UDK 37.013.74

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PROFESSIONAL TRAINING OF ELECTRONICS ENGINEERS: APPLYING US EXPERIENCE TO UKRAINIAN HIGHER EDUCATION INSTITUTIONS

The article discusses the current state of professional training of engineers, in particular, electronics engineers in Ukrainian higher education institutions (HEIs) and explores best practices from US HEIs. The research outlines the features of professional training of electronics engineers and recent changes in Ukrainian HEIs. Such challenges for Ukrainian HEIs as lack of collaboration between higher education and science with industry, R&D cost reduction for HEIs, and downsizing the research and academic staff, the disparity between the available quality of human capital training and the demanded are addressed. The study attempts to identify successful practices of US HEIs professional training of engineers in order to suggest potential improvements in education, research, and innovation for training electronics engineers in Ukraine.

Key words: *electronics engineer; engineering education; higher education institution; professional training; Ukrainian higher education; US higher education.*

https://doi.org/10.28925/1609-8595.2020.1.12

Introduction. Engineering education within the Fourth Industrial Revolution is undergoing a series of significant changes. In recent years, the United States has taken top positions among the leading countries in training of engineering professionals. In addition, there has been a growing amount of applicants demonstrating interest in educational programs in the field of engineering, in particular to those that deal with electrical and electronic engineering. The high demand for such educational programs has led to the fact that electrical and electronic engineering programs have been included in the top ten rating of most sought ones. More recent evidence shows that only a small part of the leading countries in the field of engineering education demonstrated their readiness for the challenges of our time. Ukraine, in turn, is only just beginning its path to qualitative changes in the training of specialists in electronics (Zgurovsky et al., 2018, p. 6–7).

The preliminary study of professional training of electronics engineers is based on a review of Ukrainian laws, regulations, concepts, and programs for the development of higher education. In particular, the laws of Ukraine On Higher Education (2014), On the Basic Principles of the Information Society in Ukraine for 2007–2015, Draft National Program of Informatization (2018); National Strategy for the Development of Education for 2012–2021; state R&D program – Science in Universities for 2008–2012, and the standard of higher education in electronics (2018).

A number of recent US legal documents i.e. Higher opportunities Act (2008) and regulations on higher education issued the US Department of State (2017-2018), as well as standards and accreditation and examination bodies like Accreditation Board for Engineering and Technology, Inc. (ABET), National Council of Examiners for Engineering and Surveying condition and shape the current trends of US higher professional training of electronics engineers in higher education.

Initial work with regard to provisions of modern Ukrainian and foreign science, reforms in higher education and the systematic study of Ukrainian engineering education was reported in M. Zgurovsky's (2006, 2018) works. V. Derykhovska (2016) has suggested an overview of the challenges of evaluating higher education institutions (HEI) in international ratings and compared them. HEIs context is represented by a number of studies on training specialists in engineering, in particular, the O. Ignatyuk's (2010) study of the theoretical and methodological foundations of training future engineers in technical universities, allowed to highlight a number of important aspects of training engineers, and B. Bystrova's (2018) systemized American experience in training specialists in cybersecurity has demonstrated that US experience can become a major milestone in professional training of electronics engineers in Ukraine.

This article **aims** to analyze the current condition of professional training of electronics engineers in Ukraine and the US in order to suggest strategic tasks to revise

professional training of electronics professionals in Ukraine using best practices of US HEIs.

Methods. To better examine the problem of professional training of electronics engineers, the content analysis of the literature and regulatory documents was carried out. The data from Carnegie Classification of Academic Institutions and the US National Centre for Educational Statistics were analysed to highlight the characteristics of the US HEIs organization. The HEIs network and the training quality of electronics professionals have been investigated using such world ranking systems of educational institutions as THE (Times Higher Education World University Ranking), QS (QS World University Ranking), and ARWU (Academic Ranking of World Universities).

