СЕКЦІЯ 1. МЕТОДОЛОГІЯ ТА ІСТОРІЯ ПЕДАГОГІКИ

УДК [378.091.321-047.22:378.015.31(477:73)]:37.013.74
DOI https://doi.org/10.32999/ksu2413-1865/2025-110-1

TRADITIONAL AND INNOVATIVE TECHNOLOGIES IN TEACHERS' PROFESSIONAL COMPETENCE IN TRAINING THE STUDENTS IN STEM EDUCATION

Batyuk Liliya Vasylivna,
Candidate of Biological Science (PhD), Docent,
Associate Professor of the Department of Physics and Chemistry
H.S. Skovoroda Kharkiv National Pedagogical University
l.batyuk@hnpu.edu.ua
orcid.org/0000-0003-1863-0265

In the Concept of Development of Science and Mathematics Education (STEM Education), the implementation of which is envisaged by the Government of Ukraine by 2027, the need to focus on professional training of teachers is becoming increasingly relevant for higher education institutions. In this context, it is advisable to study the historical retrospection of the development of traditional and innovative educational technologies and the use of educational technologies in the professional activities of teachers in the field of STEM education in the country that is the source of STEM education – the United States of America.

Purpose. The purpose of the article, based on historical retrospection, is to investigate the development of traditional and innovative practices of using educational technology in the professional competence of teachers in the training of students in the field of STEM education. The following tasks were solved: to investigate which technologies in the professional activities of teachers are traditional and which are innovative in the spatial content of the development of education; to determine which technologies are important for students to master for professional activities in the field of STEM education.

Methods. To achieve the set goal, specific-search and logical-synthetic analysis; system-structural analysis; chronological analysis; statistical and comparative analysis of individual aspects of the development of STEM education; theoretical-generalizing method and interpretation method were used.

Results. The results of the study showed that in the category of traditional technologies, both in the USA and in Ukraine, passive learning technologies prevail, namely explanatory-illustrative, lecture and practical learning in the classroom. In the category of innovative technologies, activity, interactive technologies, as well as technologies of personality-oriented learning prevail. Project technologies are very often attributed by teachers to the group of innovative ones, but today it is obvious that mastering them is mandatory for teachers. In the context of our study, it should be noted that the issue of liberal education, namely «artes liberales» versus «artes serviles» in the development of the educational environment and the concept of education in the United States, led to a rethinking of the direction of education, in particular in determining the development of pedagogical skills of teachers and the training of students, which was manifested in the progress and improvement of pedagogical systems.

Conclusions. It is determined that the historical development of education is aimed at moving away from academic traditional learning, which has been an unchanging principle since the founding of the first higher education institutions in the United States, to the latest innovative educational methods, namely, information and communication, digital, problem-dialogical, problem-heuristic, interactive, personality-oriented, based on multiculturalism in education. Technologies of pedagogical skills of teachers in the field of STEM education, regardless of the country, are traditional (academic) and innovative at the same time, because the learning process can be oriented both to the classics and to innovations, which is a progressive model of education that attracts both young people and teachers who use the latest educational trends in their work.

Keywords: *STEM education, USA, Ukraine, competence, higher education institutions, teacher, educational technologies.*

ТРАДИЦІЙНІ ТА ІННОВАЦІЙНІ ТЕХНОЛОГІЇ В ПРОФЕСІЙНІЙ КОМПЕТЕНТНОСТІ ВИКЛАДАЧІВ ПРИ ПІДГОТОВЦІ СТУДЕНТІВ У СФЕРІ STEM ОСВІТИ

Батюк Лілія Василівна,
кандидат біологічних наук, доцент,
доцент кафедри фізики і хімії
Харківський національний педагогічний університет імені Г.С. Сковороди
l.batyuk@hnpu.edu.ua
orcid.org/0000-0003-1863-0265

В Концепції розвитку природничо-математичної освіти (STEM-освіти), впровадження якої передбачено Урядом України до 2027 року, для закладів вищої освіти стає все більш актуальною потреба орієнтування на професійну підготовку викладачів. У цьому контексті доцільно дослідити історичну ретроспекцію розвитку традиційних та інноваційних освітніх технологій та використання освітніх технологій у професійній діяльності викладачів у сфері STEM-освіти в країні, яка є джерелом STEM-освіти – в Сполучених Штатах Америки.

Мета статті на основі історичної ретроспекції дослідити розвиток традиційних та інноваційних практик використання освітніх технології в професійній майстерності педагогів при підготовці студентів у полі STEM освіти. Вирішувались наступні завдання: дослідити, які технології, у професійній діяльності викладачів є традиційними, які є інноваційними в просторовому контенті розвитку освіти. Визначити якими технологіями важливо оволодіти студентам для професійної діяльності у полі STEM освіти.

Методи. Для досягнення поставленої мети використано конкретно-пошуковий та логіко-синтетичний аналіз; системно-структурний аналіз; хронологічний аналіз; статистичний та порівняльний аналіз окремих аспектів розвитку STEM-освіти; теоретико-узагальнюючий метод та метод інтерпретації.

