IMPLEMENTATION OF CDIO STANDARDS WITHIN A MODULAR CURRICULUM OF "METALLURGY" PROGRAM

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ABSRACT

The paper shares the experience of Siberian Federal University (SibFU) in designing and implementation of the modular curriculum for Metallurgy. Based on the backward design concept, which allows planning of the education starting from learning outcomes through learning techniques to the content of education, particular curriculum modules are defined. The modules cover broad educational fields in order to achieve integrated learning outcomes. The proposed model allows clear structuring of the learning content and various learning methods integration. The paper emphasizes the structure of the modular curriculum and specific learning outcomes that in total facilitates students' engineering thinking and professional skills. The learning outcomes of the modules are formed in in compliance with Russian Federal Educational Standards, CDIO Syllabus, and the requirements of the University industrial partners. The paper exemplifies the implementation of "Introduction to Engineering" Module which is innovative for "Metallurgy" programme: focused on soft-skills training. The results of the implementation of CDIO-based "Metallurgy" programme during the first year of CDIO initiative at SibFU are described. The analysis shows the improvement of learning process and outcome control due to the flexibility of modular curriculum design. Moreover, the proposed educational approach enables comprehensive learning and human resources administration such as modules arrangement and teaching staff mobility.

KEYWORDS

Module, Curriculum, Metallurgy, Introduction to Engineering, Standards: 2, 3, 4

INTRODUCTION

Siberian Federal University has been implementing worldwide CDIO initiative since 2013 in the framework of two undergraduate programs: metallurgy and heat engineering. The fields of mentioned engineering activity are highly demanded by the industries of the Siberian Region of Russia. The paper discusses the design and implementation features of the undergraduate curriculum of the metallurgy program based on CDIO principles.

TARGETS OF THE MODERNIZATION OF VOCATIONAL EDUCATION

Vocational education modernization on metallurgy program is focused on:

1) New socio-cultural and economic reality, the determining factors of which are:
   - high rate in knowledge updating in engineering and technology;
   - rapid updating of the production sector;
   - digitalization of society and appearing of new smart technologies;

- the necessity of implementing competence-based approach to enhance the vocational focus of the educational process.

2) Standard documents, national experience and international initiatives:
 - Federal law “Education Act of the Russian Federation” №273-FL 29.12.2012
 - The concept of long-term socio-economic development of the Russian Federation for the period till 2020 (The development of education);
 - Framework standards for accreditation of engineering programs EUR-ACE (European Accredited Engineer);
 - Worldwide CDIO initiative (Conceive-Design-Implement-Operate).

The vocational educational system responding to modern trends of economic development and social needs and also turning to the implementation of federal state educational standards which determine new educational result as the formed competence cluster has been increasing “practical orientation of education and its investment attractiveness”. As a result it is characterized as:

- “highly-intensive education”;
- personalized educational needs;
- developing wiki-education;
- mass character based on education through IT;
- based on the network project education;
- supporting a synergetic alliances and combinations in networking with universities, institutions and business (Gafurova et al., 2014).

MODULAR CURRICULUM OF “METALLURGY” PROGRAM

Competence-based approach sets the learning outcomes, achievement of which implemented on the multiparadigmatic character basis at solving different pedagogical tasks of organization and realization of the educational process. Particularly, the modular approach is used at determination of the content of program according to the Federal State Educational Standards. Module – is a relatively independent, logically completed, structured unit of the educational program which provides the formation and assessment of the learning outcomes. It is focused on such a result as the competence model of the postgraduate with the definite amount of credits and relevant educational and methodological support.

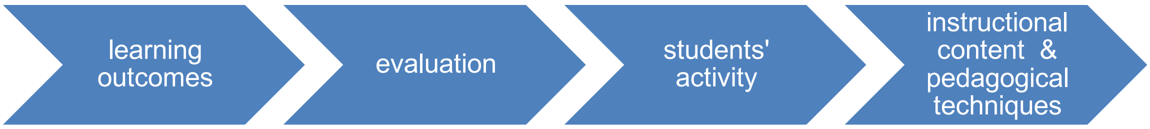
Modular curriculum raises the problem of module selection. Considering various results of the different sections of the curriculum we have identified 4 modules (Table 1).