Professional training of electronics engineers: Ukrainian context. According to the Unified State Register of Educational Establishments (Ukraine), there are 20 higher education institutions carry out professional training of electronics engineers in accredited specialties at the Bachelor's level, 18 out of 20 also offer training at the Master's level.

The peculiarities of the professional training of Ukrainian electronics engineers in HEIs are defined by the Higher Education Standard of Ukraine in the field 17 Electronics and telecommunications and the specialty 171 Electronics. (2018).

Despite a number of positive changes in the engineering field, updating the standards and curricula in engineering, we can still observe a decline in the professional training of electronics engineers.

A recent review of the literature on this topic suggests that decline in Ukraine's competitiveness over the last five years is directly related to the higher education and R&D. An analysis of recent studies on this topic reveals several trends:

• *the lack of collaboration between higher education and science with industry*, which according to the report at the World Economic Forum in Davos (2018) was rated as the lowest in Europe (Zgurovsky, 2018, p. 6);

• *reducing the costs of higher education, science and, in particular, research into innovative developments* – a negative trend has been observed in the country since 2005, reaching the level where, according to V. Sidenko, «it is extremely problematic to maintain global competitiveness of Ukrainian science», because these funds are not enough even to provide salaries to scientists, not to mention the purchase of the latest equipment, materials, literature, information resources, etc. (Sidenko, 2018, p. 9);

• *reducing the R&D staff* in the fields that are determined to be the most promising in terms of the development of the latest technologies of the future and, therefore, ensure Ukraine's competitiveness at the global market. According to Razumkov's Centre research project on Structural Transformations in the World Economy: Challenges for Ukraine (2017), during the years 2011–2016, the most significant reductions in research have been applied to such fields as biochemistry, physiology and molecular biology, general biology, physics and astronomy, applied physics and materials science, energy sector, computer science, and mathematics (Sidenko, 2018, p. 11);

• *the gap between the available quality of human capital training and the demanded one* – a trend that was determined by the results of a study of Ukrainian scientists – Foresight 2018 (Zgurovsky, 2018, p. 15–17). Thus, in the context of the Fourth Industrial Revolution, the quality of human capital is assessed by two indicators: education and skills (competencies). According to the Delphi analysis of the human capital education and human skills indicators of the Foresight 2018 survey, it was found that the main clusters of Ukrainian economy have a very low level of staffing, which indicates a significant gap between the quality of training available today and the demand for it (Zgurovsky, 2018, p. 15–17);

• *absence of structural changes in the system of training and retraining of specialists* – unlike technological world leaders, where over the last 15 years there have been significant structural changes in the training and graduation of qualified personnel in the field of natural sciences, mathematics, statistics, and informatics, in Ukraine the share of specialists with higher education in these areas has declined significantly (from 3.8% to 2.5%) (Sidenko, 2018, p. 11);

Foresight 2018 study states that the situation has become even worse: over the past 10 years, admission to higher education institutions in STEM (Science, Technology, Engineering, Mathematics) has decreased by an average of 25%, and thus, the number of graduates in these areas will decrease as early as 2020. To compare, the share of graduates in business, public administration and law in the same period ranged from 33.0% to 37.4%, while at the world level this indicator was below 20%. It should be noted that Ukraine's increasing training in ICT programs over the years (from 0.5% in 2000 to 2.6% in 2015) is only a positive trend, as it really shows the role of Ukraine as an outsourcing contractor (Zgurovsky, 2018);

In other words, according to the present graduation trends in higher education, in the global context, Ukraine acts as a provider of engineering specialists to the market of highly skilled labour, while strategic advantages in the field of ICT and development of electronic communications are being preserved by countries that are apparent leaders in technology. Thus, it becomes clear that without revision and introduction of qualitative changes in the structure of training and retraining of specialists with higher education, with a focus on priority areas, including electronic engineering, restoration of competitiveness of Ukraine, its technological development and decreasing the role of outsourcing agent in order to take the leading role. Regarding professional training of electronics engineers, our further studies demonstrate that the US appear to be the leader in this field.

