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Training Engineering Students for Interdisciplinary Teamwork

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The paper proves the necessity to provide engineering students with methodological training based on new engineering and technological approaches to contemporary production. The emphasis is made on interdisciplinary programs of engineering education and trends in their development. It also provides the example of interdisciplinary modules developing students' creativity competence.

Key words: engineering activity, interdisciplinary programs of engineering education, interdisciplinary approach, interdisciplinary modules.

Methodological training of engineering students is becoming more and more important due to the shift from labour-intensive production to sciencedriven industries. However, there is no consistent development of students' methodological competencies in modern engineering universities. It results in the fact that engineers, technologists, and economic operators lack methodological skills with sufficient amount of special knowledge. A lot of modern productions require radically new technical and technological approaches that can be developed by professionals capable of integrating ideas from different scientific areas, using interdisciplinary categories and comprehending innovation.

Thus, one of the challenges that the higher technical school is facing with is to change mass education to training highly qualified professionals who are not only specialized in particular areas but also have a fundamental theoretical base [1, p. 7].

The existing system of mass education does not take into account new social requirements from the higher school, which has led to some contradictions. There is a great demand for new technical and technological approaches to the contemporary sciencedriven production, which requires interdisciplinary specialists. However, the current engineering system is focused on particular specialties. There is a necessity to teach engineering students new methodological activity, but the teaching staff lack methodological knowledge [1, p. 11].

The basic methodological approaches to the problem solving are as follows:

- Functional systems approach allows identifying a structure, content and functions of a sub-system, defining its concept and interdisciplinary relations with the content of engineering training.
- Integrative approach allows balancing objectives of mathematical and professional training via integration of content of general, professional, special, and scientific disciplines.

In an era of limited natural resources, environmental threats, hazardous technological processes, an engineer is a key person in the current society. It is an engineer who creates wealth, advances the progress of human civilization by developing new generations of communication facilities, transport, energy sources, constructions, consumer goods, production facilities, environmental protection and natural resource processing [2, pp. 13-14].

Contemporary stage of engineering activity is characterized by new technical and technological approaches to production, and shift from labourintensive production to science-driven processes. It can be a stage of the scientific technological revolution. The scientific world landscape and techno sphere image are changed by a new image that synthesizes them as a condition for new integrating kinds of activity. Currently, there are a lot of areas of professional activity that are still weakly impacted by the integrating processes. The synthesis process is the most intensively taking place in such areas as axiomatic that is closely connected with the advanced scientific and technological trends [3, p. 131].

Technical, scientific and social knowledge have the same stages of development. The last stage involves synthesis of science, technical knowledge and social and humanitarian knowledge. It is time to stop constantly enlarging the list of courses and subjects to be studied in higher technical schools, but to synthesize new subjects and disciplines based on new understanding of a knowledge unit. Now we still use the units of experience description developed in the XX century, while our own experience is of other nature.

Currently, an engineer is a mediator between science and production, the latter is being more and more dependent on efficient engineering and technical solutions at the stages of research and development. Approximate estimations reveal that a one-ruble error at the research stage leads to 10-ruble loss at the design stage, 100-ruble loss at the stage of test model construction, and 1000-ruble loss during the production stage [1, pp. 21-22].

International engineering education programs are divided into three types:

- «traditional» programs are focused on a particular engineering job (profession, specialty) of different levels of training;
- «integrated» («united» or «inclusive») programs offer mutual activity of a higher technical school and an enterprise, or a research center involved in scientific and research activities of students;
- «interdisciplinary» programs include more subjects related to other scientific fields, since the trained engineering specialty is of "double nature" [1, p. 72-73].

According to Mr. Stir, the vice-president of the Boeing company, it should be underlined that no matter how long a university program might be, it cannot ensure training of engineering graduates who are completely ready for real engineering activity. Thus, the attempts to teach them everything are useless. A graduate should be ready for continuous professional development and constant changes in professional partnership during his/her career [4, p. 159].

In this regard, special attention should be paid to development of engineering education integrated with science and production. Thus, there are attempts to develop engineering education programs in a new way. For example, there is a new education program [5, p. 29], to train "Integrative engineers".

General trends in developing typical engineering programs are as follows [6, p. 16-17]:

- There is growing similarity in structures and content between national engineering education programs of different levels.
- A lot of national engineering education programs meet Russian standards and contain subjects relating to different scientific areas.
- Standard engineering education programs are becoming more and more interdisciplinary, and more often imply close university-science-production interaction.
- Higher technical school is developing a methodology that combines teaching particular disciplines with interdisciplinary integrative modules.
- There is a transition from information-based to problem-based learning,

conceptual approach and systemic engineering training.

- Continuous professional development and self-development of an engineer.

These trends comply well with the domestic projects of education standards implying flexible approach to professional training, as well as with the project of a new list of education programs [7, p. 47] with greater share of interdisciplinary and integrated education programs.