Table 1. Modular Curriculum of “Metallurgy” Program

Modules	Disciplines	Credits
Humanities	History; Philosophy; General English; Business English; Professional English; English for specific purposes; English for Academic Purposes; Russian Language and Culture; Personal and Career Development; Team Building; Business Ethics	43
Natural Sciences	Mathematics; Chemistry; Physics; Physical Chemistry; Thermal Physics	32
Engineering	Engineering Graphics; Mechanics; Material Science; Electrical Engineering and Electronics; Information Services; Fundamentals of Metrology, Standardization, Certification; Health and Safety; Quality Management; Legal	49

	Aspects of Professional Activity	
Metallurgical Production	Metallurgy Fundamentals; Metallurgical Heat Engineering; Metallurgical Theories and Technologies; Automation, Control and Measuring Equipment; Primary Aluminum Production; Precious Metals Refinery; Alloys Production; Recycling	73
Project	Introduction to Engineering; Theory of Inventive Problem Solving; Project Work; Technical cases; Enterprise Economy	28
Industrial Training	Foundry Equipment; Fundamentals of technology of obtaining metals from ore and secondary raw materials; Metallurgical Heat Engineering	15
Total		240

In the process of module design, we relied on the concept of backward design defining the logic of the educational process from the learning outcomes to the content and pedagogical technologies (picture 1).



Picture 1. The Process of Module Design

The learning outcomes of modules are formed according to the requirements of the Federal State Educational Standard, CDIO Syllabus and the Corporation of the sector.

As an example, Natural Sciences Module (discipline – Mathematics) is considered. One of the learning outcomes of the discipline “Mathematics” is the formation of the ability to analyze and synthesize which corresponds to the professional competence 1 in Federal State Educational Standard and Syllabus 2.1, 2.4. The content of the process of the formation of the mentioned competence is described in the table 2.

Table 2. The content of the process of the formation of the competence: the ability to analyze and synthesize

Learning outcomes	Evaluation	Students’ activity	Content
Professional competence 1 – the ability to analyze and synthesize Syllabus 2.1, 2.4 (beginner level)	▪ Presentation of products of intellectual activity (scheme-maps, mental maps, solving problems algorithms, terms reference); ▪ Written survey of students on theoretical issues with elements of self-control and mutual	▪ Organize and summarize the theoretical material in the form of mental maps, supporting schemes; ▪ Develop the algorithms for solving problems; ▪ Represent	All the units of Mathematics, active methods

	control.	concepts according to the characteristics of the defined object.	

The process of the formation of the described competence in the other subject areas of the Module is represented similarly. As a result, we have a generalized picture on the formation of the described competence in the whole Module; the level of the competence has been increasing by means of repeated students' activities in different subject areas of the Module.

Another illustration that can demonstrate the advantages of the Modular approach implementation is the elimination of the educational material duplication. For example, such theme as "Field theory" was usually taught at Math Course and as it appeared it was almost repeated at Physics Course in such themes as "Magnetic field theory" and "Electrical field theory". The fact that teachers have started working together in the Module and considering the learning outcomes of the students after completing the Module not a particular discipline made it possible to see that kind of educational material duplication. Now the theme "Field theory" is taught only at Physics Course.

The experience of the Modular approach implementation in the idea of the content of the curriculum of "Metallurgy" program let underline the advantages of this approach:
- clear and systematic structuring of the content of education is provided;
- duplication of educational material is eliminated by means of co-ordination with all the disciplines of the Module;
- intra- and extra-Module integration focused on the learning outcomes is carried out;
- rational planning of the educational process on mastering the Module is defined in the sequence, and the succession of the units, themes, subject areas;
- students' systems thinking is formed by means of elimination of the subjects' separation and mosaic content of the material in subject areas;
- the team of teachers who are responsible for the Module is created and teachers' cooperation is being enhanced.

Introduction to Engineering Module is a fundamentally new idea for the engineering educational program. It is focused not only on the development of engineering mentality but also on training soft skills of the future engineer. Further we are substantiating the importance of emphasizing this module.

One of the goals of engineering education defined by CDIO Standards 1, 4 is the formation of the design-implement competence. Mastering of the design-implement competence will be supported and facilitated by means of, firstly, "Introduction to Engineering" discipline (CDIO Standard 4), secondly, receiving project work experience by learning the disciplines of engineering, humanities and natural sciences modules. Considering engineering as a set of intellectual activities, focused on the receiving the best results connected with the implementation of the full technological circle of product and system creation, design work and production operation we define the important role of the discipline "Introduction to Engineering" in the process of the formation of the design-implement competence. Substantiating the structure and content of the discipline "Introduction to Engineering" we proceed from, firstly, the necessity of the components formation of the design-implement competence; secondly, sufficient credits amount of every unit; and thirdly, purposeful sequence of the units and their places in the curriculum.

In the curriculum of bachelors' training (the Institute of non-ferrous metals and materials) on innovative educational program according to CDIO concept the discipline "Introduction to Engineering" is represented in the composition and sequence of the following units (table 3).

