03.01 "INSTRUMENT ENGINEERING")

V.S. Ivanova, K.V. Mertins
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The article describes the possible quality provision of engineering training in profile (specialization) 12.03.01 "Instrument Engineering" via developing a creative environment. Examples of applying active teaching methods in compliance with CDIO Initiatives are discussed.

APPLICATION OF INTERNATIONAL CDIO STANDARD AND INNOVATIVE APPROACH IN THE METHODOLOGY OF SCIENTIFIC CREATIVITY

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Tyumen State Oil and Gas University

Innovative methods of scientific work combined with the international CDIO initiative criteria are new approach to engineering education. The article presents the assessment tools and evaluation techniques which can be applied during various master's thesis project stages, with main focus being paid to "production" in parts "testing" and "validation". The present article is the continuation of the work done previously.

CDIO INITIATIVE AND PROBLEMS OF ACTIVE LEARNING IMPLEMENTATION IN ENGINEERING EDUCATION

Yu.P. Pokholkov, K.K. Tolkacheva
National Research Tomsk Polytechnic University

The article considers recommendations of CDIO Standards on active learning methods and their application to the problems in the system of engineering education. Contradictions between the organization of educational process and conditions for active and effective learning (interactive, practice-oriented, problem-based and project-based learning) are discussed as the main reason of the above stated problems. To overcome the contradictions it is importnat to make significant changes in the planning and organization of training, as well as in the requirements for qualifications of teachers, that are critical for teachers' ability to use modern methods and techniques to ensure students' involvement in the learning process.

ACTIVITY OF THE ENGINEERING TEACHERS ASSOCIATION TO IMPLEMENT CDIO CONCEPTS

Yu.V. Podpovetnay
South Ural State University
(National Research University)

The article examines a new approach to higher engineering education based on the introduction of the CDIO concept. The possibilities to implement the world CDIO initiative standards which enable university faculty to design educational process in the modern way so that students' motivation to learn is constantly motivated are outlined. The experience of the Ural Engineering Teachers Association in implementing CDIO concepts to improve educational process is presented.

TEAM-BUILDING FOR IMPLEMENTING INNOVATIVE EDUCATION PROGRAM WITHIN CDIO IDEOLOGY

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Siberian Federal University

It have been revealed that to improve the quality of engineering education it is required to build a creative team of teachers for developing innovative framework which guarantees adaptation and implementation of CDIO ideas. The article presents the experience in team-building including selection criteria. The task to create the unified team of teachers, students, employers and University authorities is set.

HUMAN RESOURCE MANAGEMENT FOR DEVELOPING BASIC EDUCATION PROGRAM IN CDIO IDEOLOGY

N.V. Gafurova, O.A. Osipenko
Siberian Federal University

The article highlights the issue of human resource training for CDIO ideology implementation. The authors suggest improving CDIO program by paying special attention to human resource management that involves all the stakeholders of the program: teaching staff, university managers, university applicants, students and employers representatives.

CDIO STANDARDS IMPLEMENTAION. TUSUR UNIVERSITY CASE STUDY

M.E. Antipin, M.A. Afanasyeva, E.S. Shandarov
Tomsk State University of Control Systems and Radioelectronics

The paper presents the TUSUR University case study in implementing CDIO standards. The authors describe how TUSUR University manages to apply CDIO principles at different levels, from one discipline to the whole educational program.

MOBILE SOFTWARE ENGINEERING FIELD: INNOVATION IN EDUCATION TO SHAPE THE ENGINEER PROFILE

Z.C. Chagra
The Private High School of Engineering and Technologies

During 2011, the Private High School of Engineering and Technologies (ESPRIT) came to decide that modifications ought to take place in the study plan within the school. The mobile section is one of the main fields that were born after a global analysis of several profiles and engineering technologies. This paper addresses a model of mobile software engineering taught through the mobile section curriculum.

SUPER COURSES, A BRIDGE BETWEEN UNIVERSITY AND INCUBATOR

I. Shimi
The Private High School of Engineering and Technologies

Engineering studies are based mainly on projects and Implementing solutions and are the most required selection criteria in the industrial market, particularly during economic crisis where finding jobs isn't guaranteed anymore and only Operational engineers can become job creators. To help engineers become future entrepreneurs, super courses or accelerated undergraduate studies are becoming necessary to provide extracurricular experience in a short period of time. Here comes the important role of CDIO standards, which helps alot engineering students from designing patterns to integrate the professional world.

INTRODUCING CDIO AS A TOOL FOR NArFU EDUCATIONAL PROGRAMS

N.V. Chicherina, E.E. Ivanova, M.A. Korelskaya
Northern (Arctic) Federal University named after M.V. Lomonosov

This article describes the enhancement of upgraded engineering education programs based on international CDIO standards within the framework of Northern (Arctic) Federal University n.a. M. Lomonosov.

EXPERIENCE AND FURTHER REFLECTIONS ON PRACTICE-BASED LEARNING DEVELOPMENT AT OMSK STATE TECHNICAL UNIVERSITY

V.V. Shalay, L.O. Shtripling, N.A. Prokudina
Omsk State Technical University

The article discusses experience and prospects of practice-based learning development at Omsk State Technical University through the establishment of resource centers and basic academic departments in corresponding enterprises, as well as implementation of CDIO standards.

COLLABORATIVE PROJECTS WITHIN «STUDENT – FACULTY – ENTERPRISE» SYSTEM AS MEANS OF PROFESSIONAL COMPETENCY DEVELOPMENT

M.Yu. Chervach, Yu. B. Chervach
National Research Tomsk Polytechnic University

The article reviews student involvement in professional business project development at HEI engineering department from the CDIO model perspective. The extent of student engagement in stages of conceiving, designing, implementing, and operating is analyzed. Possible roots for project activity development within the CDIO framework are proposed.

