Benchmarking of TPU Academic Standard and CDIO Standards in Engineering Education

Prof. Alexander I. Chuchalin,

A/Prof. Tatyana S. Petrovskaya,

Dr. Evgeniya S. Kulyukina,

Ms. Marina S. Tayurskaya

Tomsk Polytechnic University (Russia)

ABSTRACT

The Russian Federation Higher Education system has been essentially reforming for the last ten years. One of the major trends of such significant modernization consists in extension of universities' academic freedoms in design and implementation of their educational programs. Tomsk Polytechnic University (TPU) developed its own Standards and Guidelines for TPU Academic Programs Quality Assurance based on the new generation of Federal State Educational Standards and international requirements to competences of engineering programs graduates (Washington Accord Graduate Attributes, EUR-ACE Framework Standards, etc.). To improve the quality of academic programs at bachelor level and to strengthen the leadership position in Russian engineering education TPU joined the CDIO Initiative in October 2011. This paper offers a survey of Tomsk Polytechnic University starting process in adoption and adaption of CDIO approach in undergraduate engineering programs reforms.

KEYWORDS

Tomsk Polytechnic University, TPU Academic Standard, Engineering Education, CDIO Standards, self-evaluation, learning outcomes

(1) ENGINEERING EDUCATION IN RUSSIA

Russian engineering education embarked on a range of modernizing processes such as the introduction of a multi-level educational system, competition with other Russian and foreign educational institutions, increased independence of students and the development of new educational technologies [1]. Employers, due to technological and later organizational changes that had taken place, began to demand a new quality of university graduates. To define this quality, key stakeholders started to work in closer cooperation: employers, universities, and the state. This movement is so influential that it has acquired a global dimension [2].

In 2009 Russian Higher Education was substantially changed with the adoption of the new Federal State Educational Standards (FSES). The principal difference between the new version of the standards and previous ones is the outcomes-based approach. The new standards define the general requirements for graduates' competencies, both professional and personal (transferable). The new approach assumes an active involvement of the program constituencies including employers and professional community in formulation of program specific learning outcomes [3]. Thus, the close interaction between the academic and the professional

community should contribute to the achievement an important goal – training of graduates that satisfy the needs of the labor market and the requirements of potential employers.

The use of an outcomes-based approach grants Russian universities more academic freedom in the design of their programs and curricula. The program must ensure that its graduates gain the required set of competencies; the ways to achieve this goal can be different. Undoubtedly, the outcomes-based model will facilitate both a dialogue between academic and professional communities and recognition of qualifications and diplomas of the graduates.

(2) TOMSK POLYTECHNIC UNIVERSITY AND ITS ACADEMIC STANDARD

Tomsk Polytechnic University (TPU) is the first technical university in the Asian part of the Russian Federation founded in 1896 as Tomsk Technological Institute (TTI) of professional engineers. Special emphasis has always been placed on close connection of education with scientific developments and actual industry demand. TTI graduates were actively involved in design and construction of industrial enterprises of Siberia, the Urals and the Far East, as well as in discovery, development and recovery of Siberian mineral resources. Traditional position of the university in top ten Russian technical higher educational institutions according to the ranking system of the RF Ministry of Education and Science justifies high speed of TPU development and continuous improvement of its competitiveness. For the time being in accordance with the results of this ranking, TPU occupies the second place among over 140 Russian higher engineering schools.

In 2009, Tomsk Polytechnic University was awarded the status of National Research University that provided for significant financial investments to the university for 10 year period and got the right to elaborate its own Academic Standard. In 2010 TPU developed and approved «Standards and Guidelines for TPU Academic Programs Quality Assurance» [4] based on the new generation of Federal State Educational Standards and international standards in engineering education (Washington Accord Graduate Attributes, EUR-ACE Framework Standards, etc.). The Academic Standard depicts TPU vision of engineering education objectives and goals. TPU Academic Standard defines the strategy and tasks of educational policy, methodology and stages of programs design, delivering, monitoring, and modernization. Inherently the TPU Academic Standard is a norm of educational programs' quality which is established and guaranteed by the University.

