

US HIGHER ENGINEERING EDUCATION: THE SPOTLIGHT ON CURRENT TRENDS

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ABSTRACT

US higher engineering institutions have gained the public trust and are holding the leading positions in the world university rankings. Being among one of the most popular fields, engineering for many years has received much attention in terms of rethinking the balance of theory and practice, the role of fundamental disciplines alongside with humanities and social sciences, the impact of the technological progress on the scope and learning outcomes of engineering education. The article aims to present research on US higher engineering education tendencies, briefly outline historical prerequisites of major changes in American engineering education, as well as to enhance the understanding of valuable international educational practices. The article discusses advances in engineering curricula design and provides suggestions for improving them in terms of learning outcomes and needs of modern engineers.

Key words: *American engineering education; engineering criteria; engineering curricula; learning outcomes; US higher engineering institutions.*

INTRODUCTION

Training of engineering professionals has been the subject of research and critical analysis much more often than any other field. With the expansion of transportation networks and immigration in the past, experienced engineers inhabited US regions, satisfying the local economic needs and, therefore, introducing significant changes in engineering education. In comparison to other educational fields, engineering has undergone the most dramatic changes. During the last century, the university rankings have witnessed a huge growth of the quality of US higher engineering institutions, which, in turn, demonstrates the limitless potential for applying US best practices into tertiary engineering education in Ukraine.

The purpose of the article is to investigate the marked tendencies in US higher engineering education, give a brief overview to its historical background, pinpointing the major changes in training engineers, principles and approaches to American higher engineering education.

BACKGROUND

Historical prerequisites for engineering education have been dealt in depth by many researchers. Issapour & Sheppard identified four major segments of engineering education: 1) the time period prior to Morrill Act of 1862, 2) the post-Civil war and prior to World War II, 3) after World War II and 4) the most recent movements to integrate engineering in K-12. (Issapour, & Sheppard, 2015, p.1). The main milestones in the development of American engineering education and discussion of its essence and forms are reflected in the professional periodicals i.e. Journal of Engineering Education, established in 1893 by the Society for the promotion of Engineering Education) (Seely, 2005, p. 114). In addition, since 1918, when Ch. Mann published the first study of engineering education in the United States, reports on the state of affairs in this field are issued every 10–15 years.

In a brief analysis of the history of the formation and development of engineering education in the United States, Seely highlights several important steps: the transition from practical “craft” training as an intern to a science-oriented training; transfer of focus from practical empirical knowledge to theoretical scientific knowledge; rapid development of the second level of higher engineering education (master’s and doctoral degrees); the loss of the link between the engineering education with the engineering industry, and the shift in the curricula with a focus on the balance between the practical and theoretical components of engineering education (Seely, 2005, p. 115–118).

In the early stages of its development, engineering education consisted of training trainees in practice in real professional conditions, often in shops. Changing the model of engineering education and its transition from purely practical training to traditional education in the classroom was caused by a number of factors. First, the development of science and technology, the emergence of electrical and chemical technologies required engineers’ knowledge of fundamental natural sciences. The social role played a fundamental role in changing the educational model of the engineering industry. The transformation of engineering education occurred during the birth and formation of the middle class in American society. Together with engineering education, during this period, the training system in other fields such as medicine, jurisprudence, and economics acquired their modern form. Academic knowledge provided by university education contributed to increasing the authority and social status of their masters. Representatives of the then engineering community were clearly aware that training in higher education institutions would contribute to raising the prestige of their profession in society (Kline, 2008, p. 1018; Seely, 2005, p. 116). These social factors, together with the problem caused by the lack of technological know-how, led to the transition to an educational model, which provided the formation of a specialist not only with practical but also with academic knowledge.

METHODOLOGY

In order to investigate the US higher engineering education and its present condition, the qualitative study included the brief description of the historical

timeline, emphasizing deductive-narrative approach, following by the critical analysis of pedagogical sources as well as statistic data on the research issue.

