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THE EFFECTIVENESS OF LECTURES IN TEACHING «ROBOTICS» IN THE USA AND UKRAINE IN THE CONTEXT OF STEM EDUCATION

The article provides a comprehensive comparative analysis of the methodological and didactic features of teaching the educational component «Robotics» at universities in the USA and Ukraine in the context of the development of STEM education, as well as an assessment of the impact of lecture material on the effectiveness of students' mastery of educational content. Special attention is paid to determining the role of the lecture in the formation of cognitive, practical and motivational components of learning, as well as the development and testing of an integrated mathematical model for assessing the effectiveness of the lecture process. To assess the effectiveness of lecture content, an integrated model for assessing the effectiveness of lectures is proposed, which includes key components of the educational process: knowledge acquisition, critical thinking, practical skills, interactivity and motivation of students. The study uses a mixed methodological approach, including comparative pedagogical analysis, content analysis of educational programs in robotics and quantitative modeling. It is shown that in the Ukrainian higher education system, the lecture remains the dominant form of teaching organization, focused on deep theoretical training, systematization of knowledge and formation of analytical thinking. At the same time, in the USA, the lecture component is integrated with active teaching methods, such as problem-based learning, project-based activities and blended learning, which ensures an increase in the level of interactivity, motivation and practical orientation of the educational process. The results of the study confirm that the effectiveness of lectures at universities in Ukraine and the USA in the context of the development of STEM education is determined not only by the quality of the content, but also depends on the synergy of cognitive, behavioral and motivational factors. The study substantiates the need to implement a hybrid learning model in Ukraine, which combines the theoretical rigorous basis of Ukrainian education with the interactive and applied orientation of American approaches. Such integration is important for improving the quality of education in the field of robotics and its alignment with modern STEM education standards and labor market requirements.

Keywords: *STEM education, robotics, university, lecture, higher education, USA, Ukraine.*

(статтю подано мовою оригіналу)

The modern transformation of higher education, driven by the development of digital technologies, artificial intelligence and industry 4.0, is significantly changing approaches to teaching STEM-educational disciplines, in particular robotics [5]. As an interdisciplinary STEM field, educational component «Robotics» integrates knowledge from physics, mathematics, mechanics, electronics, programming and

control theory, which requires effective pedagogical models for the formation of complex professional competence [4]. In this context, the lecture component of the educational process, which traditionally performs the function of systematizing knowledge and forming a theoretical base, acquires special importance [3] However, modern research shows that the effectiveness of the classical lecture model is limited in comparison with active learning methods, such as problem-based learning and project-based learning [13]. In particular, active learning methods demonstrate a statistically significant increase in student academic performance in STEM disciplines, which confirms the need to transform traditional lecture approaches [17]. This is especially relevant in robotics, since the practical component is critically important for the formation of scientific thinking. The problem is complicated by the fact that in different educational systems in particular in the United States and Ukraine the lecture material performs different didactic functions. In the United States, the lecture is increasingly considered as an element of blended learning, integrated with digital platforms and laboratory work, which increases the efficiency of material acquisition [14]. In contrast, in Ukraine, the lecture model mainly retains the classical informational and reproductive nature, which provides a high level of theoretical training, but limits the development of students' practical and interactive competences. Research in the field of engineering education confirms that insufficient integration of practical components into the lecture process reduces the overall effectiveness of learning [15]. Thus, there is a significant methodological contradiction between the traditional lecture model and modern requirements for training specialists. On the one hand, it is necessary to provide fundamental theoretical training, and on the other hand, to form practical skills, critical thinking and the ability to work with real scientific STEM systems.

Therefore, the research problem is the need for a comparative analysis of the methodological and didactic features of teaching STEM the educational component «Robotics» at universities in USA and the Ukraine and the development of an integrated model for assessing the effectiveness of lecture material, which allows taking into account the cognitive, practical, motivational and interactive components of the educational process.

The purpose of the article is a comprehensive comparative analysis of the methodological and didactic features of teaching the educational component «Robotics» at universities in USA and Ukraine in the context of the development of STEM education, as well as assessing the impact of lecture material on the effectiveness of students' mastering the educational content. Special attention is paid to determining the role of the lecture in the formation of cognitive, practical and motivational components of learning, as well as the development and testing of an integral mathematical model for assessing the effectiveness of the lecture process.

Achieving the goal involves:

– identifying structural differences between the American and Ukrainian models of teaching the educational component «Robotics» in the STEM education system;

– analyzing the role of lecture material in the formation of professional

competence of future specialists;

– quantitatively assessing the effectiveness of lectures using an integral model;

– substantiating the feasibility of implementing hybrid teaching approaches that combine theoretical fundamentals and practical orientation of STEM education.