WORLDWIDE CDIO INITIATIVE, SINGAPORE IMPLEMENTATION EXPERIENCE

E.O. Akchelov
National Research Tomsk Polytechnic University

This article is dedicated to analysis of CDIO standards implementation in Singapore Polytechnic curricula. This paper presents evidence of compliance of Singapore Polytechnic curricula with CDIO standards. It is considered that experience of CDIO implementation in Singapore Polytechnic is successful.

Public-Professional Accreditation of Curricula (Results)

Russian Association of Engineering Education (AEER) has been involved in the development and progression of public-professional accreditation system of engineering and technology programs within Russia during the last 10 years. The following issues were embraced: the study of international experience history and the development of assessment criteria and requirements for engineering and technology programs, pursuant to existing international requirements. Further, Russia, represented by AEER, was admitted to the international Alliance ENA EE (European Network for Accreditation of Engineering Education). AEER was entitled to assigning the international certification label (EUR -AC E label) for accredited programs. In view of this fact, the existing quality assessment system of education programs in Russia has been acknowledged in 14 EU countries, such as Germany, France, Great Britain, Ireland, Portugal, Turkey and others.

At the same time AEER had been taking insistent measures in entering the International Engineering Alliance Washington Accord and in 2007 AEER was included in the Alliance as associated member with Provisional signatory (website WA).

In 2012 (June 14) the International Engineering Alliance Meeting (Interim Meeting 2012, Sidney, Australia) was held, where Russia, represented by AEER, was admitted to Washington Accord (Washington Agreement) as authorized Signatory member (website WA).

Russia became the 15th Signatory- country of the Washington Agreement. This implies that all engineering education programs accredited by AEER are acknowledged by other Signatories as equivalent analogue accredited programs, including such countries as USA , Canada, Great Britain, Japan, Korea, Singapore, Ireland, Australia, South Africa and other countries.

Thus, the quality assessment system for engineering education programs developed by AEER has been acknowledged by the majority of developed countries. It can be stated that a well-developed national public-professional accreditation system for engineering education programs has been established in Russia and AEER accreditation has been internationally accepted.

Based on the results (21.12.2014) 201 EUR-ACE® labels were awarded to 282 accredited education programs from 47 Russian universities; while in Kazakhastan, 34 education programs from 7 universities were awarded
EUR-ACE® Label due to international AEER accreditation.

The following Register shows the successfully accredited education programs by AEER.

List of Accredited Programs, Russian Federation (31.12.2014)

	Program Code	Qualifi-cation	Program Name	Certificate	Accreditation Period
	Altai State Technical University named after I.I. Polzunov				
1.	100400	INT	Electrical Supply	AEER	1997-2002
2.	120100	INT	Mechanical Engineering Technology	AEER	1997-2002
3.	120500	INT	Welding Equipment and Technology	AEER	1997-2002
4.	150900	FCD	Technology, Equipment and Automation of Mechanical Engineering Productions	AEER	2003-2008
	Belgorod State National Research University				
1.	210400	FCD	Telecommunications	AEER EUR-ACE®	2012-2017
2.	210406	INT	Communication Networks and Switching Systems	AEER EUR-ACE®	2012-2017
3.	210602	INT	Nanomaterials	AEER EUR-ACE®	2012-2017
4.	120700	FCD	Land Management and Cadastre	AEER EUR-ACE®	2014-2019
5.	120700	SCD	Cadastre and Land Monitoring	AEER EUR-ACE®	2014-2019
6.	130101	INT	Exploration and Prospecting of Underground Waters and Engineering Geological Survey	AEER EUR-ACE®	2014-2019
7.	210700	FCD	Communication Networks and Commutation Systems	AEER EUR-ACE®	2014-2019
	Dagestan State University				
1.	210104	INT	Microelectronics and Solid State Electronics	AEER EUR-ACE®	2013-2018
2.	280201	INT	Environmental Protection and Rational Use of National Resources	AEER EUR-ACE®	2013-2018
	Ivanovo State Power University				
1.	140404	INT	Nuclear Power Plants and Installations	AEER EUR-ACE®	2009-2014
2.	210106	INT	Industrial Electronics	AEER EUR-ACE®	2009-2014
	National Research Irkutsk State Technical University				
1.	130100	INT	Aircraft and Helicopter Construction	AEER	2004-2009
2.	250400	INT	Chemical Engineering of Natural Power Supplies and Carbon-base Materials	AEER	2004-2009
3.	140400	SCD	Optimization of Developing Power-supply Systems	AEER EUR-ACE®	2014-2019
4.	140400	SCD	Energy Efficiency, Energy Audit and Energy Department Management	AEER EUR-ACE®	2014-2019
5.	190700	SCD	Logistic Management and Traffic Control	AEER EUR-ACE®	2014-2019
6.	280700	SCD	Ecological Safety	AEER EUR-ACE®	2014-2019
7.	280700	SCD	Waste Management	AEER EUR-ACE®	2014-2019
	Kazan National Research Technical University named after A.N. Tupolev				
1.	150600	FCD	Science and Technology of New Materials	AEER EUR-ACE®	2011-2016
2.	160100	FCD	Aircraft Construction and Rocket Production	AEER EUR-ACE®	2011-2016
3.	230100	FCD	Computer Science	AEER EUR-ACE®	2011-2016
	Kazan National Research Technological University				
1.	240100	FCD	Chemical Technology and Biotechnology	AEER	2004-2009
2.	240100	SCD	Chemical Engineering for Innovative Entrepreneurship	AEER EUR-ACE®	2013-2018
	Kemerovo Institute of Food Science and Technology				
1.	240700	FCD	Food Biotechnology	AEER EUR-ACE®	2013-2018

