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Educational Technologies in Engineering Education: Multidisciplinary Approach

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The article discusses the issue of implementation of multidisciplinary approach in engineering education through the construction of modular educational programmes, the implementation of network forms of education, as well as the use of interactive learning technologies. It is emphasized that the use of interactive technologies in the learning process is the first step in the implementation of interdisciplinarity on the level of educational programmes content aiming to foster competences of a future engineer.

Key words: interdisciplinarity, engineering education, interactive educational technologies, CDIO, case studies, competence-based approach.

Education is not a sum of knowledge, but a full understanding and a skillful application of everything you know.

A. Disterveg

It is still common for universities to teach courses discretely with no connection to one another. Such approach provides knowledge, but not understanding. By receiving the scientific knowledge specifically students, in most cases, barely understand how and to what extent this knowledge can be interconnected.

The so-called monodisciplinary method of teaching and learning, which is familiar and seems to be an essential part of the whole system of higher education, tends to be less and less efficient.

The interdisciplinary character of the modern learning is, to a great extent, determined by the fact that science transforms from a "disciplinary" area of action to a "problem-oriented" one.

It seems that today and in the future only those specialists, who learn to understand the interdependence and consistency of the world and perceive each specific science as a sphere or a subsystem of an ultimate bigger system, will achieve success.

Interdisciplinarity in a broad sense represents a method for enriching scientific mindset residing in exploration of a certain phenomenon without the limitation to one specific scientific discipline [5].

In this sense, one of the directions for the implementation of interdisciplinarity in engineering education is module design of educational programmes. By joining disciplines over a certain research subject it is possible to build an organizational and procedural interdisciplinary structure of study materials that consists of a set of topics from various disciplines essential for a particular study programme.

A module can be formed from several related disciplines that assure module's interdisciplinarity and are aimed at the formation of a wide spectrum of necessary competences, which, it their turn, lie outside of the module's scope [2, 7].

Thus, the interdisciplinary approach strives to use a holistic picture of a research subject, where all the disciplinary pictures are seen as its parts [3].

Another direction for the development of interdisciplinarity in training of engineers lies at the root of a specific form of study programmes realization – a network form.

According to paragraph 15 of the Russian Federation Federal Law on Education [6], a network form of realization of study programmes provides an opportunity for programmes mastership by the use of resources of several organizations that conduct educational activity, including foreign ones, as well as by using resources of third-party organizations, if needed.

Therefore, one of the main characteristics of a network form of engineers' training is the application of this form of training for prospective (unique) study programmes, which, as a rule, have interdisciplinary nature for the purpose of training workforce for large industry-specific, scientific or other types of projects.

For the realization of such industry-specific programmes aimed at training of highly qualified engineers in prioritized areas of field-specific, inter-field or regional development based on international educational and professional standards, the HEIs introduce educational and industrial centers and departments, including industrial departments, design units and industry-oriented innovative technological centers. In other words, HEIs create laboratory and production facilities for joint training.

A distinct context is given to the idea of interdisciplinarity in the framework of competence-based approach to education. The main aim of this approach is to foster a set of competences, rather than certain stand-alone knowledge, skills and attitudes. Objectives of the educational process in this approach consider the methods of thinking and acting rather than the disciplines themselves.

The most prospective way to enhance the quality of engineering training is to change teaching and learning methods, specifically to introduce interactive technologies.

Interactive technologies are focused on a broad interaction of students with teachers and with each other in the process of acquiring professional knowledge and skills [1]. The distinctive feature of these technologies is the development of students' personal initiative, fostering of strive for gaining new knowledge and skills, which lies at the root of the competence-based and student-oriented approaches in education.

The examples of interactive technologies are: case study, project method, computer simulation, discussions and other.

According to the CDIO Standard 8, learning should be based on active practical approach, which aims to interest students in generation, analysis, evaluation and application of ideas. This can be put into action by means of active teaching and learning methods.

However, while the active methods are firstly aimed at active interaction of students with a teacher, interactive technologies also anticipate students' interaction with one another.