Результати. Результати дослідження засвідчили, що в категорії традиційних технологій, як в США, так і в Україні, переважають пасивні технології навчання, а саме пояснювальна-ілюстративна, лекційна та форма практичного навчання на уроку. У категорії інноваційних технологій перевага діяльнісних, інтерактивних технологій, а також технологій особистісно-орієнтирного навчання. Проектні технології дуже часто відносяться педагогами до груп інноваційних, проте сьогодні очевидно, що оволодіння ними є обов'язковим для педагогів. У контексті нашого дослідження, слід зазначити, що питання ліберальної освіти, а саме «artes liberales» проти «artes serviles» при розвитку освітнього середовища і концепції освіти в Сполучених Штатів, призвело до переосмислення напряму освіти, зокрема у визначенні розвитку педагогічної майстерності викладачів та підготовки студентів, що виявилось у прогресі та покращенні педагогічних систем.

Висновки. Визначено, що історичний розвиток освіти спрямований на відхід від академічного традиційного навчання, яке було незмінним принципом із заснування перших вищих навчальних закладів у Сполучених Штатах Америки, до новітніх інноваційних освітніх методів, а саме, інформаційно-комунікаційних, цифрових, проблемно-діалогічних, проблемно-евристичних, інтерактивних, особистісно-орієнтованих, що базуються на мультикультуралізмі в освіті. Технології педагогічної майстерності викладачів у сфері STEM-освіти, незалежно від країни, є традиційними (академічними) та інноваційними водночас, адже процес навчання може бути орієнтований як на класику, так і на інновації, що є прогресивною моделлю освіти, яка приваблює як молодь, так і викладачів, які використовують у своїй роботі новітні освітні тренди.

Ключові слова: *STEM-освіта, США, Україна, компетентність, заклади вищої освіти, викладач, освітні технології.*

Introduction. In the Concept for the Development of Science and Mathematics Education (STEM Education), the implementation of which is envisaged by the Government of Ukraine by 2027 (About approval of the Concept for the Development of Science and Mathematics Education (STEM Education), 2021; On the Implementation of the Innovative Educational Project «New Ukrainian School, University, Community, Government – Coordination of Interaction on the TeachHub Intellectual Platform», 2021; On the Implementation of an Innovative Educational Project of the All-Ukrainian Level on the Topic «Scientific and Methodological Support of STEM Education in Educational Institutions», 2024), the need to focus on professional training of teachers in response to the needs of the new Ukrainian school is becoming increasingly relevant for higher education institutions. The individual success of the 21st century professional increasingly depends on STEM literacy where he/she can functioning as a high-quality professional, informed consumer, and citizen in a world of complex technologies. This component requires the ability to use digital devices and STEM skills from a set of disciplines that intersect and are integrated into an interdisciplinary

approach to learning and development. It is therefore not surprising that we are seeing a growing number of articles and books on STEM education and research that contribute to multiple perspectives and debates on STEM-related projects, assess student learning, and provide teachers with «pedagogical capital» (Machi 2009; Bybee, 2013; Raupp, 2019). The authors provide valuable suggestions, ranging from new conceptual approaches and the involvement of pedagogical partnerships (Yamada, et al., 2023; Anderson & Li, 2020; Federation of American Scientist, 2025) to the creation of comprehensive effective STEM learning environments in primary, secondary and higher education (Honey, 2014; Madden, et al., 2016; MacDonald, et al., 2020). This includes studying the demands of schools for modern technologies that a higher education graduate should have; the possibility of involving teachers as carriers of various technologies in the supervision of students in both formal and informal practices; increasing integration between disciplines and learning in the classroom and outside the classroom; the active use of electronic educational courses and digital learning technologies (Lee & Lee, 2022; Batyuk & Zhernovnykova, 2018). Some authors argue that STEM education combines only natural sciences and mathematics, others believe that STEM education is a variety of activities where research and project-based learning strategies replace traditional academic, lecture approaches (Breiner, et al., 2012) and innovative new educational approaches. From a broader perspective, STEM education can be described as a systematic process of teaching and/or learning in STEM fields (Prima, et al., 2024; Ntemngwa & Oliver, 2018; Valko, 2020). In this context, it would be advisable to study the development of traditional and innovative technologies of teacher skills in preparing students in the country that is the original source of STEM education, namely the United States of America.

Theoretical justification of the problem. As shown by the analysis of scientific, pedagogical and methodological research and publications, the US higher education system operates in the direction of actualizing STEM education, consolidating the efforts of the federal government, state governments, administration, teaching staff of higher education institutions, local communities and society as a whole (Means, et al., 2016; Boichenko & Boichenko, 2019; Margot & Kettler, 2019; Batyuk, 2025). The main task of the STEM educational field of the United States of America is to provide the necessary conditions for the formation of a harmonious personality, the development of creative and critical thinking, and the upbringing of civic qualities through the involvement of students in direct management of the team and the educational process. Immersion of future specialists in educational technologies in the context of implementing new concepts of STEM education, and in the context of further development of science and mathematics teaching technologies (problem-based learning, critical thinking, etc.) automatically leads to determining the level of readiness of the teacher for professional activity and determines the level of mastery of educational technologies, traditional and innovative, in the professional skills of teachers in training students in the field of STEM education. From this position, in our study it is important to highlight the basic modern technologies of teaching, upbringing, pedagogical communication, which are used by practicing teachers, to study their recommendations for training students. Also, in connection with the need and new opportunities for early personal immersion of a student in the profession, the issue of their pedagogical support, the development of student competence by leading practitioners – carriers of educational technologies, is acute. Such a process of mastery can be organized only under the conditions of the implementation of the mentoring mechanism, which includes the participation of the student in the joint activities of the teacher and the student. Innovative technologies have a powerful impact on learning, and the main idea of modern learning technologies is to provide students with the opportunity to use educational objects that should be compatible with learning in any educational system and with any other future technology in this area. The success of innovative teaching technologies used by teachers is closely related to the student-centered approach to learning and the competencies that will be acquired as a result of learning (Vasyutina, 2024; Demchenko, 2023; Rakhmanina, 2024). Those working on the implementation of STEM education are well aware that although the main elements have been identified (Kelley & Knowles, 2016), there are still different concepts of what exactly traditional and innovative technologies in the field of STEM education entail. STEM education involves innovation and motivates reflection.