	Program Code	Qualifi-cation	Program Name	Certificate	Accreditation Period
	Krasnoyarsk State Technical University				
1.	200700	INT	Radio Engineering	AEER	1997-2002
2.	220100	INT	Computers, Systems and Networks	AEER	1997-2002
3.	210302	INT	Radio Engineering	AEER	2003-2008
	Komsomolsk-on-Amur State Technical University				
1.	140600	FCD	Electrical Engineering, Electromechanics and Electrical Technology	AEER	2005-2010
2.	140601	INT	Electromechanics	AEER	2005-2010
3.	140604	INT	Electrical Drives and Automated Industrial Sets and Engineering Systems	AEER	2005-2010
	Kuban State Technological University				
1.	260100	FCD	Technology of Fermentation Manufacture and Winemaking	AEER EUR-ACE®	2014-2019
2.	260100	FCD	Technology of Bread Products	AEER EUR-ACE®	2014-2019
3.	260100	FCD	Technology of Fats, Essential Oils, Perfume and Cosmetic Products	AEER EUR-ACE®	2014-2019
	«MATI» – Russian State Technological University				
1.	190300	INT	Aircraft instruments, Measuring and Computing complexes	AEER	1996-2001
2.	110400	INT	Foundry of Ferrous and Non-ferrous Metals	AEER	1996-2001
3.	110500	INT	Metal Science and Thermal Treatment of Metals	AEER	1996-2001
4.	110700	INT	Welding Metallurgy	AEER	1996-2001
	Moscow State Mining University				
1.	090400	INT	Mine and Underground Construction	AEER	1996-2001
2.	090500	INT	Open-pit Mining	AEER	1996-2001
3.	130408	INT	Mine and Underground Construction	AEER EUR-ACE®	2010-2015
	Moscow State Technological University "Stankin"				
1.	120100	INT	Mechanical Engineering Technology	AEER	1993-1998
2.	120200	INT	Metal-cutting Machines and Tools	AEER	1993-1998
3.	120400	INT	Machines and Metal Forming Technology	AEER	1993-1998
4.	210200	INT	Automation of Technological Processes and Manufacturing	AEER	1993-1998
5.	210300	INT	Robots and Robotic Systems	AEER	1993-1998
6.	220300	INT	Automated Production Systems	AEER	1993-1998
	Moscow State University of Applied Biotechnology				
1.	070200	INT	Low Temperature Physics and Technology	AEER	1996-2001
2.	170600	INT	Food Production Machines and Devices	AEER	1996-2001
3.	210200	INT	Automation of Technological Processes and Manufacturing	AEER	1996-2001
4.	250600	INT	Plastic and Elastoplastic Processing Technology	AEER	1996-2001
5.	270900	INT	Meat and Meat Products Technology	AEER	1996-2001
6.	271100	INT	Milk and Dairy Products Technology	AEER	1996-2001
	Moscow State Technical University of Radio Engineering, Electronics and Automation				
1.	210302	INT	Radio Engineering	AEER	2004 -2009
2.	220402	INT	Robots and Robotic Systems	AEER	2005-2010
3.	200203	INT	Optoelectronic Devices and Systems	AEER	2005-2010
4.	220401	INT	Mechatronics	AEER	2005-2010
5.	210104	INT	Microelectronics and Solid State Electronics	AEER	2005-2010
6.	230105	INT	Computer Technology and Automated Systems Software	AEER	2005-2010
7.	230201	INT	Information Systems and Technologies	AEER	2005-2010
8.	230101	INT	Computers, Systems and Networks	AEER EUR-ACE®	2008-2013
9.	210104	INT	Microelectronics and Solid State Electronics	AEER EUR-ACE®	2010-2015
10.	200200	FCD	Optical Engineering	AEER EUR-ACE®	2010-2015
11.	210300	FCD	Radio Engineering	AEER EUR-ACE®	2010-2015
12.	211000	SCD	Quality Assurance and Certification of Electronic Equipment	AEER EUR-ACE®	2013-2018
13.	210100	SCD	Measurement and Information Technologies and Systems	AEER EUR-ACE®	2013-2018

