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

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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.

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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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