Table 3. The composition and sequence of the discipline “Introduction to Engineering” (the Institute of non-ferrous metals and materials, SFU)

Terms	Units
1	Introduction to Engineering (The History of Metallurgy, Engineering, Scientific Foundations of Intellectual Activity)
2	Information Resources (The Strategy of Resource Exploring, Information Structuring, Citation, Written Communication)
3	Business Ethics (Psychology, Business language)
4	Engineering design methods
5	Theory of Inventive Problem Solving
6	Strategic management of technologies (general principles of engineering)

The following design of the discipline “Introduction to Engineering” allows, firstly, to perform value-sense bearing function by means of formation the understanding of sense and significance of the engineering activity, the role and responsibility of the future engineers, influence of the engineering activity on society and environment, modern relations in the world of technology; secondly, to perform system-function by means of providing methodological support of the process of the design-implement competence formation through synthesizing the experience of project work of the students.

In practice we have the following results. Each term our students implement projects and the teachers, students and experts evaluate their competences in performing project work by specially developed measuring technique. The criteria for evaluation are:

1. Conceive (the ability: to state the problem; to find analogues of the problem and their solutions in various fields; to set the goal; to split the goal into tasks).
2. Design (the ability: to choose methods and means of solving the problem; to make the necessary calculations; to perform the graphic work according to calculations; to use automated design environment);
3. Implement (the ability: to make a model of the final product; to test the final product models; to select the type of the final product; to produce the final product).
4. Operate (the ability: to plan the project work, to manage the group; to choose the form and make the final product presentation; to take into account the commercial, social, ecological effect of the product).

And we add two more criteria, which are:

5. Interaction (the ability: to select tasks for themselves and other participants in the project; to participate in project activities at group meetings; to solve the complexity of the project individually and in team, to use telecommunications in performing the project).
6. Reflection (the ability: to carry out an intellectual assessment of the product; to understand the advantages and disadvantages of the final product and the work performed; to perceive personal development and results) (Ryabov, 2014).

In the issue at the end of the first academic year, according to the described measuring technique we have the following results (diagram 1).

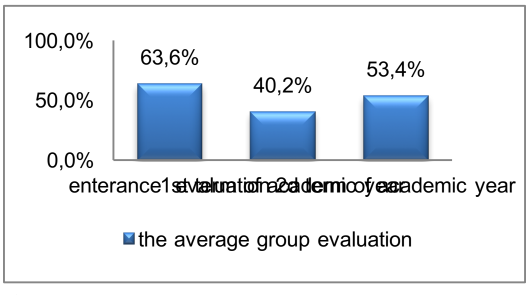


Diagram 1. The evaluation of the students’ learning outcomes in project work

The entrance evaluation was performed by students themselves and as it is easily seen in a diagram it was highly overestimated. Students were sure that they were ready to implement project work and the experience they had was enough. The results of the project work implementation at the end of the first term have decreased compared to the entrance test. But at the end of the second term the situation started to improve and we have 13,2% increasing. Experts particularly note the fact that the students started to work like a real team and their communication skills have become better. The evaluation of students' interaction, communication and team work skills are presented in diagram 2.

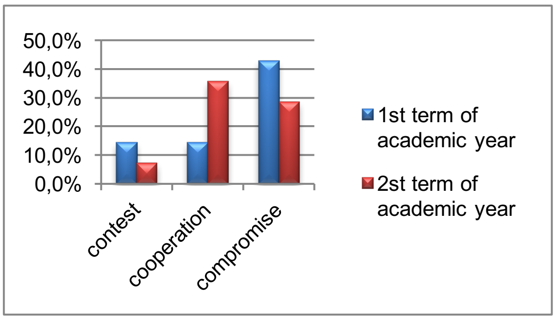


Diagram 2. The evaluation of the students' learning outcomes in interaction

Modular approach in the organization of the curriculum allows to improve the manageability of the educational process by changing the hierarchy. In terms of modular approach the head of the educational program controls module managers to whom some teachers of the module are subordinated. The duties of the module managers include the responsibility for the quality of the educational process in accordance with CDIO concept (training of the engineering graduates who should be able to: Conceive – Design – Implement – Operate complex value-added engineering systems in a modern team-based engineering environment to create systems and products by means of activity approach, active methods, integration of subject areas, implementation of project work, the development of personal and interpersonal competences), HR and methodological support of the educational process.

CONCLUSIONS

In this paper we have shared our first experience in modular curriculum of the educational program. The feasibility of modular approach implementation in curriculum design is confirmed by qualitative indicators of the students' academic success, their involvement and active position in project work as well as other extracurricular activities. Moreover, the proposed educational approach enables comprehensive learning and human resources administration such as modules arrangement and teaching staff mobility.

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