Integrative tendencies in modern engineering technology education: Overseas experience

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Abstract. The paper stresses the need for developing and implementing the integrative tendencies aimed at harmonizing technological and engineering education. The experinece of leading education systems has been studied and efforts to find a holistic approach to be used in Ukraine have been made. It focuses on the development of basic competences. Special attention is focused on the importance of ethical considerations in engineering education.

Keywords: *engineering technology education, engineering ethics, liberal education, two-cultures approach, pedagogical models.*

Introduction. Twenty-first century engineering education must meet radically revised standards and suggest new institutional and individual responses to a series of innovative criteria. Broadening requirements to higher engineering education, the extension of its role and potential in society and on the market demand generating of synergetic, holistic and high quality strategies of its development. Compared to the previous stages, these strategies intend to address the entire system of higher education, increasing the quality of teaching, promoting activities in R&D domain, strengthening relations between the universities all over the world as well as with socioeconomic environment; cross-fertilization between the technical and nontechnical aspects of students' professional development. Another major component of the strategy is promotion of intensified cooperation between academic units, businesses and production facilities in order for the universities to be recognized as repositories of professional human resources and cutting-edge solutions. The analysis of foreign experience can be very helpful in implementing the integrative tendencies in Ukraine's higher engineering technology education for it has been considered not fully competitive in modern world and insufficiently satisfying modern needs. Besides, as it is stated by the researchers, "the work environment of engineers covers the entire globe" [4, p. 17], and companies and engineering products cross borders easily. It can't be neglected, that engineers work in large multinational companies. Thus, in order to increase their cooperative skills, and in order to "gain international engineering perspective, students most often study in an international context" [4, p. 17].

A brief review of publications on the subject. Engineering education has been a concern for many scientists and educators due to the complexity of constant changes and the need for a variety of models in engineering education than can promote training of professionally competent, socially and morally responsible engineer. The issues of engineering curricula development with integration of liberal learning have been analyzed by American educators with fundamental professional background, e. g. David F. Ollis, Kathryn A. Neeley, Heinz C. Luegenbiehl, et al. [7]; contemporary ethical issues have been discussed by the US scholars Julie Little, Brandon Sorge, James E. Stieb, et al. [4], Mike W. Martin, Roland Schinzinger [6]; the perspectives of engineering education development have been the focus of Steen H. Christensen, Erin A. Cech, etc. [2]; structural transformations of engineering education in Europe have been studied by Bernard Delahousse, Wilhelm Bomke, etc. [3]. Despite the enthusiasm, the researchers do not underestimate the institutional and professional obstacles that impede the integrative tendencies. They agree that it is difficult to find instructors in technical engineering fields, social sciences, and humanities with adequate intersecting professional interests to find common teaching ground. Another obstacle is considered to be the lack of experience providing the support for collaborative learning [7].

Most educators claim that there is a call for engineers who would not just be technocrats, but public intellectuals, who would accompany the society in dealing with technical culture. At the same time there are constant disputes on creation and adaptation of engineering curricula, pedagogical methods, research opportunities, student standing and personal status. In Ukraine, in particular, engineering technology education, following the experience of leading countries demands the search for innovative strategies of engineering education perfection and regaining of former prestige both at national and world levels. Thus, it requires further considerations on integrative tendencies in modern engineering technology education that has identified **the goal** of the present paper.

Materials and methods. To achieve the set goal the main criteria, norms and principles of the engineering education stated in the reports of Accreditation Board for Engineering and Technology have been reviewed as well as the publications of foreign researches and educators who teach at leading engineering higher educational institutions. So, the methods of research and analysis prevailed in the present investigation.

Results and discussion. Today we observe a complicated process of engineering education paradigm reforming, its realignment for pursuing new objectives that conform to the modern level of the society development and the multifaceted concept of modern engineering. As it is stated by D. Ollis *et al.* "modern engineering is a human cultural activity that involves an interplay between theory, experiment, and imagination, in which human beings form and transform nature for practical ends and purposes, with the aid of tools and procedures" [3, p.91]. It is stressed that those "practical ends and purposes" involve human society in all its complexity. Technology is an applied science and technologists must find the solutions to all kinds of scientific problems that will work in the real-world environment and must be holistic, thus worked out on an integrated approach.