	Program Code	Qualification	Program Name	Certificate	Accreditation Period
	National Research University of Electronic Technology (MIET)				
1.	210100	FCD	Electronics and Microelectronics	AEER	2003-2008
2.	230100	FCD	Computer Science	AEER	2003-2008
	National Research University (MPEI)				
1.	140600	FCD	Electrical Engineering, Electromechanics and Electrical Technology	AEER	2005-2010
2.	140602	INT	Electrical and Electronic Machines	AEER EUR-ACE®	2007-2012
3.	140604	INT	Electrical Drives and Automated Industrial Sets and Engineering Systems	AEER EUR-ACE®	2007-2012
4.	140609	INT	Electrical Equipment for Aircraft	AEER EUR-ACE®	2007-2012
5.	140611	INT	Insulators, Cables and Capacitors	AEER EUR-ACE®	2007-2012
6.	140403	INT	Technical Physics of Thermonuclear Reactors and Plasma Installations	AEER EUR-ACE®	2010-2015
	National Research Tomsk Polytechnic University				
1.	071600	INT	High Voltage Engineering and Physics	AEER	1996-2001
2.	080200	INT	Geology and Prospecting of Mineral Resources	AEER	1996-2001
3.	180100	INT	Electromechanics	AEER	1996-2001
4.	200400	INT	Industrial Electronics	AEER	1996-2001
5.	210400	INT	Applied Mathematics	AEER	1996-2001
6.	250900	INT	Chemical Engineering of Modern Energetic Materials	AEER	1999-2004
7.	250800	INT	Chemical Engineering of Refractory Non-Metal and Silicate Materials	AEER	2000-2005
8.	070500	INT	Nuclear Reactors and Power Plants	AEER	2000-2005
9.	220100	INT	Computer Science	AEER	2000-2005
10.	100500	INT	Thermal Power Plants	AEER	2000-2005
11.	101300	INT	Boiler and Reactor Engineering	AEER	2000-2005
12.	230100	FCD	Computer Science	AEER	2003-2008
13.	140600	FCD	Electrical Engineering, Electromechanics and Electrical Technology	AEER	2003-2008
14.	140601	INT	Electromechanics	AEER	2004-2009
15.	140604	INT	Electrical Drives and Automated Industrial Sets and Engineering Systems	AEER	2004-2009
16.	230101	INT	Computers, Systems and Networks	AEER	2004-2009
17.	020804	INT	Geoecology	AEER	2004-2009
18.	130100	FCD	Geology and Prospecting of Mineral Resources	AEER	2005-2010
19.	200106	INT	Measurement Devices and Technologies	AEER EUR-ACE®	2007-2012
20.	200203	INT	Opto-Electronic Equipment and Systems	AEER EUR-ACE®	2007-2012
21.	240304	INT	Chemical Engineering of Refractory Non-Metal and Silicate Materials	AEER EUR-ACE®	2007-2012
22.	240901	INT	Biotechnology	AEER EUR-ACE®	2008-2011
23.	140200	FCD	Electrical Power Engineering	AEER EUR-ACE®	2008-2013
24.	150917	SCD	High-technology Physics in Mechanical Engineering	AEER EUR-ACE®	2008-2013
25.	230100	FCD	Computer Science	AEER EUR-ACE®	2008-2013
26.	140600	FCD	Electrical Engineering, Electromechanics and Electrical Technology	AEER EUR-ACE®	2008-2013
27.	140200	SCD	High Voltage Engineering and Physics	AEER EUR-ACE®	2010-2015
28.	130100	SCD	Groundwater Resources Formation and Composition	AEER EUR-ACE®	2010-2015
29.	150900	FCD	Technology, Equipment and Automation of Mechanical Engineering Productions	AEER EUR-ACE®	2011-2016
30.	220301	INT	Automation of Technological Processes and Manufacturing (Gas and Oil field)	AEER EUR-ACE®	2011-2016
31.	210100	SCD	Physical Electronics	AEER EUR-ACE®	2011-2016
32.	140200	SCD	Mode Control of Electric Power Systems	AEER EUR-ACE®	2011-2016

	Program Code	Qualifi-cation	Program Name	Certificate	Accreditation Period
33.	140400	SCD	Electrical Drives and Electrical Drive Control Systems	AEER EUR-ACE®	2011-2016
34.	200100	SCD	Stabilization and Navigation Systems	AEER EUR-ACE®	2011-2016
35.	130500	FCD	Petroleum Engineering	AEER EUR-ACE®	2011-2016
36.	130500	SCD	Geologic-geophysical Problems of Oil and Gas Field Development	AEER EUR-ACE®	2011-2016
37.	140801	INT	Electronics and Automated Physical Installations	AEER EUR-ACE®	2012-2017
38.	240501	INT	Chemical Technology of Modern Power Engineering Materials	AEER EUR-ACE®	2012-2017
39.	140404	INT	Nuclear Power Plants and Installations	AEER EUR-ACE®	2012-2017
40.	200100	SCD	Devices and Methods of Quality Control and Diagnostics	AEER EUR-ACE®	2012-2017
41.	200100	FCD	Measurement Devices and Technologies	AEER EUR-ACE®	2012-2017
42.	200100	FCD	Instrumentation Engineering	AEER EUR-ACE®	2012-2017
43.	200100	FCD	Devices and Methods of Quality Control and Diagnostics	AEER EUR-ACE®	2012-2017
44.	200100	SCD	Measurement Devices and Technologies of Nondestructive Testing	AEER EUR-ACE®	2012-2017
45.	240100	FCD	Chemical Engineering of Natural Power Supplies and Carbon-base Materials	AEER EUR-ACE®	2012-2017
46.	240100	FCD	Chemical Technology of Organic Substances	AEER EUR-ACE®	2012-2017
47.	240100	FCD	Chemical Technology of Inorganic Substances	AEER EUR-ACE®	2012-2017
48.	240100	FCD	Polymer Processing Technology	AEER EUR-ACE®	2012-2017
49.	240100	FCD	Technology of Refractory Non-Metal and Silicate Materials	AEER EUR-ACE®	2012-2017
50.	240100	SCD	Chemical Engineering of Refractory Non-Metal and Silicate Materials	AEER EUR-ACE®	2012-2017
51.	150100	SCD	Science and Technology of Nanomaterials and Coatings	AEER EUR-ACE®	2012-2017
52.	200400	FCD	Opto-Electronic Equipment and Systems	AEER EUR-ACE®	2012-2017
53.	022000	FCD	Geoecology	AEER EUR-ACE®	2012-2017
54.	201000	FCD	Biotechnical and Medical Devices and Systems	AEER EUR-ACE®	2012-2017
55.	140400	FCD	Electrical Drives and Automation	AEER EUR-ACE®	2014-2019
56.	140400	FCD	Protection Relay and Automation of Power Grids	AEER EUR-ACE®	2014-2019
57.	221400	FCD	Quality Management in Manufacturing and Technological Systems	AEER EUR-ACE®	2014-2019
58.	150100	FCD	Nanostructured Materials	AEER EUR-ACE®	2014-2019
59.	150100	FCD	Materials Science and Technologies in Mechanical Engineering	AEER EUR-ACE®	2014-2019
60.	150100	SCD	Nanostructured Materials Tool Production	AEER EUR-ACE®	2014-2019
61.	150100	SCD	Computer Simulation of Material Production, Processing and Treatment	AEER EUR-ACE®	2014-2019
62.	130101	INT	Petroleum Geology	AEER EUR-ACE®	2014-2019
63.	12.04.02	SCD	Lighting Technology and Light Sources	AEER EUR-ACE®	2014-2019
64.	12.04.02	SCD	Photonic Technologies and Materials	AEER EUR-ACE®	2014-2019
65.	15.04.01	SCD	High-technology Physics in Mechanical Engineering	AEER EUR-ACE®	2014-2019
66.	19.03.01	FCD	Biotechnology	AEER EUR-ACE®	2014-2019

