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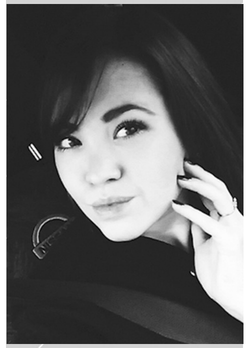

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Implementing Worldwide CDIO Initiative at Siberian Federal University: Heat Power Engineering Programme

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Abstract
The paper describes the experience and results of implementing the Standards of the CDIO Initiative into the Bachelor's degree programme in heat power engineering provided by Siberian Federal University.

Key words: engineering education, project-based learning, CDIO Initiative, heat power engineering.

Enhanced technologies and complicated technological systems, which play a crucial role in economic and social progress, have made the quality of engineering education a particularly urgent issue. The major challenge is incoherence of requirements set by the stakeholders (representatives of manufacturing and business (the prospective employer), the authorities, parents and students) and the quality of education in the sphere of technics and technology. There are several well-known reasons for this incoherence, and they are of both objective and subjective kinds. In other words, these are global challenges faced by universities and science and education communities today [1].

An efficient response to the above mentioned challenges is the CDIO Initiative CDIO (Conceive – Design – Implement – Operate) suggested more than 10 years ago by the academic staff of Massachusetts Institute of Technology, one of the world's leading institutions providing higher engineering education. The initiative implementation aims at meeting the requirement set by the employers to the quality of education and implies modification of education programme, curricula, and learning technologies. All this is supposed to ensure that students develop the competencies, which will dramatically shorten the period of adaptation at the work place [2]. Over the past 10 years, CDIO educational framework has been adopted by more than 115 universities in Europe, North and Latin Americas, Asia, Australia, New Zeland, and Africa. In Russia, the most successful CDIO Initiative collaborators are National Research Tomsk Polytechnic University, Ural Federal University, Skolkovo Institute of Science and Technology, Moscow Polytechnic University, Moscow Aviation Institute (National Research University, MAI), National Research Nuclear University "MEPHI", Moscow Institute of Physics and Technology (State University), etc.

Implementing the CDIO Initiative into engineering education implies changing the approach to education programme design and delivery, in particular [3]: sticking to the CDIO Initiative throughout the whole period of study; detailed description of personal, interpersonal, and professional competencies approved by all programme participants; the curriculum which among other things develops competencies essential to create products and systems and includes the introductory course in product and system

design; involving students in at least two projects on designing a product at different levels; creating learning environment which simulates working environment of design organizations; ensuring "integrated" education (learning and work обучение, реальная работа); practice-oriented classes; involving teachers in continuing professional development focused on CDIO; design and implementation of the assessment system adequate to monitor not only acquisition of knowledge, but also development of the ability to create new products and systems; evaluation of the education programme and tools by all stakeholders.

Although the CDIO Initiative is highly estimated and widely applied in numerous universities worldwide, its integration into a particular education programme is still an urgent issue. For instance, integrating the CDIO Initiative into Bachelor's degree programme in heat power engineering implies resolving a number of theoretical and practical tasks. The present article describes the experience and interim results of implementing CDIO standards into education of heat power engineering students at the department of Thermal Power Plants, Siberian Federal University. In 2014, Siberian Federal University was included into the official list of universities implementing CDIO worldwide, and has thus far adapted the Initiative for six.

The key point to ensure the efficiency of the education program based on CDIO standards is the system of individual and group projects (including graduation thesis). These projects secure that student develop personal, interpersonal and professional competencies, which allow creating and implementing new products and systems. The adequate aims, tasks and content of projects not only enhance the curriculum and syllabus design, but also provide new education outcomes, such as: critical thinking and the ability to solve unstructured problems, logical and systems thinking, project thinking (engineering), communicativeness and collaboration, highly developed imagination, creativity, and leadership, global thinking, proactive attitude towards learning (of both students and professional communities).