To improve the quality of academic programs at bachelor level and to strengthen the leadership position in Russian engineering education TPU joined the CDIO Initiative as the first Russian institution in October 2011. The university management and faculty team are strongly confident that the focus on CDIO Syllabus and CDIO Standards will contribute to raising the quality level of the TPU Academic Standard and to providing high quality of engineering education programs according to the demands of high-tech industry.

(3) BENCHMARKING OF TPU ACADEMIC STANDARD AND CDIO STANDARDS

Upon joining the CDIO Initiative TPU carried out the analysis of the existing the Academic Standard to understand whether it requires some changes and to identify the possibilities of its improvement. The analysis was aimed at development of a basis for a new edition of the TPU Standard in frame of CDIO context.

The sections of the TPU Academic Standard were compared with 12 CDIO Standards to define the areas of the TPU Standard that might need additions, reconsideration, and improvement. Table 1 represents the list of the TPU Standard sections where the sign "x" shows the ones

which have similar requirements to CDIO Standard (presented horizontally). Detailed analysis of both standards' requirements found out their high-level of consistency in approaches to engineering programs development and performance.

Considering the above conclusion in the beginning of 2012 TPU upgraded its Academic Standard by expanding and extending requirements to engineering programs aimed at training of world-class engineers. Therefore in Table 1 the sign "o" shows the sections of the TPU Academic Standard where the requirements corresponding to particular CDIO Standard were included or enriched. In updated Academic Standard major changes refer to the following 3 sections: General requirements to Academic programs in Engineering, Requirements to program design and development, and Requirements to study process.

Table 1
Comparison of TPU Academic Standard sections with 12 CDIO Standards

Sections of TPU Academic Standard	**CDIO Standards**											
	1	2	3	4	5	6	7	8	9	10	11	12
1. About the University (mission, strategy)	x											
2. Scope of the TPU Academic Standard	o											
3. Terms and definitions												
4. General requirements to Academic programs in Engineering (APE) (policy, quality assurance, monitoring, assessment, facilities and IT infrastructures)	x o	x o	o	o	o	x o	o	o	x o	x o	x o	x o
5. Requirements to learning outcomes of APE (international and national)		x o										
6. Requirements to program design and development		x o	x				o	o			o	
7. Structure of APE (bachelor, master, specialist)		x	x									
8. Requirements to study process (conditions, students rights and responsibilities, practice and research, academic mobility, faculty, teaching materials, facilities, final examination)					x o	x	x o	x o	x o	x o	x o	
9. Schedule of study process												
10. Program curriculum (core & personal)			x									
11. Teaching materials and documents							x	x	x	x	x o	
12. Requirements to assessment of learning outcomes											x o	
13. Requirements to monitoring and continuous development of APE												x
14. Study regulations										x	x	x
15. Approval and amendment procedure for TPU Academic Standard												

The section *General requirements to Academic programs in Engineering* emphasizes TPU right for development and implementation of own academic programs based on TPU mission, FSES, TPU research and pedagogical traditions, international standards in engineering education, word tendencies of engineering education and the labor market. Since the TPU mission is to be the center of educational excellence and to ensure producing of engineering elite we consider CDIO Concept an appropriate tool to achieve university strategic objectives and realization of its mission. In accordance with the new version of the TPU Academic Standard undergraduate engineering programs shall be designed, implemented and constantly improved in compliance with 12 CDIO Standards.

The section *Requirements to program design and development* describes the design technology of educational programs which includes planning, implementation, assessment, and continuous improvement. While defining intended learning outcomes educational program designers shall comply with the following:

- the FSES requirements in corresponding area or specialty;
- national and international requirements to graduates' competencies in engineering (Criterion 5 of the Russian Association for Engineering Education (RAEE), requirements of IEA Graduate Attributes and Professional Competencies, EUR-ACE Framework Standards, CDIO Syllabus, etc.);
- TPU strategic partners specific requirements – potential employers in the priority area of technology;
- national and international labor market demands.

It should be noted that Tomsk Polytechnic University was the first among Russian universities which began to apply the RAEE accreditation criteria not only for program evaluation but also for engineering program design. It resulted in possibility to take into account stakeholders' demands to the full extend at the stage of programs development.

We improved TPU technology of educational programs design considering the following approach: once learning outcomes are defined program designers shall specify criteria and methods of learning outcomes assessment. This innovative approach minimizes the chance of defining learning outcomes, which will be impossible to evaluate.