	Program Code	Qualifi-cation	Program Name	Certificate	Accreditation Period
67.	12.04.04	SCD	Medical and Biological Devices, Systems and Complexes	AEER EUR-ACE®	2014-2019
68.	15.03.01	FCD	Automation of Manufacturing Processes and Production in Mechanical Engineering	AEER EUR-ACE®	2014-2019
69.	21.05.03	INT	Geology and Exploration of Minerals	AEER EUR-ACE® WA	2014-2019
70.	21.05.03	INT	Geophysical Methods of Well Logging	AEER EUR-ACE® WA	2014-2019
	National Research University «Lobachevsky State University of Nizhni Novgorod»				
1.	010300	FCD	Software Engineering	AEER EUR-ACE®	2014-2019
2.	010300	FCD	Fundamental Computer Science and Information Technologies (in English)	AEER EUR-ACE®	2014-2019
3.	010300	SCD	Software Engineering	AEER EUR-ACE®	2014-2019
	National University of Science and Technology «MISIS»				
1.	150101	INT	Metallurgy of Ferrous Metals	AEER	2004-2009
2.	150105	INT	Metal Science and Thermal Treatment of Metals	AEER	2004-2009
3.	150601	INT	Science and Technology of New Materials	AEER	2004-2009
4.	150400	FCD	Metallurgy of Ferrous Metals	AEER EUR-ACE®	2011-2016
5.	150400	FCD	Physical Metallurgy of Non-Ferrous, Rare-Earth and Precious Metals	AEER EUR-ACE®	2011-2016
6.	150400	FCD	Functional Materials and Coatings	AEER EUR-ACE®	2011-2016
7.	150400	FCD	Metal Forming	AEER EUR-ACE®	2011-2016
8.	011200	FCD	Physics of Condensed Matter	AEER EUR-ACE®	2012-2017
9.	150100	FCD	Materials Science and Engineering of Functional Materials for Nanoelectronics	AEER EUR-ACE®	2012-2017
10.	150400	FCD	Metallurgy of Non-ferrous, Rare and Precious Metals	AEER EUR-ACE®	2012-2017
11.	151000	FCD	Metallurgical Machines and Equipment	AEER EUR-ACE®	2012-2017
12.	210100	FCD	Semiconductor Devices for Micro- and Nanoelectronics	AEER EUR-ACE®	2012-2017
13.	210100	FCD	Materials and Technologies of Magnetoelectronics	AEER EUR-ACE®	2012-2017
14.	210100	FCD	Micro- and Nanotechnology Processes	AEER EUR-ACE®	2012-2017
15.	220700	FCD	Automated Systems in Manufacturing	AEER EUR-ACE®	2012-2017
16.	230100	FCD	Automated Systems	AEER EUR-ACE®	2012-2017
17.	150400	SCD	Metallurgy of Non-Ferrous and Precious Metals	AEER EUR-ACE®	2014-2019
18.	011200	SCD	Physics of Condensed Matter	AEER EUR-ACE®	2014-2019
19.	011200	SCD	Physics of Nanosystems	AEER EUR-ACE®	2014-2019
20.	210100	SCD	Materials and Technologies of Magnetoelectronics	AEER EUR-ACE®	2014-2019
21.	210100	SCD	Micro- and Nanotechnology Processes	AEER EUR-ACE®	2014-2019
	Nosov Magnitogorsk State Technical University				
1.	150400	FCD	Forming of Metals and Alloys (Rolling)	AEER EUR-ACE®	2014-2019
2.	150400	SCD	Rolling Production Technology	AEER EUR-ACE®	2014-2019
	Novosibirsk State Technical University				
1.	150501	INT	Materials Science in Mechanical Engineering	AEER EUR-ACE®	2012-2017