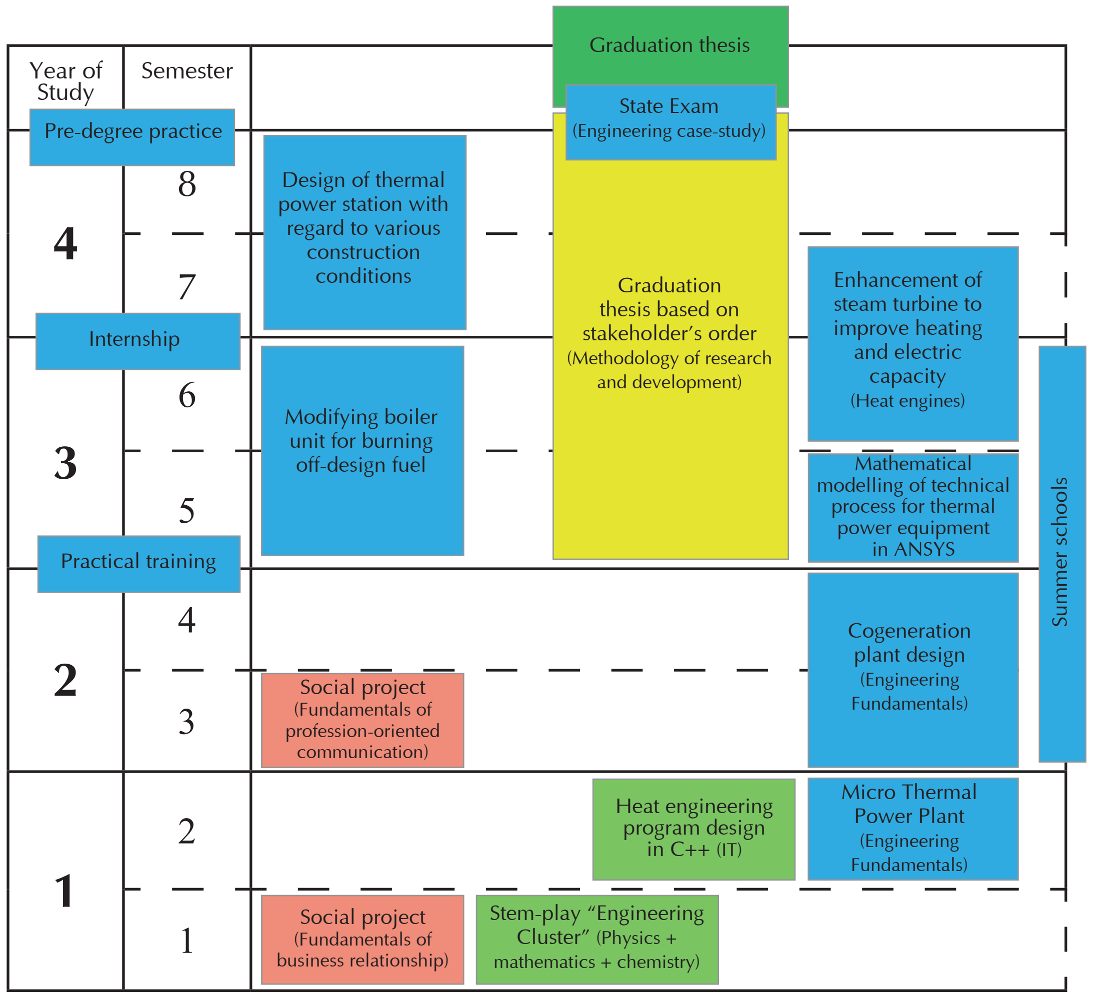
Within the first year of study students are involved into four projects. In the first semester, these are stem-play "Engineering Cluster" and social team project. The number of students in teams varies from 3 to 5. "Engineering Cluster" (designed by Moscow Polytechnic University) is a play tournament, and the task is to organize a manufacturing engineering company, which deals with design of high-tech products. The first stage implies the design of the product in virtual environment, while the second one is face-to-face work and production of the previously designed product. Creation of new products makes it necessary to resolve interdisciplinary tasks in mathematics, physics, chemistry, IT, and perspective geometry. The funding for each order is limited (fig. 1).