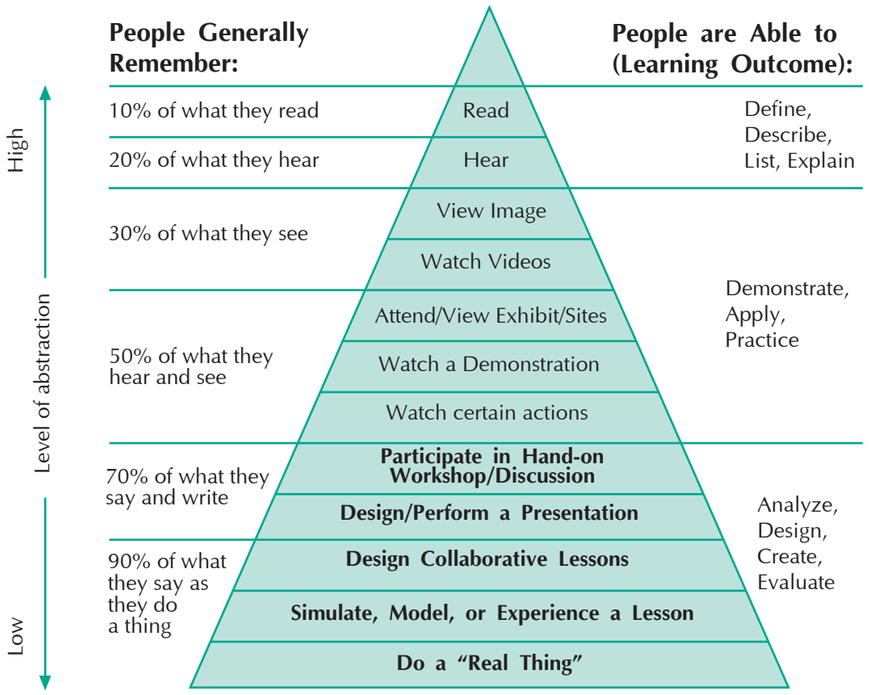
Based on the research of Edgar Dale on the connection of training methods and students' ability to apply the information received, a so-called Dale Cone has been structured (fIg. 1).

According to the Dale Cone, listening to lectures or reading materials on a certain course are the least efficient methods for learning anything; teaching others and applying the material learned to real life are the most efficient learning methods.

Although one question is still in order: how do interactive technologies ensure the realization of interdisciplinary approach?

Interactive technologies, as has been stated above, are focused on the interaction between students and teachers, as well as between students themselves. It is only within an activity that we can evaluate the level of competences' formation as learning outcomes of a study programme. At this, each study programme consists of a set of disciplines (modules), internships and final state attestation (further – programme elements). Learning outcomes are planned for each element of a study programme. These outcomes are connected with the level of knowledge, skills, attitudes and expertise that characterize stages of competences' formation and ensure the achievement of the expected learning outcomes. In other words, competences (soft skills, general professional

Fig. 1. Dale Cone of Experience



competences and specific professional competences) are formed in the process of learning several elements of a programme, and the procedure of their evaluation covers the contents of several disciplines (modules) and internships. Consequentially, this ensures the realization of interdisciplinary approach in the framework of using interactive teaching and learning methods.

One of the most efficient interactive teaching and learning method from the point of future engineers' competences formation is the method of case study.

Case study is an interactive teaching and learning method that uses portrayal of real economic, social, day-to-day and other problem situation. When working with cases students conduct search and analysis of extra information from different areas of knowledge, including the ones connected with their future professions.

"The essence of this method is that students are asked to interpret a real-life situation. The description of a problem covers not only a practical problem, but also refreshes a certain set of knowledge, which should be acquired while solving a problem. The problem itself does not have an unambiguous solution." [4, pp. 10].

In the framework of a case study a problem and its ways of solution are formed based on a set of data (a case) with a diverse description of a situation from various sources: scientific, special literature, popular science journals, mass media, etc. Cases include unambiguous information on a specific problem. Such cases are at the same time both a task and a source of information for understanding different designs of efficient actions.

The article discloses an example of a case study, which has been delivered to the students of Saint Petersburg branch of Demola (a Finnish project).

The task described in the case was to create a cheap and efficient fire alarm system for "smart houses".

The team of students working on the case included: Ilya Odnokolov (Saint Petersburg Electrotechnical University), Anastasiya Barzakovskaya (Peter the Great St. Petersburg Polytechnic University), Roman Antonov (ITMO University).

After two month of work, the team has proposed a solution: a fire alarm signaling device consisting of a sensing system that registers data on temperature, humidity and smokiness of a home and sends the data to a server. In case of an off-standard situation, the owner of a "smart home" receives notification on his/her phone.