Applying US experience to the professional training of electronics engineers in Ukraine. In order to identify the leaders HEIs that are leaders in electronic engineering programs, we analysed the results of the comparative study of the world rankings (THE, ARWU, QS). It revealed that the first 30 positions in Electrical and Electronic Engineering programs are occupied by 61 educational institutions located in 15 countries of the world (Pavlenko, 2019, p. 89).

According to O. Pavlenko (2019), among the most prestigious HEIs for training electronics engineers, almost a half (29 institutions) are located in the US and the top positions are taken by the following US HEIs: Stanford University, Massachusetts Institute of Technology, Yale, University of California (Berkeley), University of Illinois (Urbana-Champaign), Georgia Institute of Technology (p. 89).

It should be noted that in the US higher education system, undergraduate programs in electronics are mostly delivered by colleges, and master's programs in electronic engineering are concentrated in doctoral universities, universities, and colleges.

According to the updated Carnegie Classification of 2018, colleges providing undergraduate programs are divided into two subtypes according to the field in which the training programs are offered: 1) with a focus on the arts and sciences; 2) with a focus on a variety of industries. Doctoral universities, in turn, are divided into three types: doctoral universities with very high research activity; doctoral universities with high research activity and doctoral/ professional universities that are characterized by low levels of research activity (Carnegie Classification, 2018).

In our previous studies, we observed doctoral universities with a very high scientific activity to be the most representative among the US HEIs. That is, the vast majority of HEIs that train electronics engineers (34 out of 43 or 79.2%) belong by their type to a doctoral university, and their distinguishing feature, besides preparing applicants with the highest educational qualification level, is the high quality of R&D activity (Pavlenko, 2019, p. 90).

V. Sidenko (2018) argues that one of the important factors of the technological development of the country is also the level of innovative activity of enterprises. As its qualitative indicator is directly related to the volumes of patenting, it can be argued that it is not only the level of innovative activity of enterprises, but above all HEIs, as the US experience shows, are to be engaged in research and innovation in prioritized areas in the future. Today, the leaders in patenting are the United States, the European Union, and Japan. Ukraine has one of the smallest shares in international patenting processes (p. 12).

Another crucial step is to stimulate Ukrainian HEIs to align their electronics engineering programs with the international standards. For instance, most US degrees in electronics engineering are accredited by ABET, which ensures and proves their compliance with high-quality criteria. At present, none of the Ukrainian HEIs engineering degrees is accredited by the engineering agencies. Establishing ABET's quality assurance standards will make Ukrainian electronics engineering degrees more competitive and enable increased employability in the global market.

By exploring the nature of engineering as a subject, another important recommendation for Ukrainian HEIs based US practices concerns its teaching and learning. In reviewing the literature, H. Fry, S. Ketterindge & S. Marshall (2015) suggest that «the subject of engineering is very wide-ranging in terms of scale, levels of abstraction, scientific content etc. and yet there is there is also a common core in terms of engineers' skills, approaches and values» (p. 243).

US doctoral universities manage to sustain a high quality of R&D activity alongside with lecturing. Addressing the issue of academic staff that delivers electronics engineering programs in HEIs, we support H. Fry, S. Ketterindge & S. Marshall (2015) point of view that effective engineering lecturer possesses the roles of a teacher, academic and engineer. The authors question the idea of the identity of discipline-specific lecturer in the HEIs, so this allowed us to adapt their vision (Fig. 1) by demonstrating the overlapping character of the roles of an effective electronics engineering lecturer. This fusion of the roles has become commonplace both in Ukrainian and US HEIs.