BRIDGING THE PAST AND THE PRESENT OF US HIGHER ENGINEERING EDUCATION

The modern American engineering school originates from The Rensselaer School, founded in the early 1830s in the city of Troy, New York and reorganized by B. Franklin Green, as an example of the Paris Technical Schools in a multidisciplinary polytechnic institute. As J. Coyle points out, the curriculum of 1850 was designed for three years and included three blocks of training courses. The first unit consisted of disciplines such as English, foreign languages and philosophy that were read during all years of study. Another group of subjects consisted of mathematics, physics and chemistry, taught in the first two years. In the third year of study, students were offered practical courses that included descriptive geometry, mechanics, technical physics, metallurgy, practical geology, mining, geodesy, engineering, and construction (Coyle, 2009, p. 13). Before the start of the three-year training program, students were required to complete their first preparatory year, which later became part of a four-year training program that exists in the US today.

Wickenden noted that the principal characteristics of training engineers in the first US Polytechnic Institute combined teaching the courses in humanities, mathematics and natural sciences and technical subjects, which remains a distinctive feature of modern American engineering education today (Wickenden, 1929).

Following the example of the Rensselaer Polytechnic Institute, other higher education institutions were founded, including the University of Michigan. As a part of Harvard and Yale, the first schools of applied sciences appeared in 1847. However, at that time, both institutions showed a rather hostile attitude to the technical sciences, which facilitated the establishment of the Massachusetts Institute of Technology in 1860.

According to Coyle, the creation of the first institutions of higher engineering education and the establishment of the basics of higher engineering education in the United States was the result of the initiative of individuals, and the first governmental step in this area was the Morrill Land Grant Act, which contained provisions on Creating favorable conditions for industrial workers to receive humanitarian and practical education in several professional fields (Coyle, 2009, p. 14). In particular, according to the law, such education should include classical and other sciences, military tactics and disciplines of those branches of knowledge relating to agricultural mechanics.

Thus, in the field of higher engineering education at the end of the nineteenth century, the combination of the individual initiative of some prominent personalities and governmental support at the legislative level created favorable conditions for the complete departure from “craft” practical training and the establishment of research-oriented training of engineers.

The transition to the training of engineering professionals in higher education institutions has led to the problem of correlation in the curriculum between two types of knowledge: the knowledge gained in practice when

working with devices and constructions and theoretical knowledge of the cycle of natural sciences and mathematics (Seely, 1999, p. 286).

Initially, the necessity to increase the weight of scientific and theoretical knowledge in American engineering institutes was emphasized by individual engineers and scientists. For example, Wickenden in his study of engineering education in the United States called for a reduction in the proportion of practical subjects and an increase in the share of those providing general training in mathematics and science (Wickenden, 1927). The need to change the learning focus was even more acute in the 1920s with the advent of European engineers who demonstrated deep knowledge of mathematics and the ability to effectively apply them to solving various engineering problems. However, as Seely notes, shifting focus to the scientific and theoretical component of knowledge took place only in the 1950s after the publication of the Grinter's report on the state of the engineering education of the United States and the introduction of generous funding for fundamental research by the federal government (Grinter, 1956; Seely, 2005, p. 117). It is financial governmental support that has become a key factor for highlighting technical education as a central place in engineering education.

Governmental support for fundamental research has had a major impact on the research component of higher engineering education. To this day, teachers from engineering institutes and universities required practical experience in the field of engineering, and the main task of preparing students in this regard was the preparation for the understanding and applying the scientific knowledge. With the strengthening of fundamental research, the challenge is not so much focused on the understanding and application of scientific knowledge, but the creation of new knowledge. This, in turn, served as an impetus for the development of the second level of higher education in the field of engineering: of the master's and doctoral degrees.

However, governmental financial support for fundamental research has also had a negative impact on the development of US engineering education. The transfer of attention to scientific and theoretical knowledge led to a loss of connection between the training of specialists and the industry for which these specialists were preparing. Excessive theorizing of learning was due to the formation of practical skills, resulting in the graduates were not able to work effectively when they came to their jobs.

At the end of the 1960s, discussions about the need to revise the correlation between the practical and theoretical components of educational programs and the return of engineering design to curricula, as well as the renewal of cooperation between business corporations, engineering and higher education institutions trained by its specialists, broke out (Seely, 2005, p. 117).