Methodology and methods. In the process of writing the article, specific-search and logical-synthetic analysis were used (for collecting, analyzing, systematizing and generalizing the provisions of historical, scientific-pedagogical, methodological, reference literature); system-structural analysis (for systematizing scientific facts about education and STEM education); chronological analysis; statistical (collection, processing, analysis of data); comparative analysis of individual aspects of the development of STEM education; theoretical-generalizing method and interpretation method (for formulating and substantiating conclusions based on

the results of the study). The purpose of the article, based on historical retrospection, is to investigate the development of traditional and innovative practices of using educational technology in the professional competence of teachers in the training of students in the field of STEM education. The following tasks were solved: to investigate which technologies in the professional activities of teachers are traditional and which are innovative in the spatial content of the development of education; to determine which technologies are important for students to master for professional activities in the field of STEM education.

Results and discussions. The development of the concept of education as a necessary step on the path to professional training, namely training in the field of STEM education, was associated three centuries ago mainly with the Anglo-Saxon world, especially with the United States of America (Kontowski, 2014). But the original source of the idea of STEM education itself, in the training of students, can be found in the origins of the training of speakers in the schools of rhetoric of Ancient Greece and Rome. It was on such innovative, at that time, methods and technologies of gaining experience by teachers that various social communities pinned all their hopes. It was believed that the point was not in encyclopedic knowledge, but in knowledge from various disciplines, which allowed the future master, worker, teacher, employee to take their rightful place in the world and use to achieve mastery precisely those skills (now known as professional competence) that they would need in the future. This is how education was understood in ancient Rome, namely as the concept of education in the field of «artes liberals», or as it is also called, in the field of «liberal arts». The free Roman citizen-inventor Vitruvius, who came from Campania and was a contemporary of Caesar, wrote: "The knowledge of an architect combines many sciences and various skills and only on their basis can one evaluate works that belong to the sphere of other arts. An architect must possess the art of writing, be a good draftsman, know geometry, and have a lot of historical knowledge. He must listen carefully to the philosophers; he must know music and medicine and legal norms should not be alien to him. He must know astronomy and the laws of the heavenly bodies" (Rowland & Howe, 2014).

The characteristic of education in the field of «artes liberals» widespread during the formation of the United States as a nation, was a principled opposition to the so-called studies known as «artes serviles», that is, those engaged in by persons deprived of the status of free citizens, or, as an alternative and more politically correct translation is now used, those who received training of a servants nature. In the Middle Ages, educators of the time took as a basis for education the idea of Martianus Capella, a pagan writer of late antiquity, one of the first developers of the system of seven liberal arts (which included grammar, dialectic and rhetoric and advanced geometry, arithmetic, astronomy and music), and which structured early medieval education. Unfortunately, among these contemporary technologies, it is difficult to find any major innovations in relation to what we know about the disciplines and education that were developed in the ancient world. Later, in the 13th century, the issue of liberal education, namely the «artes liberals» versus the «artes serviles» in the development of the educational concept of the United States, brought to the surface in the preparation of students the question that needed to be resolved at that time: whether a democratic nation could adapt to its needs the undemocratic science of the nature of slavery and the impossibility of equal education for all. In response to this question, Thomas Jefferson, as one of the leaders of the abolition of the slave trade, as President of the United States (1801–1809), urged his compatriots not to send their descendants to Europe for education, but to receive a traditional education at home (Neem, 2013). His call led to the fact that the education of the United States at that time had a great impetus for the development, and the future primacy of the United States universities from the mid-19th century, to the greatest influence in the 1980s–2000s. Before the call of Thomas Jefferson, the idea of collegiate education, obtaining an education in the «artes liberales», based on the common life of students under the watchful eye of a teacher who also combined the role of an educator of future specialists, in universities (which were located far from urban areas), this idea was in practice limited to traditional teaching methods, the dominant model until that time, namely the study of the humanities, exclusively from the study of Latin and Greek and the recitation of classical texts by heart. This education was known as liberal education, understood by contemporary educators as a preparatory stage for real education, a kind of anteroom of education, as a means for turbulent young men to acquire some refinement, and, finally, a way to keep young people in difficult times under the beneficial influence of the knowledge and experience acquired by previous generations and the influence of religion in a country where it played at least as important a role as the acquisition of knowledge. This is a biographical stage of education in the United States, and Europe, where there was no room for any experimentation or innovation for teachers in the teaching and training of students (Geiger, 2015; Purdy, 2003). Liberal education was conducted under the auspices of Cicero and Socrates rather than Plato, and rhetoric was given priority over the philosophy of science.