	Program Code	Qualification	Program Name	Certificate	Accreditation Period
	Ogarev Mordovia State University				
1.	151900	FCD	Mechanical Engineering Technology	AEER EUR-ACE®	2014-2019
2.	210100	FCD	Industrial Electronics	AEER EUR-ACE®	2014-2019
	Peoples' Friendship University of Russia				
1.	270100	SCD	Structural Theory and Engineering	AEER EUR-ACE®	2013-2018
2.	270100	SCD	River and Underground Hydraulic Engineering Works	AEER EUR-ACE®	2013-2018
3.	270100	SCD	Theory and Practice of Organizational, Technical and Economic Decisions in Building and Construction	AEER EUR-ACE®	2013-2018
4.	141100	SCD	Internal Combustion Engines	AEER EUR-ACE®	2013-2018
5.	141100	SCD	Steam- and Gas Turbine Plants and Engines	AEER EUR-ACE®	2013-2018
	Perm National Research Polytechnic University				
1.	150700	SCD	Beam Technologies in Welding	AEER EUR-ACE®	2014-2019
2.	270800	SCD	Underground and Urban Construction	AEER EUR-ACE®	2014-2019
	Samara State Aerospace University				
1.	160301	INT	Aircraft Engines and Power Plants	AEER EUR-ACE®	2008-2013
2.	160802	INT	Spasecraft and Rocket Boosters	AEER EUR-ACE®	2008-2013
	Saint Petersburg Electrotechnical University "LETI"				
1.	220200	FCD	Automation and Control	AEER	2003-2008
2.	210100	FCD	Electronics and Microelectronics	AEER	2003-2008
3.	230100	FCD	Computer Science	AEER	2003-2008
4.	200300	FCD	Biomedical Engineering	AEER	2003-2008
5.	210400	FCD	Radio Electronic Systems	AEER EUR-ACE®	2014-2019
6.	210400	FCD	Radiotechnical Devices for Signal Transmission, Reception and Processing	AEER EUR-ACE®	2014-2019
7.	210400	FCD	Audiovision Equipment	AEER EUR-ACE®	2014-2019
8.	210100	FCD	Electronic Devices	AEER EUR-ACE®	2014-2019
9.	200100	FCD	Information and Measurement Technique and Technology	AEER EUR-ACE®	2014-2019
10.	200100	FCD	Laser Measurement and Navigation Systems	AEER EUR-ACE®	2014-2019
11.	200100	FCD	Devices and Methods of Monitoring of Quality and Diagnostics	AEER EUR-ACE®	2014-2019
12.	231000	SCD	Development of Distributed Software Systems	AEER EUR-ACE®	2014-2019
13.	010400	SCD	Mathematical Provisions and Software of Computers	AEER EUR-ACE®	2014-2019
14.	220451	SCD	Automation and Control of Industrial Complexes and Mobile Objects	AEER EUR-ACE®	2014-2019
15.	220452	SCD	Automated Control Systems for Sea Vehicles	AEER EUR-ACE®	2014-2019
16.	220453	SCD	Shipborne Information and Control Systems	AEER EUR-ACE®	2014-2019
17.	140452	SCD	Automated Electromechanical Complexes and Systems	AEER EUR-ACE®	2014-2019
18.	230161	SCD	Microsystem Computer Technologies: Systems on Chip	AEER EUR-ACE®	2014-2019
19.	230162	SCD	Distributed Intelligent Systems and Technology	AEER EUR-ACE®	2014-2019
20.	230151	SCD	Computer Technologies in Engineering	AEER EUR-ACE®	2014-2019
21.	201051	SCD	Biotechnical Systems and Technologies of Rehabilitation and Prosthetics	AEER EUR-ACE®	2014-2019

	Program Code	Qualifi-cation	Program Name	Certificate	Accreditation Period
22.	201053	SCD	Information Systems and Technologies in Patient Care Institutions	AEER EUR-ACE®	2014-2019
23.	210153	SCD	Electronic Devices and Equipment	AEER EUR-ACE®	2014-2019
24.	210176	SCD	Physical Electronics	AEER EUR-ACE®	2014-2019
25.	210152	SCD	Microwave and Telecommunication Electronics	AEER EUR-ACE®	2014-2019
26.	211006	FCD	Information Technologies for Radio Electronic Engineering	AEER EUR-ACE®	2014-2019
27.	211008	FCD	Information Technologies in Microwave Electronic Engineering	AEER EUR-ACE®	2014-2019
	Saint Petersburg National Research University of Information Technologies, Mechanics and Optics				
1.	27.04.03	SCD	Intelligent Control Systems of Technological Processes	AEER EUR-ACE®	2014-2019
2.	09.04.01	SCD	Embedded Computer Systems Design	AEER EUR-ACE®	2014-2019
3.	09.04.02	SCD	Automation and Control in Educational Systems	AEER EUR-ACE®	2014-2019
4.	09.04.03	SCD	Overall Automation of Enterprise	AEER EUR-ACE®	2014-2019
5.	24.04.01	SCD	Quality Control of Products of Space Rocket Complexes	AEER EUR-ACE®	2014-2019
6.	12.04.02	SCD	Applied Optics	AEER EUR-ACE®	2014-2019
7.	16.04.01	SCD	Integrated Analyzer Systems and Information Technologies of Fuel and Energy Complex Enterprises	AEER EUR-ACE®	2014-2019
8.	19.04.03	SCD	Biotechnology of Therapeutic, Special and Prophylactic Nutrition Products	AEER EUR-ACE®	2014-2019
	Saint-Petersburg State Polytechnic University				
1.	010800	SCD	Mechanics of Deformable Solid Body	AEER EUR-ACE®	2014-2019
2.	210700	SCD	Protected Telecommunication Systems	AEER EUR-ACE®	2014-2019
3.	210100	SCD	Micro- and Nanoelectronics	AEER EUR-ACE®	2014-2019
4.	223200	SCD	Physics of Low-dimensional Structures	AEER EUR-ACE®	2014-2019
5.	151900	SCD	Machine-building Technology	AEER EUR-ACE®	2014-2019
6.	140100	SCD	Technology of Production of Electric Power and Heat	AEER EUR-ACE®	2014-2019
7.	220100	SCD	System Analysis and Control	AEER EUR-ACE®	2014-2019
8.	270800	SCD	Engineering Systems of Buildings and Constructions	AEER EUR-ACE®	2014-2019
9.	270800	SCD	Construction Management of Investment Projects	AEER EUR-ACE®	2014-2019
	Siberian State Aerospace University				
1.	220100	FCD	System Analysis and Control	AEER EUR-ACE®	2011-2016
2.	230100	FCD	Computer Science and Computer Facilities	AEER EUR-ACE®	2011-2016
	Siberian Federal University				
1.	210200	SCD	Microwave Equipment and Antennas	AEER EUR-ACE®	2010-2015
2.	230100	SCD	High-Performance Computing Systems	AEER EUR-ACE®	2010-2015
	Stary Oskol Technological Institute named after A.A. Ugarov (branch of National University of Science and Technology «MISIS»)				
1.	150400	FCD	Metallurgy of Ferrous Metals	AEER EUR-ACE®	2012-2015
	Taganrog Institute of Technology of Southern Federal University				
1.	210100	FCD	Electronics and Microelectronics	AEER	2003-2008
2.	230100	FCD	Computer Science	AEER	2003-2008