This study uses a comprehensive methodological approach that combines a comparative analysis of educational systems, elements of pedagogical modeling, and a quantitative assessment of the effectiveness of the lecture process in the field of robotics. The empirical basis of the study was: syllabi of courses in STEM educational disciplines of robotics; curricula and methodological materials; open online courses (MOOC, Stanford Online, edX); scientific publications in the databases Scopus, Web of Science, IEEE Xplore, ScienceDirect; results of pedagogical research in the field of STEM education.

To assess the effectiveness of lecture material, an integrated lecture evaluation model was used:

$$E_l - w_1K + w_2C + w_3P + w_4I + w_5M_5$$

where E_l – integral effectiveness of the lecture; K – level of theoretical knowledge acquisition (assessed through the analysis of the content of lectures); C – development of critical thinking (the ability to analyze and solve engineering problems); P – practical skills (the level of laboratory and project activities); I – level of interactivity (the degree of student involvement in the educational process); M – motivational component (the level of educational motivation, determined through pedagogical indicators); w_i – weight coefficients (determined by the expert method, $\sum w_i = 1$).

All indicators were normalized in the range $x_i \in [0,1]$ which provides the ability to compare different educational systems in a single measurement scale. The method of expert assessments (Delphi approach) was used to determine the weight coefficients of the model, which take into account the importance of each component of the educational process. The study has the following limitations: the use of open educational data without access to internal academic statistics of

universities; the expert nature of some of the assessments; and the focus on leading universities, which may limit the generalization of the results to the entire higher education system.

The analysis of methodological and didactic approaches to teaching robotics at universities in USA and the Ukraine revealed significant structural differences in the role of lecture material and its impact on students' learning outcomes (see Table 1).

Table 1.

The effectiveness of using lecture material in the educational process in the STEM educational component «Robotics» at universities in the USA and Ukraine.

University / *Course*	Lecture Type	K	C	P	I	M	E_l
Stanford – CS223A (USA)/ *Introduction to Robotics*, [6]	Classical + demonstration	0.9	0.8	0.7	0.6	0.7	0.74
Stanford – CS237B(USA) / *Robot Autonomy*, [2]	Problem-based learning	0.8	0.9	0.9	0.85	0.9	0.87
Stanford – CS226 (USA)/ *Statistical Robotics* [7]	Theoretical-algorithmic	0.95	0.9	0.75	0.7	0.8	0.82
Stanford – ME23N (USA)/ Soft Robotics, [16]	Hands-on lecture	0.7	0.8	0.95	0.9	0.95	0.86
Cornell – CS4750 (USA)/ *Foundations of Robotics*, [8]	Lecture + projects	0.85	0.85	0.9	0.8	0.85	0.85
Cornell – CS5757 (USA)/ *Optimization in Robotics*, [9]	Theory + application	0.9	0.9	0.85	0.75	0.8	0.84
Michigan – ROB204 (USA)/ *Human-Robot Interaction*, [19]	Socio-technical	0.75	0.9	0.85	0.9	0.9	0.86
Ivan Franko National University of Lviv (Ukraine) / *Robotic Systems and Their Security*, [18]	Classical lecture + labs	0.92	0.75	0.7	0.5	0.65	0.70
Lviv Polytechnic National University (Ukraine) / *Education program «Robotics»*, [12]	Theory + programming	0.9	0.85	0.75	0.6	0.7	0.76
KPI (Ukraine) / *Robotics & Mechatronics*, [10]	Engineering-oriented lecture	0/95	0.85	0.75	0.6	0.7	0.77
Kharkiv National University of Radio Electronics (Ukraine) / Cyber-Physical Systems, [11]	Integrated lecture + IT labs	0.9	0.85	0.8	0.65	0.75	0.79
Volodymyr Dahl East Ukrainian National University (Ukraine) / Robotics modules [1]	Modular applied learning	0.85	0.8	0.85	0.7	0.75	0.79

It was determined that the effectiveness of the lecture process depends on the balance of five key components: the level of knowledge acquisition (K), the development of critical thinking (C), practical skills (P), interactivity (I), and student motivation (M).

Ukrainian universities are characterized by the dominance of the theoretical component (K = 0.90-0.95), which reflects the traditional engineering model of education. At the same time, the level of interactivity (I = 0.50-0.70) remains

relatively low, which indicates the dominance of the lecture-reproductive approach. The average integral index of lecture effectiveness in Ukraine is $E_L \approx 0.70\text{-}0.79$.

US universities demonstrate a different didactic structure of lectures, where they perform mainly an orientational and problematizing function. High values of interactivity (I = 0.80-0.90), practical component (P = 0.80-0.95) and motivation (M = 0.85-0.95) indicate the dominance of the student-centered approach. The average integral index of lecture effectiveness in the US is $E_L \approx 0.85\text{-}0.87$. Thus, the American model demonstrates a higher balance between theoretical knowledge and practical application.

Comparative analysis allows us to establish fundamental differences between the two educational models (see Table 1): 1) The Ukrainian system is oriented towards cognitive depth (knowledge-centered approach); 2) The American system is based on a competency-based learning approach. It was found that the effectiveness of lectures in the USA increases mainly due to the components P, I and M, while in Ukraine the component K dominates.