The twentieth century brought a series of enormous changes, in particular, colleges and universities were more oriented towards the economic global market. The launch of state initiatives to create educational space, starting with the Morrill Land-Grant Acts of 1862 (Drexler, 2021; Morrill Act (1862), 2025), legislative acts of the United States that regulated the allocation of land from the federal government for the organization of practical agricultural education and the establishment of colleges in American states using the proceeds from the sale of federally owned lands (obtained from the indigenous tribes) and by the end of the century met with a wide response in radical American society. Despite the prevailing stereotype of Americans' hostility to philosophy, this biographical type of educational space, with the provision of land for educational institutions, provided practical training in skills such as agriculture, engineering, or homemaking (modern STEM and Agriculture). In the context of today's educational space, STEM and agriculture are inextricably linked, with agriculture being a practical context for STEM education. By incorporating agricultural concepts into STEM instruction, educators can provide traditional hands-on and innovative new experiences for use in teaching students in STEM education that demonstrate real-world applications of science, technology, engineering, and mathematics. This integration not only enhances students' understanding of STEM subjects, but also fosters a greater appreciation for the vital role that agriculture plays in our society and environment. The powerful baggage of traditions, historically changing ideas about this type of education and finally the great flexibility of the STEM model itself (in terms of cost and content) – all these factors contribute to the feeling that it is difficult to capture the essence of the concept of the STEM educational environment and its common core. At scientific conferences dedicated to STEM education, a significant participation is the voices that unsuccessfully try to demand the adoption of a common definition in the concept of what the STEM concept is. This term is closely related to the intellectual landscape and evokes the best associations associated with the possibilities of this «relatively new» educational trend; trends .based on confidence in the long-term return on investments made, .based on both the acquisition of knowledge and the development of skills that will be needed in adult life, such as critical thinking, creativity, analysis, the ability to solve critical issues.

Each generation poses a new question about how to adapt traditions to modernity. Because what was obvious in the past is no longer obvious today. Such was the fate of Latin as a language of instruction, such was, until recently, the question of women and representatives of national minorities in education (Klemenčič, 2020). In the mid-19th century, Francis Wayland Parker, who believed that education should include the comprehensive development of the individual, namely, mental, physical and moral, and was an opponent of standardization, isolated learning and cramming (later the philosopher John Dewey called him the «father of progressive education»), wondered what to do so that his school where he taught did not go bankrupt. According to Francis Wayland Parker, education was not only about pushing information into the heads of students, but also about teaching them to think for themselves and become independent people (Patridge, 2022). In response to own question, Francis Wayland Parker resorted to innovative technologies in the skill of a teacher and lecturer, namely, he decided to allow the optionality of most courses, so that students could plan their own classes. He paid a loss for his innovative idea: his experimental pedagogical center merged with the Faculty of Education of the University of Chicago in 1901. The school he managed became a kind of laboratory of the university. The school was later headed by John Dewey, who was strongly influenced by the ideas of F. Parker (Sikandar, 2015; Williams, 2017)

Two decades later, an "epic" change in education took place at Harvard, where students were not only exempted from the obligation to attend mass and know Greek, but also introduced a system of elective courses, which was supposed to encourage the choice of specialization and provide better-prepared candidates with information about the opportunities and their future at the faculties. Education is now accessible to many people, but the greatest merit of the development of education in the United States is that a directed current was born, which has not weakened to this day, aimed at moving away from academic traditional learning, which was the principle since the founding of the first higher education institutions in the United States, to the latest innovative methods, emphasizing the ability to critically analyze information, advantages and prospects, globalization and multiculturalism in education. The learning process is now longer and, perhaps, more difficult for the student, where teachers take into account other factors, in addition to standardized test results. Studies show (Batyuk, 2023) that most often teachers of educational institutions in the practice of teaching natural and mathematical educational disciplines use such traditional teaching technologies as problem-based learning technologies, lecture teaching technology, information and communication, explanatory and illustrative and practical teaching forms in the lesson. The frequency of use of these forms is located in the rating of use, ranging from 1 (inclusive) to 10 (inclusive). The top of the rating

of innovative educational technologies, which are also used by teachers of natural and mathematical educational in higher education institutions, are such technologies as project, information and communication, digital learning, problem-dialogical, problem-heuristic, development of critical thinking, interactive, personality-oriented, based on electronic educational resources (virtual laboratory work, etc.)

Studies show that in the category of traditional technologies, both in the USA and in Ukraine, passive learning technologies generally prevail, namely explanatory-illustrative, lecture and the form of practical learning in the lesson. In the category of innovative technologies, the advantage of activity, interactive technologies, as well as technologies of personal-oriented learning has been revealed. Project technologies are very often attributed by teachers to the innovative group, but today it is obvious that mastering them is mandatory for teachers (Yamada, 2023). A similar statement applies to a number of other technologies related to solving inventive problems, etc., attributed to the innovative group. Regarding project technology, in all likelihood, for teachers and lecturers it is important not only to transfer solid, proven knowledge, although, of course, the USA is considered the best educational system, but it is in this area that accusations of radically overestimating standards are often repeated. New modern communication technologies in the context of online learning in Ukraine have opened a completely new chapter for higher education institutions, forcing educators to rethink the entire educational process. Thus, the instability of modernity, the economy, social changes or military aggression contribute to attempts to redefine education and traditional and innovative technologies of teacher skills in preparing students in the field of STEM education.