Many experts now contend that the final stimulus to implement the necessary changes was the accreditation process and the adoption of new criteria by Accreditation Board for Engineering and Technology (ABET) in the United States in 1997, entitled Engineering Criteria, (EC2000). Unlike the previous version, according to which the necessary conditions for accreditation of educational programs are curriculum, appropriate teaching staff and material resources, the new accreditation criteria are focused not on what is taught but on the results of training. In particular, the new criteria determine 11 learning

outcomes, according to which students' skills should be assessed and demonstrated in educational programs (Engineering change, 2006).

In 2006, on the initiative of ABET in the United States, to study on the effectiveness of the new criteria EC2000 was conducted. The study was based on two main issues:

- What was the impact of EC2000 accreditation criteria on the learning outcomes of educational programs accredited by the United States Patent and Technology Council; and
- What was the impact of EC2000 accreditation criteria on the organization of the educational process, educational policy and methodology for training specialists in the field of engineering, which in turn could affect the learning outcomes (Engineering change, 2006, p. 1).

According to the research results, curricula for educational engineering programs have changed dramatically since the introduction of the new EC2000 criteria. However, the distinctive feature of this process was that virtually none of the higher education institutions reduced the share of classical and fundamental disciplines (mathematics, natural sciences, and engineering). The main changes related to the professional skills and knowledge that are defined by the third criterion of learning outcomes and are manifested in a significant increase in the importance of the components for specialists. Thus, Criterion 3 consists of 11 learning outcomes listed from “a” to “k” and is often referred to as “Criterion 3.a-k”.

Engineering programs must demonstrate that their graduates have (Engineering change, 2006, p. 18–19):

- (a) an ability to apply knowledge of mathematics, science, and engineering;
- (b) an ability to design and conduct experiments, as well as to analyze and interpret data;
- (c) an ability to design a system, component, or process to meet desired needs;
- (d) an ability to function on multi-disciplinary teams;
- (e) an ability to identify, formulate, and solve engineering problems;
- (f) an understanding of professional and ethical responsibility;
- (g) an ability to communicate effectively;
- (h) the broad education necessary to understand the impact of engineering solutions in a global and societal context;
- (i) a recognition of the need for, and an ability to engage in life-long learning;
- (j) a knowledge of contemporary issues;
- (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The model of the correlation of changes in educational programs to the learning outcomes determined by the new EC2000 criteria is depicted in Fig. 1

As we can see, changes in educational programs are interconnected with the process of teaching students, which, in turn, affects the learning outcomes. Among the components that have undergone changes in educational programs and had a significant impact on classroom studies and outside-the-classroom activities, were those relating to the curriculum, the organization and implementation of the educational process, the professional culture of teaching staff and teaching methods. In particular, according to the study, the positive

impact on student learning was to focus on classical disciplines, to accomplish tasks that contribute to skills development in order to design and implement projects, as well as active learning and evaluation of their professional level by the lecturers.