The practical focus of such tasks allows applying theoretical knowledge to solving practical tasks. Case studies compensate for an entirely academic education and provide a wider view on the future profession.

Interactive form of cooperation between students ensures a more efficient mastership of study material due to a high emotional involvement and active participation of students. The emphases are put on acquisition of a ready-made knowledge, and not on its development.

Teamwork allows enhancement of soft skills: responsibility, communication skills, stress resilience, critical thinking, time management and financial management, etc.

Being an interactive technology, a case study, as seen from practice, arouses positive attitude among students, who see it as a "game" ensuring mastering of theoretical contents and acquiring experience of practical application of learned material.

This teaching and learning technology has been compared with the Educational Standard 12.03.05 Laser Technology (which is true for a study programme of one of the ITMO University students, who worked on the case mentioned above) from the point of assessing competences' formation. The comparison shows that case studies directly form at least 4 competences: an ability to work in a team, an ability to tolerate social and cultural differences; an ability to process and present experimental research data; an ability to conduct search, maintenance and analysis of information from various sources and databases, to present it in a required format by using information technologies, computer and network technologies; an ability to develop optimum solution, while creating products of professional equipment in compliance with the requirements on quality, price, time limits, competitiveness and safety, as well as environmental safety.

Thus, introduction of the interactive technologies to the training process of future engineers allows not only to ensure interdisciplinarity, but also to integrate interdisciplinary ties on a higher level of complexity.

The first two methods (the modular and network forms) of the realization of interdisciplinary approach refer to the design of study programmes based on transformations of the structure of main professional educational programmes and require a significant alteration of the whole programmes, whereas the last method – introduction of interactive teaching and learning methods – in this sense is less intrusive. It allows executing interdisciplinary connections even within a linear disciplinary study programme, thus it can be considered to be a first step towards the realization of interdisciplinary approach in engineering education.

However, it is possible that an active use of interactive teaching and learning methods would provoke inner transformations of programmes by means of interdisciplinary connections and evaluation tools, which would naturally lead at least to a modular structure of study programmes, if not to a network one, since a student needs to go from an area of knowledge to an area of action and life purposes in order to become a professional engineer.

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Interdisciplinary Project – Basis for Designing Study Programmes

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The specifics of engineering activity lie at the root of projects' implementation. An ability to independently develop and implement projects, as well as to assess their impact and significance is a necessary competence of each graduate. Thus, the core component of training competitive specialists is the introduction of interdisciplinary projects to the learning process. These projects are discussed in the article as a basis for designing of professional study programmes for higher education.

Key words: interdisciplinary project, engineering education, design of study programmes, project- and practice-oriented education.

The topic of interdisciplinarity is not new to the area of engineering education. It has been addressed repeatedly in the development of main professional educational programmes and in execution of fundamental and applied scientific research. The main aim of introducing interdisciplinarity is to obtain a new and novel product as a response to modern challenges of science and society.

The CDIO Initiative raises a question of the need for the formation of educational programmes that include interconnected disciplines, where training intends fostering an ability to create products, processes and systems, communication skills and personal development skills. Students should receive wide experience of conducting design and experimental activities within the training process both in classrooms and in modern training laboratories. Training should be based on exploring engineering activities in line with the model "Conceive – Design – Implement – Operate" real systems, processes and products on international market (CDIO model) [1].

The criteria and procedure of the professional accreditation of educational programmes have been developed by the Association for Engineering Education of Russia (AEER) with an aim to assess the quality of engineering specialists' training in higher education institutions and vocational schools. These criteria state that "the basic knowledge of design in the context of uncertain and controversial requirements, the abstract thinking skills and ability to analyze complex multicomponent problems that do not have a single-valued solution are essential for comprehensive engineering activities"; a student "has to be ready to manage interdisciplinary projects, to have a grip on the principles of management, to conduct efficient communication within society and professional communities. At the same time he/she is required to be able to solve technical tasks with regard to legal and cultural aspects, safety and health precautions, to understand the responsibility for the decisions made" [2].

The foresaid determines the need for new approaches to the development of main professional educational programmes for higher education. The authors disclose interdisciplinary educational projects as one of such approaches. While developing main professional educational programmes the transition from course/discipline (knowledge-based) organization of educational process to a block-modular, project-based and practice-oriented, person-based, result-oriented organization is

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