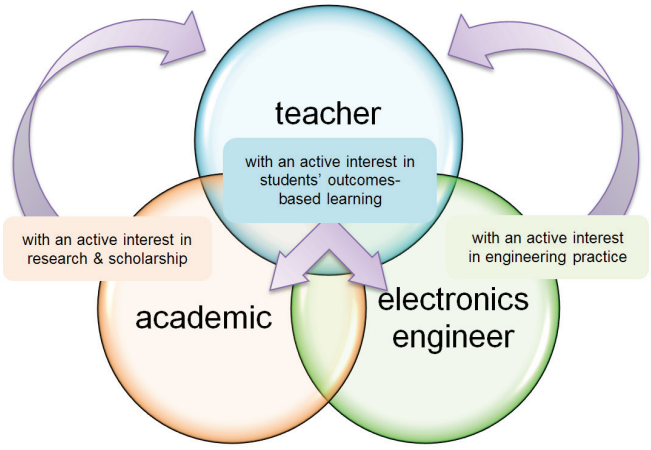

Figure 1. **The roles of an effective electronics engineering lecturer**
Source: Adapted from Fry, Ketterindge & Marshall (2015)

While Ukrainian HEIs are still taking their first steps in becoming more autonomous in terms of decision making, US HEIs has increased the role of university autonomy through offering a variety of electronics engineering programs, with high international and intranational diversity of the programs and engineering degree courses.

The evidence presented in the international Assessment of Higher Education Learning Outcomes research suggests that «it is useful for HEIs to review

if their educational programmes and curriculum are effective or not by using the results of learning outcomes» (AHELO, 2013, p. 64). In 2018, the national campaign to revise Higher Education Standards of Ukraine stimulated considerable progress in revising HIEs programs in the field 17 Electronics and telecommunications and the specialty 171 Electronics with regard to the direct evaluation of student performance.

The idea of outcomes-oriented programs reviews is supported by H. Coates (2014), who reports on significant progress has been made in specifying sector or institutional learning outcomes and measuring their achievement in the United States. A group of researchers O. Zlatkin-Troitschanskaia, R. J. Shavelson & C. Kuhn (2015) write that «such assessment calls for elaborate assessment methods». However, a full discussion lies beyond the scope of this study.

We need to address US HEIs best practices in order to improve the quality of professional training of electronics engineers in Ukraine through a number of regulatory changes and multidimensional nature of engineering training. US HEIs best practices highlight the need for a comprehensive study of professional training of electronics engineers and actively incorporating outcome-based approaches to the training of electronics engineers with a high degree of interdisciplinarity. In addition, the need for a quick response to changes in the nature and structure of labour determines the number of key strategic tasks for training Ukrainian electronics engineers in the coming years.

Conclustions. Ukraine needs to take a number of important steps to reach the level of technologically advanced countries, and many of these are related to changes in higher education that serve priority areas of the future. This greatly applies to implementing US HEIs best practices in professional training of electronics engineers in Ukraine. The increase in funding for higher education, science, research and innovation along with performance-based professional training of electronics engineers will prioritise the education and innovation policies at the national educational.

Recent reforms have led to Ukrainian HEIs autonomy, which puts a lot of responsibility on universities granting degrees in electronics engineering. Namely, with regard to professional training of electronics engineers, this means establishing stronger cooperation between Ukrainian HEIs and the industrial sector, structural changes in the system of training and retraining of specialists, facilitating the participation of educational institutions in international patenting processes etc. In particular, in terms of revising the national professional standards and university electronics engineering programs, analysis of the high-tech labour market and analytical forecasting of the prospects for the development of individual sectors of industry and adjusting the set of specialties for which the training of specialists is carried out.

Further work needs to be done to investigate US experience in assessing higher education learning outcomes and its potential for Ukrainian HEIs granting degrees in electronics engineering.

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ПРОФЕСІЙНА ПІДГОТОВКА ІНЖЕНЕРІВ-ЕЛЕКТРОНІКІВ: ЗАСТОСУВАННЯ ДОСВІДУ США В ЗАКЛАДАХ ВИЩОЇ ОСВІТИ УКРАЇНИ

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Залучення міжнародного досвіду в галузі підготовки інженерів є найбільш складним завданням для українських ЗВО. Хоча важливість вивчення передового міжнародного досвіду загальновизнана, лише деякі дослідження намагалися проаналізувати професійну підготовку фахівців з електроніки в національному та міжнародному контексті. Наше дослідження свідчить про те, що українським ЗВО необхідно переглянути і запровадити