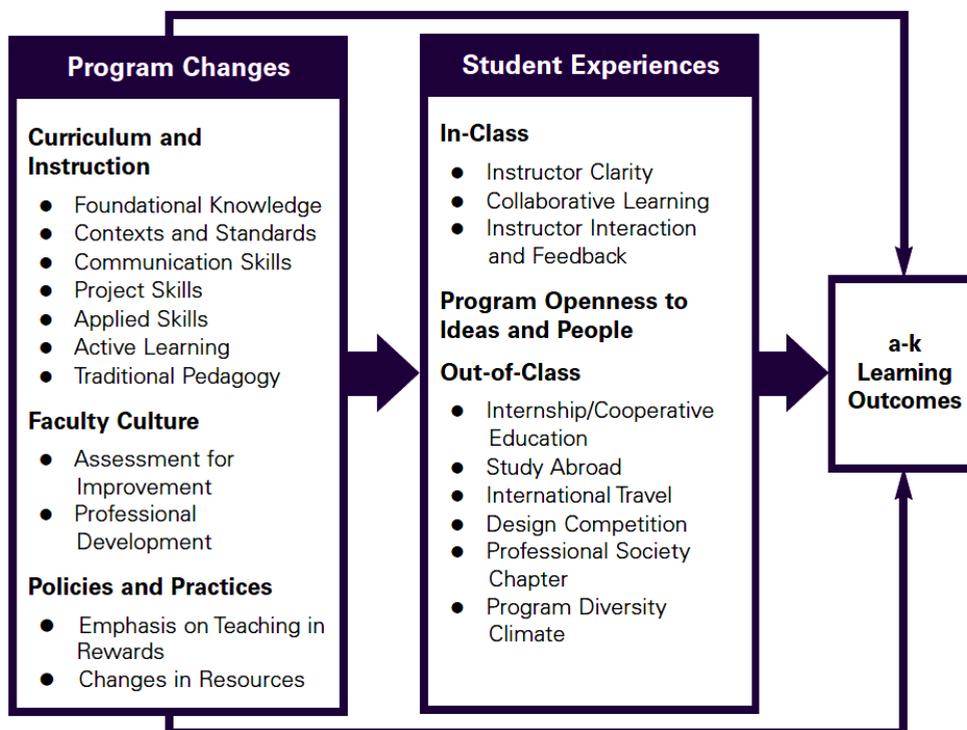


Figure 1. Analytical Model for Linking EC 2000 to a-k Learning Outcomes
Resource: Engineering change, 2006, p. 10.

It is worth noting that the bringing of educational programs in engineering with new accreditation requirements did not occur due to a decrease in the proportion of the theoretical component, consisting of classical and fundamental sciences. The availability of a large number of credits from the humanities and social sciences in curricula has always been a distinctive feature of American higher engineering education (Coyle, 2009, p. 15). The inclusion of humanitarian disciplines as an integral part of the engineering curriculum has a long historical tradition. Back in 1939, in a traditional study on the state of engineering education in the United States titled “Aims and Scope of the Engineering Curriculum”, Hammond put forward a recommendation that for humanities and social sciences, it is spent at least 20% of the academic time, emphasizing that they must be distributed in such a way that at least one course from this cycle is delivered during all years of study. Soon, this recommendation became a regulatory requirement that each semester of eight should include one course in the humanities and social cycle. Among them, three disciplines were considered as the most important for engineers: development of technical documentation, economics and history (Seeley, 2005, p. 120). It was believed that the study of the basics of writing technical documentation contributed to the formation of written communicative skills.

The economy was needed by engineers in order to easily flow into big business corporations. As to history, engineers were recommended to study history of science and technology.

As it is mentioned in EC2000, among 11 learning outcomes, at least half can be achieved through the study of humanities and social sciences, namely: communication skills, teamwork, awareness of current problems, etc. This is another proof that the humanitarian and social component is of great importance in modern education in the field of engineering (Seeley, 2005, p. 121).

In general, the results of the study indicate that changes in educational programs of engineering specialties in accordance with the new EC2000 accreditation criteria have had a positive effect on the learning outcomes. It is important to note that among the various components of educational engineering programs that define the process of training specialists in this field, the most influential were those that directly relate to studying in classrooms, that is, various elements of contact learning. The conclusions of the conducted research also indicate that the change of educational programs and curricula in accordance with the new EC2000 accreditation criteria ensured the formation of professional skills graduates from the engineering professions while preserving the technical and scientific knowledge provided by the traditional engineering education until the year (Engineering change, 2006, p. 7).

The evidence from the study suggests that important elements in the training of engineering professionals are the creation of opportunities for internships, participation in project contests and professional student associations. However, the value of contactless training was significantly lower than contact education.

Given this, one of the topical issues of modern engineering education in the United States is to identify changes that need to be made in the field of engineering education in the United States to ensure its effective functioning in the 21st century. The main directions of change required by modern American education in the field of engineering were mentioned in 2010 in an explanatory note to the National Engineering Institute of the United States “Educating the Engineer of 2020”. In particular, the recommendations expressed in the document relate to such aspects of higher education in the field of engineering as the degrees of higher engineering education and their content; accreditation of educational programs that offer US higher education institutions in engineering; 21st century engineer skills the role of engineering education in society; methodology of training specialists in the engineering industry, etc.