The section *Requirements to study process* provides for creation of student-centered educational environment at TPU through individualization of students' curricula. In compliance with new TPU Academic Standard the share of passive transmission of information including lectures will decrease considerably (up to 20-40% of in-class activities), while the rate of active and interactive learning are to be increased (up to 30-40%) which corresponds to CDIO Standards 7 and 8. Educational programs will focus more on practice-oriented (course projects, internship, research and final qualification work) and students' self-study (CDIO Standard 5). The new version of TPU Academic Standard introduces the set of requirements to competencies and qualification of faculty staff involved into the study process. The university shall offer them opportunities for continuous professional development (internships in companies, research laboratories and other organizations based on the disciplines taught), as well as for improvement of their teaching skills (CDIO Standard 9 and 10).

It is noteworthy that CDIO Standard and CDIO Syllabus translated into Russian and adopted to terminology applied in Russian educational institutions were included into the TPU Academic Standard as its annexes.

(4) SELF-EVALUATION OF A TPU PROGRAM AGAINST CDIO STANDARDS

To modernize engineering educational programs in compliance with CDIO Concept and the new TPU Academic Standard, three pilot engineering programs were identified in accordance with University priority research and education areas: Electrical Engineering, Chemical Technology and Mechanical Engineering. Within each program prospective teachers were engaged to working groups (or CDIO teams) and they worked out a plan of CDIO gradual implementation. According to the first stage working groups carried out self-evaluation of programs using CDIO rubrics, determined necessary program requirements and have defined key areas of the academic program modernization and of learning environment (learning facilities and material and technical resources) renovation.

To illustrate the compliance of TPU educational programs with CDIO Standards, we provide the results of self-assessment of Bachelor's program in Electrical Engineering realized at the Institute of Energy.

Electrical Engineering program has been implemented since 2003; over 500 of its graduates were awarded Bachelor degrees. Practice shows that about 97% of bachelors continued their studies in Master degree programs which could be explained by the following factors: on the one hand, the employers were not ready to provide adequate job placement to bachelor graduates (as they were more adjusted to hire 5-year program graduates with Specialist Diploma); on the other hand, the content of the educational program seemed far more suitable for further studies rather than for performing engineering activity. Hence, today TPU is aware of the competitive advantage and high demand in bachelors ready to solve complex engineering problems.

Table 2 demonstrates the level of the Electrical Engineering Program compliance with respect to each of the 12 CDIO Standards and contains gathered evidences of TPU level of performance. The Table shows the highest program ranking (Grade 3) under Standards 2, 6, 12 due to dynamic TPU external policy such as participation in Federal education programs and contests and in development of and piloting Russian system for professional accreditation.

Table 2
TPU Electrical Engineering Program compliance with CDIO Standards

CDIO Standard	Grade	Evidences of program's compliance with CDIO Standard
1. The Context	1	TPU recognized the need to adopt CDIO and a process to address it has been initiated.
2. Learning Outcomes	3	Learning outcomes are defined and aligned with international (EUR-ACE, WA) and national standards (FSES, RAEE). Program learning outcomes are regularly reviewed and validated with key program stakeholders, including faculty, students, and industry representatives (revisions are incorporated in minutes).
3. Integrated Curriculum	2	Development of professional and personal competences is integrated into curriculum. Courses are mutually supporting but there is no explicit plan to integrate personal and interpersonal skills, and product, process, and system building skills.
4. Introduction to Engineering	1	The need for an introductory PBL course is recognized and its elaboration has been initiated. Introductory PBL course will be implemented starting in 2012-2013 academic year.
5. Design-Implement Experience	2	Elements of design-implement experience are integrated into curriculum. Students carry out about 7 projects but they are mono-disciplinary. Student internship within branch enterprises is a part of curriculum and Department has more than 100 agreements with companies. The agreements define terms, objectives, intended outcomes and provided for assessment.
6. Engineering Workspace	3	There are modern laboratories to support hands-on, knowledge, and skills activities. Equipment is keeping up to date due to federal target- financing. 3 international scientific research centers are available and equipped by EU level companies: *«Danfoss»* (Denmark), *«Moeller»*, *«Lappkabel»* (Germany), etc. Some new and remodeled workspaces are in use.

