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PREPARATION OF STEM TEACHERS IN THE USA AND UKRAINE: COMPARATIVE STUDY OF TEACHERS TRAINING PROGRAMS

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In the article a comparative analysis of STEM teachers training programs is conducted. In order to identify similarities and differences in the provision of educational services to future teachers of STEM disciplines in American and Ukrainian higher education institutions, an analysis of educational-professional programs of US and Ukrainian universities, hosted on the sites of designated education institutions is conducted. The results of a comparative analysis of STEM teachers training programs in the United States and Ukraine have shown that this area is a priority direction of the national educational policy in both countries. At the same time, significant differences were found in the provision of educational services to future STEM teachers, the main one being the absence of special teachers training programs in Ukrainian higher education institutions that would teach STEM disciplines in an integrated way, while in the United States for this purpose was created UTeach program, which allows students to gain knowledge on an integrated STEM course teaching methodology and to develop relevant competences. In Ukraine, future teachers may teach STEM subjects after obtaining a bachelor's/master's degree in one of STEM specialties (mathematics, physics, chemistry, biology, etc.), while in the USA, a special STEM teachers training program provides only a bachelor's

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degree. Significant differences were found in the content of STEM teachers training programs, which lie, first and foremost, in the in-depth study of STEM courses and teaching methods in US higher education institutions as opposed to Ukrainian universities, where scientific-subject training takes up less than a third of time planned in the framework of the educational-professional program. Taking into account the above mentioned, the prospects for further research are seen in developing guidelines for modernization of the content of STEM teachers training programs based on an integrated approach, taking into account positive conceptual ideas of the American experience.

Key words: STEM education, STEM teachers, STEM teachers training, STEM teachers training programs, STEM courses, STEM disciplines, STEM curriculum, higher education institution, USA, Ukraine.

ПІДГОТОВКА STEM-УЧИТЕЛІВ У США ТА УКРАЇНІ: ПОРІВНЯЛЬНЕ ДОСЛІДЖЕННЯ ПРОГРАМ ПРОФЕСІЙНОЇ ПІДГОТОВКИ ВЧИТЕЛІВ

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У статті здійснено порівняльний аналіз програм професійної підготовки STEM-учителів. З метою виявлення спільних рис та відмінностей у наданні освітніх послуг майбутнім учителям STEM-дисциплін в американських та українських закладах вищої освіти здійснено аналіз освітньо-професійних програм університетів США та України, розміщених на сайтах означених закладів освіти. Результати проведеного порівняльного аналізу програм професійної підготовки STEM-учителів у США та Україні засвідчили, що ця сфера є пріоритетним напрямом національної освітньої політики в обох країнах. Разом із тим, виявлено суттєві відмінності в наданні освітніх послуг майбутнім учителям STEM дисциплін, головною з яких є відсутність в українських закладах вищої освіти спеціальних програм професійної підготовки вчителів, які б викладали STEM-дисципліни інтегровано, тоді як у США з цією метою створено спеціальну програму UTeach, що дозволяє студентам здобути знання з методики викладання інтегрованого STEM-курсу та сформуванню відповідні компетентності. В Україні майбутні вчителі можуть викладати STEM-дисципліни після здобуття ступеня бакалавра/магістра з однієї зі спеціальностей STEM (математика, фізика, хімія, біологія тощо), у той час як у США спеціальна програма підготовки STEM-учителів передбачає здобуття лише ступеня бакалавра. Виявлено значні відмінності в змісті програм професійної підготовки STEM-учителів, що полягають, насамперед, у наданні переваги поглибленому вивченню STEM-дисциплін та методик їх викладання в американських закладах вищої освіти на противагу українським вишам, де науково-предметна підготовка займає менше третини запланованого освітньо-професійною програмою часу. Ураховуючи вищезазначене, перспективи подальших досліджень полягають у розробленні рекомендацій щодо модернізації змісту програм професійної підготовки вчителів STEM-дисциплін на засадах інтегрованого підходу з урахуванням позитивних концептуальних ідей американського досвіду.