Conclusions. Over the past two decades, new educational initiatives have appeared in Ukraine, which are developing independently, adopting, to some extent, the experience the American educational system. STEM education, regardless of the country and educational institutions, has certain teaching features, namely, general knowledge combined with a deeper acquaintance with a certain field of knowledge, intensive teamwork and building a new level of communication between the teacher and the student. The technologies of teacher skill in preparing students in the field of STEM education are traditional (academic) and innovative at the same time, depending on what exactly we want to get in the process of obtaining education, because the learning process can be focused on both classics and innovations, which is a progressive model of education that attracts both young people and the teachers they use in their work the educational trends of different democratic countries. Prospects for further research are aimed at investegation STEM education practice use in higher education that contribute to an open, just, and democratic society. Use the knowledge gained to address the most pressing issues related to the societal goals of higher education in Ukraine and around the world.

ЛІТЕРАТУРА:

1. Валько Н.В. Система підготовки майбутніх учителів природничо-математичних дисциплін до застосування STEM технологій у професійній діяльності. (Дис. ... д-ра пед. наук.) МОН України, Херсонський державний університет.Класичний приватний університет. Запоріжжя. 2020. 510 с.

2. Васютіна, Т.М. (2024) Освітні медіаресурси та цифрові застосунки як засоби реалізації STEM-технологій у підготовці майбутніх педагогів. *Наукові записки. Серія: Педагогічні науки*, 7, 18–24. DOI: https://doi.org/10.59694/ped_sciences.2024.07.018

3. Демченко, І., Григоренко, Т., Ревнюк, Н., Іващенко, К. (2023). Вплив освітнього середовища закладів вищої освіти на формування ключових компетентностей та соціальних навичок здобувачів. *Наукові інновації та передові технології*, 2(16), 271–283. DOI: https://doi.org/10.52058/2786-5274-2023-2(16)-271-283

4. Кабінет Міністрів України. Про затвердження плану заходів щодо реалізації Концепції розвитку природничо-математичної освіти (STEM-освіти) до 2027 року (№ 131-р., 2021, січень 13). https://zakon.rada.gov.ua/laws/show/131-2021-%D1%80#Text

5. Наказ Міністерства освіти і науки України. Про реалізацію інноваційного освітнього проекту «Нова українська школа, університет, громада, влада – координація взаємодії на інтелектуальній платформі TeachHub» за вересень 2021 – квітень 2026. (№ 1041, 2021, вересень 29). https://mon.gov.ua/static-objects/mon/uploads/public/661/692/42a/66169242ab846373875908.pdf

6. Наказ Міністерства освіти і науки України. Про реалізацію інноваційного освітнього проекту всеукраїнського рівня за темою «Науково-методичне забезпечення STEM-освіти в закладах освіти» у вересні 2024 – грудні 2027 року. (№ 1438, 2024, жовтень 9). https://mon.gov.ua/npa/pro-realizatsiiu-innovatsiinoho-osvitnoho-proiektu-na-vseukrainskomu-rivni-za-temoiu-naukovo-metodychne-zabezpechennia-stem-osvity-v-zakladakh-osvity-u-veresni-2024-hrudni-2027-rokiv

7. Пріма, Р. М., Пріма, Д. А. (2024). Потенціал STEM-технологій у професійній підготовці майбутніх педагогів. *Перспективи та інновації науки (Серія «Педагогіка», «Психологія», «Медицина»)*, 5(39), 419–425. DOI: https://doi.org/10.52058/2786-4952-2024-5(39)-419-425

8. Рахманіна, А. С. (2024). Розвиток особистості майбутнього педагога через формування STEM-компетентностей. *Гуманітарні студії: педагогіка, психологія, філософія*, 15 (1), 43–50. DOI: https://doi.org/10.31548/hspedagog15(1).2024.43-50

9. Anderson, J., Yeping, Li (Eds.), 2020. *Advances in STEM Education*. Springer Nature Switzerland AG. 569 p. DOI: https://doi.org/10.1007/978-3-030-52229-2

10. Batyuk, L. (2023). Digital literacy among students in medical institutions of higher education in distance

learning situations. Scientific notes of the Department of Pedagogy, 52, 147–154. DOI: https://doi.org/10.26565/2074-8167-2023-52-17

11. Batyuk, L. (2025). Major aspects of STEM education based on U.S. government initiatives. *Educational Challenges*, 30(1), 88–105. DOI: https://doi.org/10.34142/2709-7986.2025.30.1.06

12. Batyuk, L., Zhernovnykova, O. (2018). Strategy for the development of digital competence in the national education system of Ukrainian society. *Journal of Education, Health and Sport*, 8(11). 912–921. DOI: https://doi.org/10.12775/JEHS.2018.8.11.087

13. Boichenko, M., Boichenko, V. (2019). STEM-education in the USA and Ukraine: comparative analysis. *Педагогічні науки: теорія, історія, інноваційні технології*, 5 (89), 3-13. DOI: https://doi.org/10.24139/2312-5993/2019.05/003-013.