7. Integrated Learning Experience	2	Some projects have integration of personal and interpersonal skills with disciplinary knowledge.
8. Active Learning	2	TPU Academic Standard encourages faculty to include active learning methods in courses across the curriculum, but no documented evidence of their application and impact is collected.
9. Enhancement Faculty Competence	2	The content of faculty development programs is regularly updated in accordance with world educational trends. There is a systematic plan of faculty development but it lacks in strong collaboration with industry.
10. Enhancement of Faculty Teaching Competence	2	TPU regularly invites international experts for development or delivering faculty workshops including PBL. There is a systematic plan of faculty development but there is unwillingness to follow it.
11. Learning Assessment	2	Methods used do not cover assessment of all learning outcomes and mainly aimed only on disciplinary knowledge.
12. Program Evaluation	3	The program has national and international professional accreditation. In 2006 it was recognized as substantially equivalent to ABET Criteria [5]. In 2008 it was accredited by RAEE [6] with awarding of the EUR-ACE Label [7]. Every 5 years the program undergoes obligatory state accreditation.

The overall state on compliance of Electrical Engineering Program with CDIO Standards is demonstrated in Figure 1 where numbers of CDIO Standards (1-12) are put on the X-axis and levels of performance (0-5) - on the Y-axis. The graph identifies the area of the program compliance with CDIO Standards as well as finds out trouble spots. The failures became TPU departure points in aligning the level of compliance with CDIO Standards and prescribed TPU start-up activities to meet this goal. Thus the initial step was to raise TPU level of performance in Standards 1 and 4, which is described in the next paragraph.

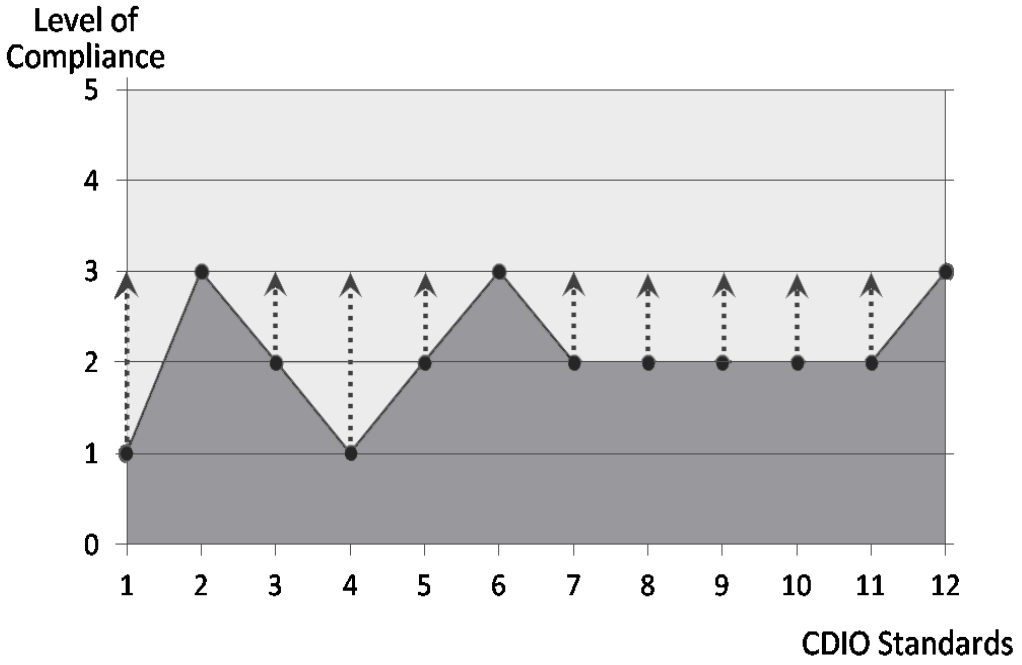

Figure 1. Illustration of the TPU Program compliance with CDIO Standards

(5) ENDEAVORS UNDERTAKEN

Adoption of CDIO philosophy (Standard 1) is a starting point in successful producing of competitive engineers. This important stage is also the most difficult since acceptance of any new concept is generally preceded by profound learning and analysis. Expanding of CDIO philosophy seems challenging in terms of dissemination of its ideas among great number of TPU faculty (over 2,200 teachers) involved into training of bachelors in over 70 engineering programs. What should be done to bring together understanding and vision of the educational program objectives of both a mathematics teacher and a technology instructor (theory vs. practice)? How to motivate the teacher of humanities to deliver his/her course as a part of integrated learning rather than a particular subject?