The interdisciplinary approach [8, pp. 83-85] implies that subjects and even some particular themes and modules are viewed as parts of particular stages of professional training. Each of these parts can contain a number of interdisciplinary modules with individual character in terms of scientific knowledge and united by uniform requirements to learning outcomes. The modules of general training are united on the basis of their focus on developing analysis and synthesis skills that constitute the first level of intellectual engineering activity. The modules of general engineering training make a group responsible for algorithmic and intellectual motorial level, while the modules of special training are supposed to develop creative intellectual level (Fig.1).

To develop this or that psychological and professional level of engineering activity is an essential task of faculty staff. A module can involve the topics and parts of both prerequisites and post requisites. The sub-module that includes prerequisites should be finished with typical tasks and equations developed by the staff training the post-requisites.

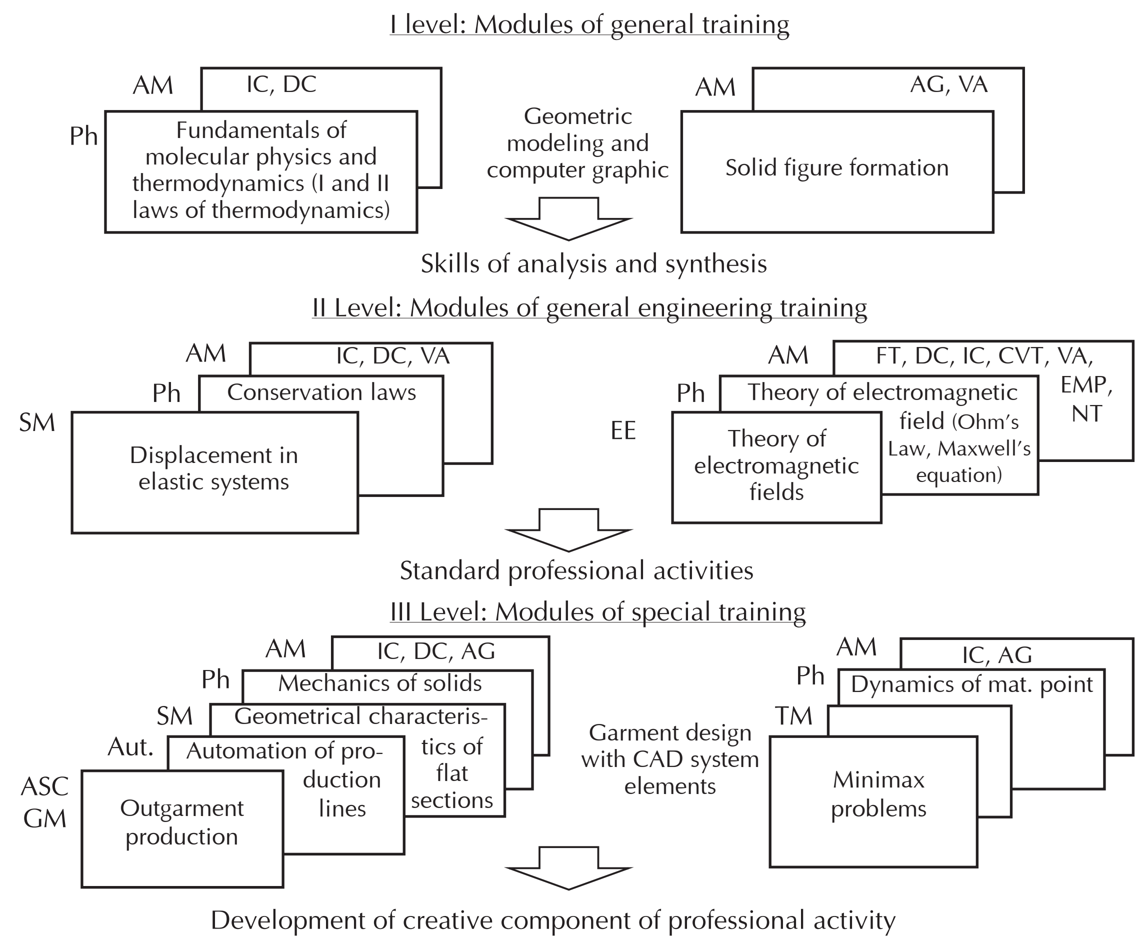
Modular training implies teamwork of different departments following development of training programs in each discipline. The example of a modular content in specialty "Electric Motor Drive and Automation of Production Units and Technological Complexes" is an interdisciplinary module "Electromagnetic Field Theory". It is based on "Field Theory" from Advanced Mathematics, and accompanied with "Differential and Integral Calculus", "Complex Variable Theory", "Vector Analysis", "Partial Differential Equations", "Numerical Techniques". The basic theme of Physics in the module is "Electromagnetic Field Theory" accompanied with the "Om's Law" and "Maxwell's Equation". The module is finished with studying "Electromagnetic Field Theory" from the Electrical Engineering course (Fig.1) [1, pp. 225-227].