Ключові слова: STEM-освіта, STEM-учителі, професійна підготовка STEM-учителів, програма професійної підготовки STEM-учителів, STEM-курси, STEM-дисципліни, STEM-урикулум, заклад вищої освіти, США, Україна.

Introduction of the issue.

Recognition of STEM (Science, Technology, Engineering, Mathematics) education as a priority area of the education system development and necessity of implementation of the

STEM component in the educational process at all stages (from preschool to higher education institutions) causes the problem of preparation of a new generation of teachers, able to teach integrated STEM subjects. Thus, there

is a contradiction between the requirements of the Ministry of Education and Science of Ukraine for active development of STEM areas both in formal and informal education and lack of qualified specialists, who have got special training. In this context relevant is the issue of modernization of the system of teachers training, which will prepare graduates, competitive at modern labour market. At the same time, such countries, as the USA, Singapore, Finland, Australia, Germany, etc. have significant experience of training STEM teachers, positive conceptual ideas of which can be creatively implemented in the system of Ukrainian higher education.

Current state of the issue.

Development of STEM education in Ukraine and abroad has been the subject of research of many domestic scientists for more than ten years. Different aspects of the phenomenon under investigation have been revealed in the studies of V. Andriievska, S. Babiichuk, O. Barna, M. Boichenko, I. Chernetskyi, V. Chernomorets, S. Dembitska, S. Halata, O. Hirnyi, O. Kiian, O. Korshunova, O. Kurnosenko, O. Kuzmenko, S. Kyrylenko, R. Levytska, O. Lozova, N. Morze, O. Patrykeieva, N. Polikhun, I. Savchenko, S. Sioma, I. Slipukhina, H. Skrypka and others.

The outline of unresolved issues brought up in the article. At the same time, the issue of preparation of STEM teachers, despite its relevance in conditions of modernization of the system of education in the light of the New Ukrainian School Concept, has not been highlighted.

Aim of research is to compare STEM teachers training programs of US and Ukrainian universities.

The analysis of the problem is made on the basis of fundamental and applied research of the theorists and practitioners of STEM education, in

which considered problem is discussed versatile and systemically.

In order to find out similarities and differences in the studied countries we have analyzed the websites of American and Ukrainian universities which provide information on STEM teachers training programs.

In our study the following research methods have been used: terminological analysis – with the help of which the essence of STEM education phenomenon is defined; comparative analysis – aimed at defining similarities and differences in the content of STEM teachers training programs in US and Ukrainian universities.

Results and discussion. Conducting comparative analysis of STEM teachers training programs envisages definition of the main concepts of research in a comparative plane. In the English-speaking discourse the term "STEM" is an acronym for the first letters of such disciplines as Science, Technology, Engineering, and Mathematics. In Ukraine, as well as in other countries of Post-Soviet space, unfortunately, most education theorists and practitioners misunderstand the first constituent of this concept, referring Science not to Natural Sciences, as it is in the English-speaking countries, but to science as a whole. Nevertheless, official glossary [1], developed by the Institute of Education Content Modernization, emphasizes on the meaning, proposed by the National Science Foundation (NSF) and generally used in the English-speaking countries.

Active introduction of the term STEM in the sphere of education has led to appearing of such related terms as "STEM teachers", "STEM school", "STEM classes", "STEM disciplines", "STEM literacy", "STEM teaching and learning", "STEM competencies and skills", etc. All these terms are united by the idea of understanding STEM as an integrated phenomenon. We agree with American scientists A. Glancy,

T. Moore, S. Guzey, C. Mathis, K. Tank and E. Siverling, that "this possibility can lead to new "STEM" degrees, certifications, endorsements, and teacher PD, meaning specifically an integrated approach to teaching STEM [4].