14. Breiner, J. M., Harkness, S. S., Johnson, C. C., Koehler, C. M. (2012). What Is STEM? A Discussion about Conceptions of STEM in Education and Partnerships. *School Science and Mathematics*, 112, 3–11. DOI: https://doi.org/10.1111/j.1949-8594.2011.00109.x

15. Bybee, R. W. (2013). The Case for STEM Education: Challenges and Opportunities, National Science Teachers Association. 116 p.

16. Drexler, K. (2021). Morrill Act: Primary Documents in American History. https://guides.loc.gov/morrill-act

17. Federation of American Scientist. (2025). Establishing White House Initiative For STEM Educational Excellence & Workforce Development At The U.S. Department Of Education. https://fas.org/publication/whisew/

18. Geiger, R. L. (2015). The history of American higher education : learning and culture from the founding to world war II. Library of Congress Cataloging-in-Publication Data. Princeton University Press. 585 p.

19. Honey, M., Pearson, G., Schweingruber, H. (Eds.). STEM integration in K-12 education: Status, prospects, and an agenda for research. Washington, DC: National Academies Press. 2014. 181 p. DOI: https://doi.org/10.17226/18612

20. Kelley, T. R., Knowles, J. G. (2016). A Conceptual Framework for Integrated STEM Education. *International Journal of STEM Education*, 3(11), 1–11. DOI: https://doi.org/10.1186/s40594-016-0046-z

21. Klemenčič, M. (2020). Alternative Higher Education. By P. N. Teixeira, J. C. Shin, (ed.), *The International Encyclopedia of Higher Education Systems and Institutions*: Bok (pp. 117–124). Springer, Dordrecht. DOI: https://doi.org/10.1007/978-94-017-8905-9_27

22. Kontowski, D. (2014). Liberal education. Tradycyjna? Nowatorska? By Ratajczaka K. *Innowacje edukacyjne: wczoraj, dziś, jutro*: Book (pp. 23–29). Repozytorium Uniwersytetu im. Adama Mickiewicza (AMUR), Poznań.

23. Lee, Y.-F., Lee, L-S. (2022). Status and Trends of STEM Education in Highly Competitive Countries: Country Reports and International Comparison. Technological and Vocational Education Research Center. 534p.

24. MacDonald, A., Danaia, L., Murphy, S. (Eds.). (2020). *STEM Education Across the Learning Continuum.* Springer Nature Singapore Pte Ltd. 316p. DOI: https://doi.org/10.1007/978-981-15-2821-7

25. Machi, E. (2009). *Improving US competitiveness with K-12 STEM education and training. Heritage special report. SR-57*. A report on the STEM education and National Security Conference, October 21–23, 2008. Washington, DC: Heritage Foundation. pp. 1–15. https://files.eric.ed.gov/fulltext/ED505842.pdf

26. Madden, L., Beyers J., O'Brien, S. (2016). The importance of STEM education in the elementary grades: Learning from pre-service and novice teachers' perspectives. *Electronic Journal of Science Education*, 20(5), 1–18.

27. Margot, K. C., Kettler, T. (2019). Teachers' perception of STEM integration and education: A systematic literature review. *International Journal of STEM Education*, 6(2), 1–16. DOI: https://doi.org/10.1186/s40594-018-0151-2.

28. Means, B., Wang, H., Young, V., Peters, V., Lynch, S. J. (2016). STEM-focused high schools as a strategy for enhancing readiness for postsecondary STEM programs. *Journal of Research in Science Teaching*, 53(5), 709–736. DOI: https://doi.org/10.1002/tea.21313

29. Morrill Act (1862). (2025). The U.S. National Archives and Records Administration. https://www.archives.gov/milestone-documents/morrill-act

30. Neem, J. N. (2013). Developing Freedom: Thomas Jefferson, the State, and Human Capability. *Studies in American Political Development*. 27 (1), 36–50. DOI: https://doi.org/10.1017/S0898588X13000023

31. Ntemngwa, C., Oliver, S. (2018). The implementation of integrated science technology, engineering and mathematics (STEM) instruction using robotics in the middle school science classroom. *International Journal of Education in Mathematics, Science and Technology*, 6(1), 12–40. DOI: https://doi.org/10.18404/ijemst.380617

32. Patridge, L.E. (2022). Talks On Teaching by Francis Wayland Parker. Legare Street Press. 184 p.

33. Purdy, W. C., (2003). The History of Higher Education in the Western United States. *A thesis submitted in partial fulfillment of the requirements for the degree Master of Arts in Education*. 187 p.

34. Raupp, A.B. (2019). STEM education's lost decade and tenor. Forbes technology council. https://www.forbes.com/sites/forbestechcouncil/2019/07/25/stem-educations-lost-decade-and-tenor/#43f6101260c8

35. Rowland, I. D., Howe, T. N. (Eds.). (2014). *Vitruvius: Ten Books on Architecture*. Cambridge University Press. 352p. DOI: https://doi.org/10.1017/CBO9780511840951

36. Sikandar, A. (2015). John Dewey and His Philosophy of Education. *Journal of Education and Educational Developmen*, 2(2), 191 – 201.