The scientific progress destroys the barriers between different scientific branches and areas. The opposition between "Exact science" and "Other science" is being vanished. The gap between science and humanities proves to be false, since the difference between social and natural phenomena has been exaggerated. The idea of the science unity is becoming more obvious. According to Max Planck, "all sciences form an internal unified whole. The distinction of disciplines is mostly caused by limitation of human mind rather than inner nature of phenomena and objects. Actually, there is a continuous link from physics to chemistry, through biology and anthropology to social science. This chain cannot be broken unless in an arbitrary way". However, the unity of science and natural interaction of its disciplines are not something inherent and ultimate. This is a result of historical development, the outcome of a long, controversial and never ending way of the universe's theoretical exploration. The Unity of science is implemented as the process of its integration [1, p. 275].

To acknowledge the unity of science [9, p. 29] does not mean to interpret subjectively specific features of its disciplines and to deny the objective qualitative (though not absolute) borders between them. The integration of scientific disciplines is implemented through their further differentiation, and the advanced study and analysis facilitate theoretical synthesis.

There has hardly any leading scholar in pedagogy and education who

Fig. 1. Interdisciplinary modules



Legend:
Ph – Physics, SM – Strength of Materials, TM – Theoretical Mechanics, EE – Electrical Engineering, Aut. – Automatics, ACS GM – Automated Control System of Garment Manufacture, AM – Advanced Mathematics, VA – Vector Analysis, AG – Analytical Geometry, DC – Differential Calculus, IC – Integral Calculus, CVT – Complex Variable Theory, FT – Field theory, EMP – Equations of Mathematical Physics, NT – Numerical Techniques.

would have supported the idea of learning separate disciplines. As Jean-Jacques Rousseau noted, "…when you have a bent for sciences, the first thing you feel is the connection between them that ensures their mutual support and interrelation. The human mind is incapable of perceiving all the sciences, which makes it necessary to choose one as a basic science. However, without being aware of other disciplines, you are often benighted in your basic science as well…" [10].

As science advanced, the integration trends and interrelation of different disciplines became more and more distinct.

Vladimir I. Vernadsky, a founder of such integrated scientific disciplines as geochemistry, biogeochemistry, and radiogeology, noted: "The logical laws in natural sciences vary in different Earth's geological layers. We cannot clearly imagine the phenomena and processes that really occur there. We can only treat them mathematically, in the symbolic form, reflecting the reality logically without empirical confirmation. This is a significant contribution of mathematics in natural science" [11, p. 69].

While observing the trends and development of the modern-day science [12, p. 8-12], it can be concluded that differentiation and integration are two opposite but closely interrelated processes focused on the world study and exploration.

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Education Standards as a Basis for Interdisciplinary Integrative Module

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The author proves axiological function of the integrative approach, which is applied in engineering education to meet the new education standards. The conditions to enhance discipline integration process are determined in terms of systemology fundamentals. The author describes the stages of the integrative module design. The experience in the design of interdisciplinary integrative educational module (automotive transport) is shared and discussed.

Key words: integrative approach, interdisciplinary integrative module, education standards (competences), methodological perspective, professional training.

Introduction

Today, the main objective of engineering training is graduate's professional competence, which fails to be reached through summing all pieces of information obtained from different disciplines [1]. It is noteworthy that traditional engineering education is characterized by "disciplinarity", i.e. educational process comprises a range of particular disciplines, each implying certain logics of study. In this situation, it is for the student to integrate all the information, which is in contradiction with competency-based education widely implemented at higher education institutions today. Moreover, traditional "disciplinary" engineering training does not develop the ability for integrative engineering activity as well [2].

Therefore, competency-based education necessitates changes in the model of traditional engineering education. One of the pedagogical challenges is integration of studied disciplines, which implies identifying the criteria to select and structure the educational information [3].

However, traditional discrete disciplinary approach to educational process design is still important for modern engineering education, since the disciplines taught are the methodological basis for interdisciplinary integrative modules. The integrative approach to educational process design is used as a supplementary one, and the co-existence of integrative and discrete disciplinary approaches is secured by education standards, a set of education objectives, i.e. competencies [4]. These competencies are the expected learning outcomes and should be developed regardless of the approach.

Methodological basis for interdisciplinary integrative module design

The main document to regulate university educational process is basic professional education program (BPEP) designed for a particular specialty [5]. These documents prescribes the learning outcomes of university education, which are referred to as a set of competencies. As a result, each competency is obligatory to obtain, and together they are referred to as education standards. In case of discrete disciplinary training, the distribution of competencies over the disciplines is quite challengeable. This necessitates the design of interdisciplinary integrative modules, which will ensure the development of relevant competencies. The structure of such educational process is unique since it allows combining the elements which used to be isolated within the discrete disciplinary educational pattern.