The results obtained are consistent with modern research in the field of STEM education, which emphasizes the transition from a lecture-centric model to active learning. In particular, it was found that increasing the interactivity of learning directly affects the level of material acquisition; integration of practical tasks into the lecture process increases student motivation; the use of problem-based learning and hands-on approaches is a critical factor in efficiency in the STEM educational process at universities. The Ukrainian education system retains a strong fundamental mathematical and engineering base, which is its competitive advantage. However, the insufficient level of interactivity and weak integration of practical components limit the development of students' applied competence. At the same time, the American model demonstrates higher efficiency due to the systemic integration of digital learning platforms, simulation environments and project-oriented lectures. Thus, the key factor in improving the quality of the STEM educational discipline «Robotics» at universities Ukraine is the transition to a hybrid learning model that combines the theoretical depth of the Ukrainian school with the practical focus of the American one.

Conclusions. As a result of the study, a comprehensive comparative analysis of methodological and didactic approaches to teaching STEM educational component «Robotics» at universities in the USA and Ukraine in the context of the development of STEM education was carried out, and the impact of lecture material on the effectiveness of learning content was assessed.

It was established that the Ukrainian model of higher education is characterized by the dominance of a lecture-oriented approach, which provides a high level of fundamental theoretical training of students. At the same time, limited interactivity and insufficient integration of practical components reduce the effectiveness of the formation of applied competence. The American model, on the contrary, is based on student-centered, problem-oriented and project approaches, which provide a higher level of motivation, interactivity and the ability to apply

knowledge in practice. Based on the proposed integral mathematical model for evaluating the effectiveness of lecture material, it has been proven that educational effectiveness is a multifactorial quantity that depends on the balance of cognitive (K), analytical (C), practical (P), interactive (I) and motivational (M) components. Comparative analysis showed that in the Ukrainian system the component of theoretical knowledge (K) dominates, while in the USA efficiency is formed due to the synergy of practical activity, interactivity and motivation (P, I, M).

The feasibility of implementing a hybrid model of teaching robotics, which combines the strengths of the Ukrainian and American educational systems, is substantiated. Such a model involves preservation of fundamental theoretical training; increasing the level of interactivity of lectures; integration of laboratory and project components into the lecture process; active use of digital educational technologies. The practical significance of the results obtained lies in the possibility of their use for the modernization of STEM educational component «Robotics» at universities in the USA and Ukraine curricula, optimization of lecture content, and improvement of the quality of training of future specialists in the STEM education system. Prospects for further research are associated with empirical verification of the proposed model based on statistical data, the use of regression analysis, and the expansion of the sample of universities to increase the representativeness of the results.

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Батюк Л. В. Ефективність лекцій у викладанні «робототехніки» в США та України в контексті STEM-освіти.

У статті здійснено комплексний порівняльний аналіз методичних і дидактичних особливостей викладання освітнього компонента «Робототехніка» в університетах США та України в контексті розвитку STEM-освіти, а також оцінювання впливу лекційного матеріалу на ефективність засвоєння навчального змісту студентами. Особлива увага приділяється визначенню ролі лекції у формуванні когнітивних, практичних та мотиваційних компонентів навчання, а також розробленню та апробації інтегральної математичної моделі оцінювання ефективності лекційного процесу.

Для оцінки ефективності лекційного контенту запропоновано інтегральну модель оцінювання ефективності лекцій, що включає ключові компоненти навчального процесу: отримання знань, критичне мислення, практичні навички, інтерактивність та мотивацію студентів. У дослідженні використовується змішаний методологічний підхід, включаючи порівняльний педагогічний аналіз, контент-аналіз освітніх програм з робототехніки та кількісне моделювання. Показано, що в українській системі вищої освіти лекція залишається домінуючою формою організації навчання, орієнтованою на глибоку теоретичну підготовку, систематизацію знань і формування аналітичного мислення. Водночас у США лекційний компонент інтегрується з активними методами навчання, такими як проблемно-орієнтоване навчання, проєктна діяльність та змішане навчання, що забезпечує підвищення рівня інтерактивності, мотивації та практичної спрямованості освітнього процесу. Результати дослідження підтверджують, що ефективність лекцій в університетах України та США в контексті розвитку STEM-освіти визначається не лише якістю контенту, а й залежить від синергії когнітивних, поведінкових та мотиваційних факторів. У дослідженні обґрунтовується необхідність впровадження в Україні гібридної моделі навчання, яка поєднує теоретичну строгу основу української освіти з інтерактивною та прикладною спрямованістю американських підходів. Така інтеграція є важливою для покращення якості освіти у сфері робототехніки та її узгодження із сучасними стандартами STEM-освіти та вимогами ринку праці.

Ключові слова: *STEM-освіта, робототехніка, університет, лекція, вища освіта, США, Україна.*

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