One of the tasks of higher education institutions in the field of engineering should be their active participation in ensuring technological literacy of society and a better understanding of technological processes, as well as cooperation with schools in order to ensure an adequate level of education in mathematics, natural and technological disciplines for twelve years of school education. This recommendation is in line with the provisions set out in the report published by UNESCO in relation to the current state of the engineering sector as a whole and education in particular in the European space (2010). Thus, among the main tasks of engineers working in the field of higher education indicated the dissemination of technological knowledge, promoting a deeper understanding of the technological processes of society and increasing the awareness of society with the advantages and disadvantages of the technological process (Miszalski, 2010, p. 308).

Another aspect that needs change in the field of training engineers in the US is the teaching method. Thus, the report emphasizes the importance of including real situational tasks and examples from the engineering sector and their use as one of the leading methods of training in teaching. In the professional resources, there are also suggestions for radical changes to the existing model of engineering education in the United States. In particular, Kalonji believes that the training of specialists in the engineering industry requires a fundamental transformation and offers the participation of students in multidisciplinary, multicultural and interdisciplinary engineering projects as an alternative to education based on training courses (Kalonji, 2005, p. 147).

CONCLUSIONS

It should be noted that despite the changes that have taken place in engineering education for centuries, many of the difficulties and issues remain unchanged. For modern education in the engineering field, the issues of the educational programs content, their length, and the balance of theoretical and practical components, the share of specialized courses and general training disciplines, as well as the correspondence of educational programs and the results of training to the actual needs of the engineering industry are still relevant.

One of the key tasks of today's education in the field of US engineering is preparation for the future, which is primarily to anticipate the challenges of society that the engineers will face and to train specialists who will be able to deal with them effectively.

Further studies, which take positive changes and best practices of US higher engineering education and their implementation to Ukrainian tertiary engineering education, will need to be undertaken.

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ВИЩА ІНЖЕНЕРНА ОСВІТА В США: ВИСВІТЛЕННЯ СУЧАСНИХ ТЕНДЕНЦІЙ

Павленко Ольга, старший викладач, Національний технічний університет України «Київський політехнічний інститут імені Ігоря Сікорського», пр-т Перемоги 37, 03056 Київ, Україна, pavlenko.olga.v@gmail.com

У статті розглядається стан сучасної інженерної освіти у закладах вищої освіти США. Зокрема, проаналізовано становлення інженерної освіти у США, досліджено основні передумови змін у підготовці фахівців інженерного профілю на сучасному етапі. Проаналізовано матеріали національних досліджень з підготовки інженерів у США щодо висвітлення таких проблем як наповнення навчальних планів, балансу теорії та практики, співвідношення фундаментальних дисциплін з гуманітарними та соціальними науками, впливу викликів технологічного прогресу та ринку праці на зміст підготовки інженерів. Встановлено, що на початку ХХ ст. для інженерної освіти у закладах вищої освіти США було характерне поєднання навчання технічних дисциплін з математичними, природничими та гуманітарними науками, що і дотепер залишається відмінною рисою сучасного американського інженерного навчання. В дослідженні проаналізовано Критерії інженерної діяльності

(ЕС 2000), які було розроблено Американською радою з акредитації у галузі інженерних наук і технологій (АВЕТ) з метою покращення якості інженерної освіти в США. За даними звітів з підготовки інженерів в США, науковцями було сформовано перелік змін та розроблено аналітичну модель взаємозалежності освітніх програм з інженерії, ролей науково-педагогічних працівників та студентів протягом навчальної діяльності та навчальних досягнень (Criterion 3.a-k). Встановлено, що для якісних змін інженерної освіти у закладах вищої освіти США необхідно поглиблювати рівень обізнаності суспільства щодо переваг фундаментальної трансформації методів навчання, а саме важливості включення реальних ситуаційних завдань і прикладів з інженерної галузі та їх використання як одного з провідних методів навчання. Окрім того, як альтернативу традиційному викладанню, залучати студентів до участі мультидисциплінарних, мультикультурних та міждисциплінарних інженерних проектах, членстві у професійних організаціях.

Ключові слова: американська інженерна освіта; критерії інженерної діяльності; інженерні програми; результати навчання; американські заклади вищої інженерної освіти.

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