It should be stressed, that the key concept of our study – STEM teacher – is understood similarly in the US and Ukrainian educational and scientific space. As it is noted in "Glossary of STEM education terms and concepts" [1], a teacher of STEM disciplines is a motivated teacher, who teaches STEM subjects on the basis of integrated and interdisciplinary interaction with all learning components, versatile creative personality with knowledge and skills in the theory of the subject and learning technologies, aware in the field of ICT, ready to undertake research activities, able to re-think critically his experience in the light of modern science.

In the USA STEM teachers are trained at 46 universities in 22 states and the District of Columbia in the frames of UTeach program. US policy-makers define UTeach as a unique university-based program for

preparation of a secondary STEM (Science, Technology, Engineering, Mathematics) teacher.

First UTeach program was implemented at The University of Texas at Austin in 1997 as an "innovative way to recruit undergraduate science, technology, engineering, and mathematics (STEM) majors and prepare them to become teachers" [6].

In Ukraine, unfortunately, there are no special programs for training STEM teachers, as well as no integrated STEM specialty. In these conditions the function of STEM teachers fulfill mainly the teachers of Natural Sciences, Physics and Mathematics. Consequently, specialists who will be able to teach STEM subjects are trained at pedagogical universities, academies and classical universities in the framework of the following specialties: 014.04 Secondary Education (Mathematics), 014.08 Secondary Education (Physics), 014.06 Secondary Education (Chemistry), 014.07 Secondary Education (Geography), 014.15 Secondary Education (Natural Sciences), 014.05 Secondary Education (Biology and Human Health) (Tab. 1).

Table 1

Number of higher education institutions which train teachers in STEM subjects

Specialty	Number of HEIs
014.04 Secondary Education (Mathematics)	48
014.08 Secondary Education (Physics)	41
014.06 Secondary Education (Chemistry)	36
014.07 Secondary Education (Geography)	6
014.15 Secondary Education (Natural Sciences)	15
014.05 Secondary Education (Biology and Human Health)	26

Systematized by the authors on the basis of information, available at the website:

<https://osvita.ua/vnz/guide/search-17-0-0-151-0.html>.

Unlike traditional teachers training programs with majors in secondary education/specific content areas related to STEM, UTeach program is aimed at obtaining simultaneously bachelor's degree in an integrated STEM field and secondary teacher certification. The duration of study is four years. The distinctive feature of UTeach program is compactness (in general, the number of credits ranges from 120 to 126), which is achieved by reducing the number of required education courses and eliminating a small number of upper-division content courses. UTeach programs offer Bachelor of Science (BSc) degrees with a Teaching Option, with majors in Biology, Chemistry, Physics, Mathematics, Computer Science, or Engineering [3].

In Ukraine, training of bachelors is provided in the frames of the Law of Ukraine on "Higher education", which states that "Bachelor's degree is an

educational degree obtained at the first level of higher education and awarded by a higher education institution as a result of successful completion of an educational-professional program by the applicant for higher education, the volume of which is 180-240 ECTS credits" [2]. Consequently, all future Ukrainian STEM teachers have to fulfill similar requirements in order to obtain their first (bachelor's) degree. Like in the USA, the duration of study for this degree is four years (Tab. 2).

The main difference from Ukrainian and the main advantage of American STEM teachers training program is integrated STEM content, based on current research both in STEM in general and STEM education in particular. Future STEM teachers have an opportunity to learn about STEM field knowledge development, history and philosophy of science and mathematics and domain-specific student learning. In Ukraine, on the contrary, future STEM teachers can learn only historical aspects of development of the field of knowledge (discipline) they are major in.