No one can argue that high-quality science, technology and engineering education is critical for the prosperity and security of any country. Its primary goal is to increase learners' interest, their perception of this education's value and their ability to efficiently participate in the relevant areas. Engineering is being considered subordinated to science and it is believed that engineering education requires students to master large doses of mathematics and physical sciences, excluding liberal education from influencing the scientific culture to which engineers find themselves attached. As it is emphasized by S. Christensen "the result has been a serious limitation in engineers' capacity to examine the social meanings and effects of their work" [3, p. 27], reducing the focus on addressing human and social development goals.

Science is now considered more than a school subject, or the periodic table, or the properties of waves, it is an approach to the world, a critical way to understand, explore and engage with the world, and then have the capacity to change that world. Different issues of engineering education were developed by Rosalind Williams (the Dean for Undergraduate Education and Student Affairs at Massachusetts Institute of Technology). She wrote that "engineering has evolved into an open-ended "Profession of Everything" in a world where technology shades into society, into art, into management with no strong institutions to define an overarching mission. All the forces that are pulling engineering in different directions – toward science, toward the market, toward design, toward systems, toward socialization – add logs to curricular jam" [10]. At the same time she confronts hyper-specialization with narrowly defined skills and competences for pre-established jobs by identifying the demand for "educating active, rigorous and flexible individuals rather than skilled workers for the pre-established jobs" [10]. For R. Williams, the curricular response should be a convergence between the technological and liberal arts, educating the students both for life and flexible employment. In analyzing and solving real-world engineering problems it could be useful to broaden the capacity of engineers to integrate technical expertise, sociocultural analysis, and professional ethics.

The amount of technical knowledge keeps growing. So does the desire to include ever more professional but non-technical training, notably in communications and teamwork. On top of all this, there is a huge demand for education in management and businessrelated economics. According to the surveys most engineering students would minor in management if such an option were available.

There is a strong need for introduction of interdisciplinary studies. A good example here is presented by Germany where they study Industrial Engineering which is a combination of economics and either Mechanical, Electric or Information Engineering, Integrated Product Development which is the combination of different engineering lectures and Mechatronics which is a combination of basic mechanical engineering, electronics and information engineering. The main aim was to match the requirements of changing markets for engineers and products and to reach an integration of the separated curricula.

It is believed that in the absence of integration of ethical considerations from their personal and professional roles, engineers might become confused or complacent regarding the importance of ethics and its connection with public police [3, p. 132]. "Engineering ethics" is a branch of professional ethics that is defined as "the study of the decisions, policies and values that are morally desirable in engineering practice and research" [6, p. 8]. Engineers and technologists, enhancing the convenience and beauty of our everyday lives, encounter a number of moral challenges and technological risks that prove the complexity of engineering ethics itself and the ways of its integrating in professional training. Among the problems arising from shortcomings on the part of engineers are lack of vision, incompetence, lack of time and materials due to poor management, compartmentalized information rather than shared among different departments, improper use or disposal of the product, dishonesty and inattention [6, p. 5].

The side effects of engineering on environment and safety of human beings and the ecosystem can be felt at different scales, both local and global. Consequently, scientists do not also lessen the role of environmental issues, describing the engineers' attitude toward the environment as "ecoscepticism" so it is claimed for reforming engineering education to better integrate environmental issues [3, p. 29].

Accreditation Board for Engineering and Technology (ABET) identifies that engineering technology programs usually focus on application and implementation and that courses are more practical than theoretical in nature. However, it requires the engineering programs to promote an understanding of professional and ethical responsibility and "the broad education" necessary to understand the impact of engineering solutions in a global economic, environmental, and societal context. It is suggested that students be immersed in engineering design and practice, incorporating societal, economic, and cultural concerns in the design process, as early and as pervasively as possible [1]. In addition, this holistic perspective considers far more than just the narrow, "technical" dimension of a problem and most scientists agree that humanities and social sciences (HSS) play a significant role in the framework of professional training of modern engineering technologists. From a professional development standpoint, it is mentioned that engineering education should emphasize the development of students as emerging professionals and educated citizens, "equally at home with societal concerns as they are with technical issues" [5, p. 93].

The so called two-cultures approach in engineering education, articulated by P. C. Snow, distinguishes between the culture of science and the culture of the humanities. But today's reality often demands competent professionals with the fundamental liberal preparation, with the culture of professional and private communication. ABET singled out the six components among engineering education quality criteria which are not generally considered as objectives of engineering disciplines: ability to work in interdisciplinary projects; realization of professional and ethic responsibility; ability for efficient communication; group work skills; conscious approach in solving engineering problems, which influences economic, social and ecological welfare; the ability to learn during whole life [1].