Social projects are developed within the scope of such disciplines as "Fundamentals of Business Relationship" and "Fundamentals of Profession-oriented Communication", in the first and second years of study, respectively. The social projects aim at developing personal and interpersonal skills. It is noteworthy that the social projects suggested to students are focused on social challenges faced by different stakeholders, in particular, the graduating department (projects on occupational guidance for schoolchildren), the university (holding adaptational, creative, and sport events), the employer (organizing and holding event on introduction into professional community, as well as volunteer work with Youth Councils of energy companies)

The final project of the first study year (Bachelor's degree programme in heat power engineering) is an individual engineering project "Micro Thermal Power Plant". Within this project, the first year student works step-by-step with the mini thermal power plant, which follows Rankine cycle: calculation and 3D design, component manufacturing and equipment installation, testing and adjusting (fig. 2).

This project allows resolving a number of methodological and professional tasks: students learn how chemical energy of fossil fuel (natural gas) is converted into electrical

Fig. 1. System of educational projects for Bachelor's degree programme in heat power engineering based on CDIO standards

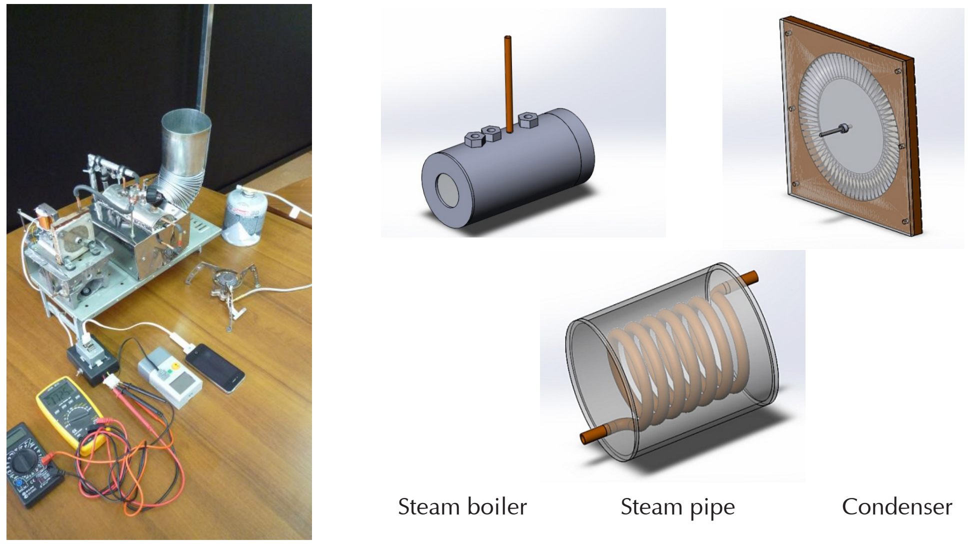


energy; thermophysical properties of water and steam, the principle of Rankine cycle, and heat losses in a generating plant; simplified method of heat calculation for a steam-power workshop and its essential components; design principles and methods to design the components of a boiler, steam turbine, electric power generator, and condenser. It is important to note that the power plant component design integrates such disciplines as "IT" and "Engineering Graphics".

As mentioned above, students work on their projects throughout the second semester, and present the results in the form of competition, in which each participant demonstrates the plant performance and capacity. The results are ranked on the basis of the plant capacity, and the student's final mark for the project strongly depends on his/her rating position (the other criteria taken into account are reliability of design specifications and estimates, the plant configuration and originality, the way the student answers the questions asked by the committee of experts (fig. 3).

Over the second year of study, students carry out team projects aimed at designing various generating plants (thermal and electrical power, including cogeneration and trigeneration). This task allows combining

Fig. 2. Engineering Sample "Micro Thermal Power Plant"



the elements of proactive training with the knowledge acquired within natural sciences and different special disciplines: Engineering Fundamentals, IT, Engineering and Computer-generated Graphics, Physics, Mathematics, Mechanics, Thermodynamics, Heat and Mass Transfer, Fluid Dynamics. The basic options in generating plant design are as follows: plants based on Rankine cycle with various combinations of heat engines (Cyclone Engine, Waste Heat Engine, steam expansion joint, steam turbine rotor (rotor and blade) assembly, Scroll-expander turbine) and heat-transfer agents (the Organic Rankine Cycle); various combinations of conventional and renewable energy sources (wind-solar-diesel plants, heat pumps, solid fossil fuel gas-generating plants), and other hybrid versions. Project implementation includes the following steps: the analysis of technical design specifications, technical and economic comparative analysis of several alternatives, common stages of engineering design (pilot project, draft design, engineering project plan, engineering documentation (in a simplified form)), estimation of specific energy consumption and production cost, design and estimate documentation. The examples of implemented projects are given in fig. 4.