To facilitate adoption of the CDIO Context and to convince the faculty to accept necessary changes arranged a number of actions. The CDIO Standards and CDIO Syllabus were translated into Russian and disseminated among TPU faculty and staff within several workshops (including one with CDIO representatives). From 2012 CDIO seminars are held on a regular basis. They deal with a variety of issues on modernization of educational programs and are conducted both by university management and experts in the area. Thus the immediate goal is adoption of CDIO philosophy by teachers of core disciplines within the pilot programs by 2013.

To refer to Standard 4 an Introductory PBL course has been developed to be launched in 2012-2013 academic year. It is supposed to be a starting course within the practice-oriented module designed for engineering students, which will imply gradual development of practical engineering skills. The first feedback received from programs' stakeholders will be used for course improvement.

At present TPU activities are aimed at enhancing its level of compliance with Standards 3, 5, 7 - 11. This task is assumed to be achieved by improving faculty teaching and CDIO skills (Standards 9,10) through faculty and staff internships and mobility to CDIO collaborator-universities. This allows teachers to gain experience in new teaching and learning methods (Standards 7,8), integrated curriculum design and assessment (Standards 3,5,11). We believe that the key role in study process is assigned to teachers that should become moderators of educational environment. In other words, teachers and program coordinators should define curriculum and study conditions in accordance with program objectives and intended learning outcomes.

The current objective set by Tomsk Polytechnic University is implementation of the integrated curriculum starting 2013-14 developed according to the requirements of the new TPU Academic Standard.

(6) CONCLUSION

Thus, we can ascertain that CDIO Initiative incurred significant interest among TPU faculty, since CDIO approach to engineering education:

- coincides with TPU mission in its key objectives (training of world level engineers);
- essentially enhanced and supplements the TPU Academic Standard with deep philosophical background;
- represents a platform for discussion and exchange of experience in urgent issues of engineering education.

We believe that the new version of TPU Academic Standard will facilitate the new quality of TPU engineering programs that will produce the next generation of engineering leaders. By applying the CDIO approach to the development of educational environment corresponding to demands of world market Tomsk Polytechnic University will ensure continuous improvement of both the TPU Academic Standard and educational programs. Being the first Russian university joined the CDIO Initiative TPU plans to engage other Russian higher engineering schools to this context and disseminate its CDIO experience through conferences, seminars and publishing papers in respective educational journals.

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Biographical Information

Alexander I. Chuchalin, doctor of technical sciences, professor, vice-rector for academic & international affairs, CDIO leader of Tomsk Polytechnic University, Russia. His current research activity is focused on engineering education pedagogy, educational programs design, accreditation of educational programs in engineering and technology, university management and quality management in HEIs.

Tatyana S. Petrovskaya, PhD, ass. Professor, deputy vice-rector for academic & international affairs of Tomsk Polytechnic University, Russia. Her current research focuses on mechanisms and concepts for educational programs development and evaluation in accordance with international standards and guidelines in engineering education. She coordinates creation of a student-centered environment within university.

Evgeniya S. Kulyukina, PhD in pedagogy, expert of department for international cooperation of Tomsk Polytechnic University, Russia. She is coordinator of national and international projects (such as TEMPUS, etc.) aimed at development, elaboration and professional accreditation of educational programs in engineering in accordance with international trends in engineering education.

Marina S. Tayurskaya, deputy director of the Center for International Academic Programs of Tomsk Polytechnic University, Russia. She works on organization of academic mobility programs for students and faculty, development of cooperative (incl. double-, dual- , joint degree) programs with leading European universities. Her current PhD research is aimed at adoption and adaptation of CDIO concept in Russian engineering universities.

Corresponding Author
Mrs. Marina S. Tayurskaya
Tomsk Polytechnic University
30, Lenin Ave., 634050, Tomsk, Russian Federation
+7 3822 555604, mst@tpu.ru