37. Williams, M. K. (2017). John Dewey in the 21st Century. *Journal of Inquiry & Action in Education*, 9(1), 91–102.

38. Yamada, R., Yamada, A., Neubauer, D. E. (Eds). (2023). Transformation of Higher Education in the Age of Society 5.0. International and Development Education. Palgrave Macmillan, Cham. pp. 159–167. DOI: https://doi.org/10.1007/978-3-031-15527-7_12

REFERENCES:

1. Anderson, J., Yeping, Li (Eds.), 2020. *Advances in STEM Education*. Springer Nature Switzerland AG. 569 p. https://doi.org/10.1007/978-3-030-52229-2

2. Batyuk, L. (2023). Digital literacy among students in medical institutions of higher education in distance learning situations. Scientific notes of the Department of Pedagogy, 52, 147–154. DOI: https://doi.org/10.26565/2074-8167-2023-52-17

3. Batyuk, L. (2025). Major aspects of STEM education based on U.S. government initiatives. *Educational Challenges*, 30(1), 88–105. DOI: https://doi.org/10.34142/2709-7986.2025.30.1.06

4. Batyuk, L., Zhernovnykova, O. (2018). Strategy for the development of digital competence in the national education system of Ukrainian society. *Journal of Education, Health and Sport*, 8(11). 912–921. DOI: https://doi.org/10.12775/JEHS.2018.8.11.087

5. Boichenko, M., Boichenko, V. (2019). STEM-education in the USA and Ukraine: comparative analysis. *Pedagogical sciences: theory, history, innovative technologies,* 5 (89), 3–13. DOI: https://doi.org/10.24139/2312-5993/2019.05/003-013.

6. Breiner, J. M., Harkness, S. S., Johnson, C. C., Koehler, C. M. (2012). What Is STEM? A Discussion about Conceptions of STEM in Education and Partnerships. *School Science and Mathematics*, 112, 3–11. DOI: https://doi.org/10.1111/j.1949-8594.2011.00109.x

7. Bybee, R. W. (2013). The Case for STEM Education: Challenges and Opportunities, National Science Teachers Association. 116 p.

8. Demchenko, I., Grigorenko, T., Revnyuk, N., Ivashenko, K. (2023). Vpliv osvitnogo seredovisha zakladiv vishoyi osviti na formuvannya klyuchovih kompetentnostej ta socialnih navichok zdobuvachiv [The influence of the educational environment of higher education institutions on the formation of key competencies and social skills of learners]. *Naukovi innovaciyi ta peredovi tehnologiyi* – Scientific innovations and advanced technologies, 2(16), 271–283. DOI: https://doi.org/10.52058/2786-5274-2023-2(16)-271-283 [In Ukrainian].

9. Drexler, K. (2021). Morrill Act: Primary Documents in American History. https://guides.loc.gov/morrill-act

10. Federation of American Scientist. (2025). Establishing White House Initiative For STEM Educational Excellence & Workforce Development At The U.S. Department Of Education. https://fas.org/publication/whisew/

11. Geiger, R. L. (2015). The history of American higher education : learning and culture from the founding to world war II. Library of Congress Cataloging-in-Publication Data. Princeton University Press. 585 p.

12. Honey, M., Pearson, G., Schweingruber, H. (Eds.). STEM integration in K-12 education: Status, prospects, and an agenda for research. Washington, DC: National Academies Press. 2014. 181 p. DOI: https://doi.org/10.17226/18612

13. Kabinet Ministriv Ukrayini. Pro zatverdzhennya planu zahodiv shodo realizaciyi Koncepciyi rozvitku prirodnicho-matematichnoyi osviti (STEM-osviti) do 2027 roku. (№ 131-r., 2021, sichen 13). – Cabinet of Ministers of Ukraine. On approval of the action plan for the implementation of the Concept for the Development of Science and Mathematics Education (STEM Education) until 2027 (№ 131-p., 2021, January 13). https://zakon.rada.gov.ua/laws/show/131-2021-%D1%80#Text [In Ukrainian].

14. Kelley, T. R., Knowles, J. G. (2016). A Conceptual Framework for Integrated STEM Education. *International Journal of STEM Education*, 3(11), 1–11. DOI: https://doi.org/10.1186/s40594-016-0046-z

15. Klemenčič, M. (2020). Alternative Higher Education. By P. N. Teixeira, J. C. Shin, (ed.), *The International Encyclopedia of Higher Education Systems and Institutions*: Bok (pp. 117–124). Springer, Dordrecht. DOI: https://doi.org/10.1007/978-94-017-8905-9_27

16. Kontowski, D. (2014). Liberal education. Tradycyjna? Nowatorska? By Ratajczaka K. *Innowacje edukacyjne: wczoraj, dziś, jutro*: Book (pp. 23–29). Repozytorium Uniwersytetu im. Adama Mickiewicza (AMUR), Poznań.

17. Lee, Y.-F., Lee, L-S. (2022). Status and Trends of STEM Education in Highly Competitive Countries: Country Reports and International Comparison. Technological and Vocational Education Research Center. 534 p.

18. MacDonald, A., Danaia, L., Murphy, S. (Eds.). (2020). *STEM Education Across the Learning Continuum.* Springer Nature Singapore Pte Ltd. 316p. DOI: https://doi.org/10.1007/978-981-15-2821-7

19. Machi, E. (2009). *Improving US competitiveness with K-12 STEM education and training. Heritage special report. SR-57*. A report on the STEM education and National Security Conference, October 21–23, 2008. Washington, DC: Heritage Foundation. pp. 1–15. https://files.eric.ed.gov/fulltext/ED505842.pdf

20. Madden, L., Beyers J., O'Brien, S. (2016). The importance of STEM education in the elementary grades: Learning from pre-service and novice teachers' perspectives. *Electronic Journal of Science Education*, 20(5), 1–18.