Within the scope of project-based learning, the role and content of practical training and internship undergo significant changes. Students not only acquire knowledge on company structure, major and service equipment, process flow design at the energy company, but also have to search for a project idea, which can be further transformed into graduation thesis. Hence, the majority of students start working on their graduation thesis in the third year of study and are actually involved into this work over two years.

The topic of the graduation thesis can be borrowed from the second year projects (if the project is of high commercial potential), or suggested by the department on the basis of conducted research (in this case, the department is also a stakeholder), or formulated by the energy company and include new plant design, enhancement and reengineering of heat and power equipment. The graduation thesis can be done within the scope of a particular discipline or integrate adjacent subjects. The curricula of the third and forth years of study include the discipline "Methodology of research and development" (6 academic hours a week), as well as the so called "project day", when students have an opportunity to develop an applied project

Fig. 3. Defense of the course project "Micro Thermal Power Plant"

in the company under the supervision of a professional.

Apart from the applied project based on the topic of the prospect graduation thesis, during the third and fourth years students carry out four course projects (course works), which aims at acquiring essential professional knowledge: "Design of Heat and Power Plants and Processes". "Boiler Plant". "Heat Engines", and "Industrial and Thermal Power Plants".

The essential condition to enhance the education process is proactive participation of strategic partners: leading energy companies interested in high quality staff. The companies currently participating in this process are as follows: Unipro PJSC, Siberian Generating Company, JSC "OGK-2", Danfoss, the engineering company "Powerz", and other regional and federal energy enterprises. These companies have significantly influenced the education programme in heat power engineering provided at Siberian Federal University. The cooperation between the company and university takes not only traditional forms (target preparation, scholarships, internship, participation state certification), but also imply informal arrangement on strategic partnership. This efficient partnership is secured through enhancing the department and laboratory facilities; organizing new working environment; co-funding student projects; formulating project topics, supporting and implementing projects; participating in career guidance activities; ensuring students' participation in Youth Councils of the company, as well as in other sport, artistic, and other corporative events.

The experience of Siberian Federal University in implementing project-based learning into Bachelor's degree programme in heat power engineering was approved by the experts of the strategic partners (potential employers), who are closely involved in holding project weeks. Moreover, this experience allowed increasing the performance indicator of many educational departments. Over the three years of the experiment (starting with 2014, when first students were admitted to the CDIO programme), the average grade of the Universal State Exams in the relevant disciplines has increased from 182.3 to 197.5, with the number of students admitted equal to 50. The students come from 18 region of the RF and 5 countries of the former Soviet Union, and the internationalization level of the programme has risen over the period from 1.2% to 16%. The number of students who were admitted and then graduated from the programme, has also increased, from 63% to 95%. Students' publication activity and the indicator of their participation in various

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Fig. 4. Examples of implemented generating plant projects

a) Generating plant based on the Organic Rankine Cycle (1.2 kW)

b) Wind-solar-diesel plant (1 kW)

conferences and scientific and technical competitions hold at different levels has significantly improved and currently makes three times as much as it used to be at the beginning of the period.

However, one should also take into account the risks connected with implementation of a new educational technology, which are as follows: lack of competency which teaching and educational support staff have to admit since they do not possess enough experience in project development and implementation; insufficient university infrastructure and inadequate education programme of the department; need for significant management, institutional (at the university level), physical, and financial resources.

Although only the interim results of the project implementation have been indicated, one can clearly notice a number of objective and subjective advantages, which allows suggesting this approach not only to enhance engineering education of other profiles at Siberian Federal University, but also to improve the quality of heat power engineering programmes provided by other Russian universities.

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