	Program Code	Qualification	Program Name	Certificate	Accreditation Period
3.	230100	FCD	Computer Science	AEER EUR-ACE®	2010-2015
4.	220200	FCD	Automation and Control	AEER EUR-ACE®	2010-2015
5.	210100	FCD	Electronics and Microelectronics	AEER EUR-ACE®	2012-2017
6.	200100	FCD	Equipment Engineering	AEER EUR-ACE®	2012-2017
	Tambov State Technical University				
1.	210201	INT	Design and Technology of Radioelectronic Devices	AEER	2006-2011
2.	140211	INT	Electrical Supply	AEER	2006-2011
	Togliatty State University				
1.	140211	INT	Electrical Supply	AEER EUR-ACE®	2009-2014
2.	150202	INT	Industrial Welding Technology and Equipment	AEER EUR-ACE®	2009-2014
3.	151002	INT	Mechanical Engineering Technology	AEER EUR-ACE®	2009-2014
	Tomsk State University of Control Systems and Radio Electronics				
1.	210100	FCD	Industrial electronics	AEER EUR-ACE®	2013-2018
2.	222000	FCD	Innovation Management in Electronic Engineering	AEER EUR-ACE®	2013-2018
	Trekhgorny Technological Institute				
1.	230101	INT	Computers, Systems and Networks	AEER	2004-2007
	Tyumen State Oil and Gas University				
1.	130501	INT	Design, Construction and Operation of Gas and Oil Pipelines and Storage Facilities	AEER	2006-2011
2.	130503	INT	Development and Exploitation of Oil and Gas Fields	AEER	2006-2011
3.	130504	INT	Oil and Gas Drilling	AEER	2006-2011
4.	190601	INT	Automobiles and Transportation Facilities	AEER	2007-2012
5.	190603	INT	Transport and technological machinery and equipment service (oil and gas production)	AEER	2007-2012
6.	190701	INT	Transportation organization and transport management (automobile transport)	AEER	2007-2012
7.	130602	INT	Oil and Gas Fields Machinery and Equipment	AEER EUR-ACE®	2008-2013
8.	150202	INT	Industrial Welding Technology and Equipment	AEER EUR-ACE®	2008-2011
9.	190205	INT	Lifting, Transportation Means and Road Machines	AEER EUR-ACE®	2008-2013
10.	240401	INT	Chemical Technology of Organic Substances	AEER EUR-ACE®	2009-2014
11.	240403	INT	Chemical Engineering of Natural Power Supplies and Carbon-base Materials	AEER EUR-ACE®	2009-2014
12.	240801	INT	Machines and Apparatus of Chemical Production	AEER EUR-ACE®	2009-2014
13.	280201	INT	Environmental control and rational use of natural resources	AEER EUR-ACE®	2010-2015
14.	280102	INT	Safety of technological processes and productions	AEER EUR-ACE®	2010-2015
15.	120302	INT	Land cadastre	AEER EUR-ACE®	2010-2015
	Tyumen State University of Architecture and Civil Engineering				
1.	270800	SCD	Water Supply and Sanitation	AEER EUR-ACE®	2013-2018
2.	270800	SCD	Industrial and Civil Construction	AEER EUR-ACE®	2013-2018
3.	280700	SCD	Safety of Technological Processes and Production	AEER EUR-ACE®	2013-2018
	Ural State Forest Engineering University				
1.	270205	INT	Automobile Roads and Aerodromes	AEER	2006-2011
	Ural Federal University				
1.	240302	INT	Technology of Electrochemical Productions	AEER EUR-ACE®	2008-2013

	Program Code	Qualifi-cation	Program Name	Certificate	Accreditation Period
	Ufa State Aviation Technical University				
1.	280200	FCD	Environment Protection	AEER	2005-2010
2.	230100	FCD	Computer Science	AEER	2005-2010
3.	150501	INT	Material Science in Mechanical Engineering	AEER	2005-2010
4.	280200	SCD	Environment Protection	AEER EUR-ACE®	2008-2013
	Ufa State Petroleum Technological University				
1.	130504	INT	Oil and Gas Drilling	AEER EUR-ACE®	2007-2012
2.	130603	INT	Oil and Gas Processing Equipment	AEER EUR-ACE®	2007-2012
3.	150400	FCD	Processing Machinery and Equipment	AEER EUR-ACE®	2007-2012
4.	240100	FCD	Chemical Engineering and Biotechnology	AEER EUR-ACE®	2008-2013
5.	240403	INT	Chemical Engineering of Natural Power Supplies and Carbon-base Materials	AEER EUR-ACE®	2008-2013
6.	130602	INT	Oil and Gas Fields Machinery and Equipment	AEER EUR-ACE®	2008-2013
7.	130501	INT	Design, Construction and Operation of Gas and Oil Pipelines and Storage Facilities	AEER EUR-ACE®	2009-2014
8.	551830	SCD	Equipment Design Theory for Oil and Gas Processing, Petrochemical and Chemical Production	AEER EUR-ACE®	2010-2015
9.	551831	SCD	Technological Systems and Equipment Reliability	AEER EUR-ACE®	2010-2015
10.	550809	SCD	Chemical Engineering of Fuel and Gas	AEER EUR-ACE®	2010-2015
11.	270100	FCD	Building Construction	AEER EUR-ACE®	2011-2016
12.	550109	SCD	Building Construction	AEER EUR-ACE®	2011-2016
13.	131000	FCD	Petroleum Engineering	AEER EUR-ACE®	2013-2018
14.	151000	FCD	Production Machines and Equipment	AEER EUR-ACE®	2013-2018
	Vladimir State University named after Alexander and Nikolay Stoletovs				
1.	150900	FCD	Technology, Equipment and Automation of Mechanical Engineering Productions	AEER EUR-ACE®	2012-2017
2.	230100	FCD	Computer Science	AEER EUR-ACE®	2012-2017