Table 2

Comparative characteristics of provision of STEM teachers training programs in the USA and Ukraine

USA	Ukraine
Programs	
Special STEM teachers training programs (Uteach)	No special STEM teachers training programs Teachers training programs in specialties: 014.04 Secondary Education (Mathematics), 014 Secondary Education (Physics), 014.06 Secondary Education (Chemistry), 014.07 Secondary Education (Geography), 014.15 Secondary Education (Natural Sciences), 014.05 Secondary Education (Biology and Human Health)

Range	
46 universities in 22 states and the District of Columbia (bachelor's degree) 2 universities (Tufts University, Montana state university)	Pedagogical universities, academies and classical universities. Number varies according to specialties (Table 1)
Degrees/terms/credits	
Bachelor of Science (BSc) degrees with a Teaching Option, with majors in biology, chemistry, physics, mathematics, computer science, or engineering / 4 years / 120-126 credits) Master of Science (MSc) / Master of Arts (MA) / 2-3 years – full-time, up to 6 years - part-time / 30 credits	Bachelor's degrees (with majors in the listed above specialties) / 4 years / 180-240 credits ECTS Master's degrees / 1,5-2 years / 120 credits ECTS

Besides, in every UTeach program course, instruction emphasizes the underlying connections between mathematics and science, as well as among the sciences, taking into account the similarities and differences in teaching and learning each of them. Furthermore, students from the various STEM majors take UTeach courses together and are encouraged to collaborate whenever possible. In Ukraine, mathematics and science are traditionally separated and training of Mathematics teachers and Science teachers is provided at different departments. Thus, in current conditions there are no opportunities for collaboration of future STEM teachers majoring in mathematics and science. But the worst is the situation with such constituent of STEM as Engineering, since engineers are trained at technical/classical universities, which do not collaborate with pedagogical ones. At the same time, students of pedagogical universities do not receive information in the field of engineering.

In the framework of comparative analysis of STEM teachers training programs in the USA and Ukraine we'd like to pay special attention to the curriculum. The curriculum of STEM teachers' preparation in Ukrainian HEIs differs significantly from US one. First of all, the number of credits in Ukrainian universities is twice more than in American HEIs, accordingly, the number of disciplines in US universities is much smaller. At the same time, in spite of general similarities in curriculum design, there are some differences in the number and content of courses, provided by Ukrainian and US universities, which can be explained by decentralization of higher education (traditional for USA and modern trend for Ukraine), and as a result, autonomy of the universities in both countries.

In Ukraine STEM teachers training curriculum consists of compulsory subjects (75 %) and disciplines of free choice of the student (25 %). Both compulsory subjects and disciplines of free choice of the student are divided into two sections: I. General training cycle, which includes: 1) humanitarian

training and 2) fundamental training; II. Professional training cycle, which includes: 1) psychological-pedagogical training and 2) scientific-subject training. Curriculum also envisages teaching practice, coursework, and certification.

It should be noted that STEM teachers training curriculum of Ukrainian universities includes a lot of subjects which are not always connected directly with student's major. UTeach curriculum, on the contrary, consists of a sequence of tightly articulated courses. Instead of separate courses on important topics (e.g. instructional technology, assessment, and equity and special populations (gifted, twice exceptional, students with disabilities and so on)), which are proposed by STEM teachers training curriculum in Ukrainian universities, in the US universities these topics are embedded in all UTeach courses.

UTeach curriculum includes the following groups of courses:

- UTeach Recruitment Courses – designed to encourage STEM majors to "try out teaching". These courses are arranged in two steps: Step 1: Inquiry Approaches to Teaching and Step 2: Inquiry-Based Lesson Design;

- UTeach STEM Education Courses – are based on current research in teaching and learning specifically within the STEM domains;

- UTeach STEM Content Courses – are generally taken concurrently with STEM education courses and are designed to fulfill multiple degree requirements while emphasizing content of particular importance to secondary math and science teachers;

- Apprentice Teaching – this course consists of a semester-long teaching experience and a seminar that provides a culminating opportunity for students to demonstrate proficiencies required for certification and acquiring experience and confidence needed for their first teaching positions;

- Portfolio – students provide evidence through the portfolio that they are proficient across a number of criteria ranging from subject-matter knowledge to effective instructional design and classroom management. Along with proficiencies required during the final Apprentice Teaching experience, this collection of evidence must satisfy minimum criteria in order for a student to be eligible for certification. A preliminary portfolio requires students to satisfactorily address a subset of the final portfolio criteria in order to be admitted into Apprentice Teaching [3].