якісні зміни в структурі підготовки і перепідготовки фахівців з електроніки в сфері вищої освіти з акцентом на пріоритетні національні напрями досліджень і відновити конкурентоспроможність України, її технологічний розвиток, а також відійти від ролі агента з аутсорсингу і взяти на себе провідну роль в цій галузі. Що стосується професійної підготовки фахівців з електроніки, наші дослідження показали, що США є лідером в цій області. У дослідженні виявлено успішні практики професійної підготовки інженерів у США в галузі освіти, досліджень та інновацій для підготовки фахівців з електроніки в Україні. Займаючи лідируючі позиції в таких світових рейтингах, як THE, ARWU, QS, ЗВО США є взірцем для впровадження університетської автономії, пропонуючи різноманітні результато-орієнтовані програми з електроніки з високим різноманітністю таких програм як усередині країни, так і на міжнародному рівні. Отримані дані свідчать про те, що українські ЗВО все ще потребують нормативних змін і впровадження багатопланового технічного навчання. Ґрунтуючись на досвіді американських ЗВО, українська вища освіта потребує всебічного перегляду професійної підготовки фахівців з електроніки з акцентом на результато-орієнтовану підготовку. Крім того, ключовими завданнями підготовки українських фахівців з електроніки в найближчі роки є введення більш високого ступеня міждисциплінарності і необхідність швидкого реагування на зміни в природі і структурі освіти, науки та інновацій.

Ключові слова: *вища освіта в США; заклад вищої освіти; інженер-електронік; інженерна освіта; професійна підготовка; українська вища освіта.*

ПРОФЕССИОНАЛЬНАЯ ПОДГОТОВКА ИНЖЕНЕРОВ-ЭЛЕКТРОНИКОВ: ИСПОЛЬЗОВАНИЕ ОПЫТА США В ВЫСШИХ УЧЕБНЫХ ЗАВЕДЕНИЯХ УКРАИНЫ

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Привлечение международного опыта в области подготовки инженеров является наиболее сложной задачей для украинских вузов. Хотя важность изучения передового международного опыта общепризнана, лишь немногие исследования пытались проанализировать профессиональную подготовку инженеров-электронщиков в национальном и международном контексте. Наше исследование свидетельствует о том, что украинским вузам необходимо пересмотреть и внедрить качественные изменения в структуре подготовки и переподготовки специалистов по электронике в сфере высшего образования с акцентом на приоритетные национальные направления и восстановить конкурентоспособность Украины, ее технологическое развитие, а также уйти от роли агента по аутсорсингу и взять на себя ведущую роль в этой отрасли. Что касается профессиональной подготовки инженеров-электронщиков, наши исследования показали, что США являются лидером в этой области. В исследовании выявлены успешные практики профессиональной подготовки инженеров в США в области образования, исследований и инноваций для подготовки инженеров-электронщиков в Украине. Занимая лидирующие позиции в таких мировых рейтингах, как THE, ARWU, QS, вузы США служат образцом для внедрения университетской автономии и предлагают разнообразные ориентированные на результаты программы по электронике с высоким разнообразием программ как внутри страны, так и на международном уровне. Полученные данные свидетельствуют о том, что украинские вузы все еще нуждаются в нормативных изменениях и внедрении многопланового технического обучения. Основываясь на опыте американских вузов, украинское высшее образование нуждается во всестороннем пересмотре профессиональной подготовки инженеров-электронщиков с акцентом на результато-ориентированную подготовку. Кроме того, ключевыми задачами подготовки украинских инженеров-электронщиков в ближайшие годы являются введение более высокой степени междисциплинарности и необходимость быстрого реагирования на изменения в природе и структуре образования, науки и инноваций.

Ключевые слова: *инженер-электроник, инженерное образование, высшее учебное заведение, профессиональная подготовка, украинское высшее образование, высшее образование в США*

Стаття надійшла до редакції 15.01.2020
Прийнято до друку 27.02.2020