Through engineering things are brought into being, hence, engineers put their mark on this world, meaning

that it reflects the engineers' values to some extent. The process of decision making and finding solutions to all kinds of engineering problems may be affected by their values which can be referred to engineering ethics. An engineer usually deals with three categories of ethics: technical ethics, professional ethics and social ethics. As J. Herkert suggests, in exercising his technical ethics, an engineer is engaged in making technical decisions as an individual actor; whereas professional ethics is referred 'to ethical rights and responsibilities that arise in the relationships with the representatives of the same profession, clients (including the public) or employers" [8, p. 15]. Social ethics which is reflected in their personal role "entails the involvement and responsibilities of engineers in relation to questions of broad technology policy" [2, p. 16]. Engineers need ways of dealing with all kinds of ethical issues in a consistent and holistic manner, which is almost impossible without ethical considerations and lack of humanities' integration into engineering curricula.

Taking into consideration the fact that the work of engineers "covers the entire globe" and engineering products "cross borders easily" [4, p. 17], it can't be neglected that engineers work in large multinational companies. Thus, in order to increase their cooperative and communicative skills, and in order to gain international engineering perspective, students must study an international context, with its involvement in HSS.

Following the idea that "engineering is to be a profession, and not just a technical craft" [3, p. 158], engineers must be taught to harmonize natural sciences with human values and social organization and be able to competitively participate in all kinds of professional and social processes. The major tool for implementing this educational vision is the curriculum. The engineering curricula can have strong emphasis on the cultural and economic contexts of engineering solutions, on acquisition of values and competences of future professionals, as well as on the formation of leadership and communication skills.

Integration, which is often used interchangeably with Id, is referred to crossing boundary limitations between fields and research and practice. Integrated curriculum in its simplest conception is about making connections across disciplines, to real life and experiences. The question is how to incorporate new, effective pedagogical models and integrate HSS into an already crowded curriculum in order to achieve these educational goals. Among the established approaches to teaching Humanities to engineers are content-based instruction and interdisciplinarity (Id) which allow the engagement of future academic and workplace requirements to other basic competences, i. e. societal, cultural and communicative. Id is often mentioned as the key to the development of knowledge production and decision-making in modern teaching. G. Tejedor and J. Segalàs emphasize that Id "implies identifying the transitions of relevant societal problems through knowledge integration in mutual learning processes, which results socially robust and transferable" [8].

The effective methods of teaching reading and writing to engineering technology students can help create a specific academic and professional context that encourage students to take their reading and writing seriously, promote their critical thinking and creativity, prepare them for academic and professional audience. Modern methods of teaching communication and writing skills include discussion, group work, project-based learning, computer communication and conferencing. In teaching foreign languages, being in contact with them when learning other contents, the languages can support the acquisition process as well as the process of intercultural communication both at private and professional levels. Foreign language learning, at the same time, correlates positively with success in other content areas, and promotes the interdisciplinary view of the curriculum. By integrating other curricula areas and authentic target language materials into the foreign language curriculum, educators will both expand learners' general knowledge and encourage in the foreign language competence.

Conclusions. In conclusion, engineering education requires an integrated and holistic approaches in creating the minds of engineering students, motivating them, increasing their confidence and awareness. It demands integration of technical expertise, sociocultural analysis, and professional ethics. Social, economic, and even political contexts of engineering practice must be taken into account by the curricula and the faculty to help students develop ethical values, teamwork and communication skills, administrative and business fundamentals. Reviewing curricula and adapting them to modern requirements, making humanities and social sciences more integral to engineering education are the key issues, which demand further consideration.

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Интегративные тенденции в современном инженерно-технологическом образовании: зарубежный опыт
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Аннотация. Статья актуализирует необходимость развития и внедрения интегративных тенденций в инженерно-технологическом образовании, нацеленных на ее гармонизацию. Изучен опыт образовательных систем лидирующих стран, сделана попытка найти целостный подход, который мог бы быть использован в инженерном образовании Украины. Основное внимание уделено формированию базовых компетентностей и развитию инженерной этики.

Ключевые слова: *инженерно-технологическое образование, инженерная этика, гуманитарные науки, подход двух культур, педагогическая модель.*