List of Accredited Programs, Republic of Kazakhstan (31.12.2014)

	Program Code	Qualifi-cation	Program Name	Certificate	Accreditation Period
	D. Serikbayev East Kazakhstan State Technical University (Ust-Kamenogorsk, Republic of Kazakhstan)				
1.	050703	FCD	Information Systems	AEER EUR-ACE®	2011-2016
2.	050713	FCD	Transport, Transport Facilities and Technology	AEER EUR-ACE®	2011-2016
	L.N. Gumilyov Eurasian National University (Astana, Republic of Kazakhstan)				
1.	050702	FCD	Automation and Control	AEER EUR-ACE®	2011-2016
2.	050732	FCD	Standardization, Metrology and Certification	AEER EUR-ACE®	2011-2016
3.	050901	FCD	Organization of Transportation, Traffic and Operation	AEER EUR-ACE®	2011-2016
4.	6N0702	SCD	Automation and Control	AEER EUR-ACE®	2011-2016
5.	6N0732	SCD	Standardization, Metrology and Certification	AEER EUR-ACE®	2011-2016
6.	6N0901	SCD	Organization of Transportation, Traffic and Operation	AEER EUR-ACE®	2011-2016

	Program Code	Qualification	Program Name	Certificate	Accreditation Period
	Innovative University of Eurasia (Pavlodar, Republic of Kazakhstan)				
1.	050701	FCD	Biotechnology	AEER EUR-ACE®	2010-2015
2.	050718	FCD	Electrical Power Engineering	AEER EUR-ACE®	2010-2015
	Kazakh National Technical University named after K.I. Satpaev (Almaty, Republic of Kazakhstan)				
1.	050704	FCD	Computer Science and Software	AEER EUR-ACE®	2010-2015
2.	050711	FCD	Geodesy and Cartography	AEER EUR-ACE®	2010-2015
3.	050712	FCD	Mechanical Engineering	AEER EUR-ACE®	2010-2015
4.	050718	FCD	Electrical Power Engineering	AEER EUR-ACE®	2010-2015
5.	050723	FCD	Technical Physics	AEER EUR-ACE®	2010-2013
6.	050713	FCD	Transport, Transport Facilities and Technology	AEER	2011-2016
7.	050716	FCD	Instrumentation Engineering	AEER	2011-2016
8.	050719	FCD	Radio Engineering, Electronics and Telecommunications	AEER EUR-ACE®	2011-2016
9.	050720	FCD	Chemical Technology of Inorganic Substances	AEER EUR-ACE®	2011-2016
10.	050721	FCD	Chemical Technology of Organic Substances	AEER EUR-ACE®	2011-2016
11.	050722	FCD	Printing	AEER EUR-ACE®	2011-2016
12.	050724	FCD	Processing Machinery and Equipment	AEER EUR-ACE®	2011-2016
13.	050729	FCD	Construction	AEER EUR-ACE®	2011-2016
14.	050731	FCD	Life Safety and Environmental Protection	AEER EUR-ACE®	2011-2016
15.	050732	FCD	Standardization, Metrology and Certification	AEER EUR-ACE®	2011-2016
	Karaganda State Technical University (Karaganda, Republic of Kazakhstan)				
1.	050702	FCD	Automation and Control	AEER EUR-ACE®	2010-2015
2.	050707	FCD	Mining Engineering	AEER EUR-ACE®	2010-2015
3.	050709	FCD	Metallurgy	AEER EUR-ACE®	2010-2015
4.	050712	FCD	Mechanical Engineering	AEER EUR-ACE®	2010-2015
5.	050713	FCD	Transport, Transport Facilities and Technology	AEER EUR-ACE®	2010-2015
	Kostanay Engineering and Pedagogical University (Kostanay, Republic of Kazakhstan)				
1.	050713	FCD	Transport, Transport Equipment and Technology	AEER EUR-ACE®	2011-2016
2.	050732	FCD	Standardization, Metrology and Certification	AEER EUR-ACE®	2011-2016
	Semey State University named after Shakarim (Semey, Republic of Kazakhstan)				
1.	050727	FCD	Food Technology	AEER EUR-ACE®	2010-2015
2.	050724	FCD	Processing Machinery and Equipment	AEER EUR-ACE®	2010-2015

List of Accredited Secondary Professional Education Programs (31.12.2014)

	Program Code	Qualifi-cation	Program Name	Certificate	Accreditation Period
	Tomsk Polytechnic College				
1.	131003	T	Oil and Gas Drilling	AEER	2014-2019
	Tomsk Industrial College				
1.	140448	T	Technical Operation and Maintenance of Electrical and Electromechanical Equipment	AEER	2014-2019
	Tomsk College of Information Technologies				
1.	230115	T	Computer Systems Programming	AEER	2014-2019

ENGINEERING EDUCATION

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Full-text e-journal:
www.aeer.ru

Association for Engineering
Education of Russia, 2014

Published at:
«Kopir» LLC
Novosibirsk, 2014