In this context it should be stressed that future Ukrainian STEM teachers while obtaining their first (bachelor's) degree have the opportunity to observe teachers at work (educational teaching practice, 2 year of study) and get teaching experience at schools (during 8 weeks of teaching practice, 4 year of study). The results of teaching practice are assessed according to students' documentation (portfolio, journals of practice, etc.).

In order to become a teacher (and STEM teacher in particular) in both countries bachelor's degree is enough. But in Ukraine traditionally most students get second – master's degree. This fact explains wide offer of master's degree programs of Ukrainian universities, which cover all the above mentioned STEM specialties (Tab. 1). Curriculum of master's degree programs consists of the same components as in bachelor's degree programs, namely: compulsory subjects and disciplines of free choice of the student. These sections are also divided into general training cycle and professional training cycle.

In the USA, the percentage of students, who obtain master's degree, compared to Ukraine, is smaller. Furthermore, UTeach program is specially designed for bachelors and does not include masters training.

Nevertheless, some US universities offer masters programs for future STEM teachers. With the help of searching system [masterstudies.com](https://www.masterstudies.com/MSc/STEM-Education) (<https://www.masterstudies.com/MSc/STEM-Education>) we have found three masters programs in STEM education, provided by two education institutions: Tufts University (Master of Arts in Elementary STEM Education and Master of Science in Science, Technology, Engineering and Math (STEM) Education) and Montana state university (Master of Science in Science Education).

In the frames of our study we'd like to focus on Tufts University Master of Science in Science, Technology, Engineering and Math (STEM) Education program. MSc in STEM Education program is aimed at preparing educators to work in formal and informal STEM education settings, in particular schools, research centers, museums, industry, cultural institutions, and community agencies. It also prepares future candidates for PhD programs.

MSc program admits candidates with bachelor's degree in Mathematics, Biology, Chemistry, Physics, Technology, Engineering, Education, Psychology, Child development, Cognitive science, and other related areas. Candidates without BA/BSc in Mathematics, Sciences, or Engineering should take additional graduate level courses. The maximum time limit for completion of this program for full-time students is three years.

Having entered into MSc in STEM Education program of Tufts University, each student is assigned two program advisors, one from the Departments of Education or Child Development and another from the Mathematics, Sciences, or Engineering Departments. The program advisors assist the student in making choices regarding courses, content area, internships, and research activities. The choice is

determined by an evaluation of each student's needs in terms of understanding: Mathematics, Science, or Engineering content knowledge; socio-cultural foundations of education; theory and research on human development and learning in different content areas; specific knowledge directly related to the development of the MS thesis, project, research, or internship [5].

Conclusions and research perspectives. Comparative analysis of STEM teachers training programs of US and Ukrainian universities has allowed making a conclusion on similarities and differences of education services provision in the studied countries. The main difference is that in Ukraine there are no special programs for preparation of STEM teachers while in the USA there is a specially designed program UTeach, implemented in 46 universities. In Ukraine, teachers, who can teach STEM subjects, major in mathematics, physics, chemistry, geography, natural sciences, biology, etc. At the same time Ukrainian HEIs offer teachers training programs both of bachelor's and master's levels in the mentioned above specialties, while in the USA most programs provide bachelor's degree only. Important in conditions of modernization of domestic system of higher education is analysis of curriculum of STEM teachers training, which differs significantly from Ukrainian one and is aimed at obtaining knowledge and skills of teaching integrated STEM subjects, because new Ukrainian school needs just such teachers. In this context the prospects for further research are seen in the outlining positive conceptual ideas of American experience of implementing of STEM teachers training programs and designing curriculum, which can be creatively implemented in Ukrainian higher education institutions.

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