21. Margot, K. C., Kettler, T. (2019). Teachers' perception of STEM integration and education: A systematic literature review. *International Journal of STEM Education*, 6 (2), 1–16. DOI: https://doi.org/10.1186/s40594-018-0151-2.

22. Means, B., Wang, H., Young, V., Peters, V., Lynch, S. J. (2016). STEM-focused high schools as a strategy for enhancing readiness for postsecondary STEM programs. Journal of Research in Science Teaching, 53(5), 709–736. DOI: https://doi.org/10.1002/tea.21313

23. Morrill Act (1862). (2025). The U.S. National Archives and Records Administration. https://www.archives.gov/milestone-documents/morrill-act

24. Nakaz Ministerstva osviti i nauki Ukrayini. Pro realizaciyu innovacijnogo osvitnogo proektu "Nova ukrayinska shkola, universitet, gromada, vlada – koordinaciya vzayemodiyi na intelektualnij platformi TeachHub" za veresen 2021 – kviten 2026. (№ 1041, 2021, veresen 29). – Order of the Ministry of Education and Science of Ukraine. On the implementation of the innovative educational project "New Ukrainian school, university, community, government – coordination of interaction on the intellectual platform TeachHub" for September 2021 – April 2026. (No. 1041, 2021, September 29). https://mon.gov.ua/static-objects/mon/uploads/public/661/692/42a/66169242ab846373875908.pdf [In Ukrainian].

25. Nakaz Ministerstva osviti i nauki Ukrayini. Pro realizaciyu innovacijnogo osvitnogo proektu vseukrayinskogo rivnya za temoyu «Naukovo-metodichne zabezpechennya STEM-osviti v zakladah osviti» u veresni 2024 – grudni 2027 roku. (№ 1438, 2024, zhovten 9). – Order of the Ministry of Education and Science of Ukraine. On the implementation of an innovative educational project of the all-Ukrainian level on the topic "Scientific and methodological support of STEM education in educational institutions" in September 2024 – December 2027. (No. 1438, 2024, October 9). https://mon.gov.ua/npa/pro-realizatsiiu-innovatsiinoho-osvitnoho-proiektu-na-vseukrainskomu-rivni-za-temoiu-naukovo-metodychne-

zabezpechennia-stem-osvity-v-zakladakh-osvity-u-veresni-2024-hrudni-2027-rokiv [In Ukrainian].

26. Neem, J. N. (2013). Developing Freedom: Thomas Jefferson, the State, and Human Capability. *Studies in American Political Development*. 27 (1), 36–50. DOI: https://doi.org/10.1017/S0898588X13000023

27. Ntemngwa, C., Oliver, S. (2018). The implementation of integrated science technology, engineering and mathematics (STEM) instruction using robotics in the middle school science classroom. *International Journal of Education in Mathematics, Science and Technology*, 6(1), 12–40. DOI: https://doi.org/10.18404/ijemst.380617

28. Patridge, L.E. (2022). Talks On Teaching by Francis Wayland Parker. Legare Street Press. 184 p.

29. Prima, R. M., Prima, D. A. (2024). Potencial STEM-tehnologij u profesijnij pidgotovci majbutnih pedagogiv [The potential of STEM technologies in the professional training of future teachers]. *Perspektivi ta innovaciyi nauki (Seriya "Pedagogika", "Psihologiya", "Medicina")* – Prospects and innovations of science (Series "Pedagogy", "Psychology", "Medicine"), 5(39), 419–425. DOI: https://doi.org/10.52058/2786-4952-2024-5(39)-419-425 [In Ukrainian].

30. Purdy, W. C., (2003). The History of Higher Education in the Western United States. *A thesis submitted in partial fulfillment of the requirements for the degree Master of Arts in Education*. 187p.

31. Rahmanina, A. S. (2024). Rozvitok osobistosti majbutnogo pedagoga cherez formuvannya STEM-kompetentnostej [Development of the personality of a future teacher through the formation of STEM competencies]. *Gumanitarni studiyi: pedagogika, psihologiya, filosofiya* – Humanities: Pedagogy, Psychology, Philosophy, 15 (1), 43–50. DOI: https://doi.org/10.31548/hspedagog15(1).2024.43-50 [In Ukrainian].

32. Raupp, A.B. (2019). STEM education's lost decade and tenor. Forbes technology council. https://www.forbes.com/sites/forbestechcouncil/2019/07/25/stem-educations-lost-decade-and-tenor/#43f6101260c8

33. Rowland, I. D., Howe, T. N. (Eds.). (2014). *Vitruvius: Ten Books on Architecture*. Cambridge University Press. 352 p. DOI: https://doi.org/10.1017/CBO9780511840951

34. Sikandar, A. (2015). John Dewey and His Philosophy of Education. *Journal of Education and Educational Developmen*, 2(2), 191–201.

35. Valko, N. V. (2020). *Sistema pidgotovki majbutnih uchiteliv prirodnicho-matematichnih disciplin do zastosuvannya STEM tehnologij u profesijnij diyalnosti [Valko N.V. System of training future teachers of natural and mathematical disciplines for the application of STEM technologies in professional activities]*. (Dis. ... d-ra ped. nauk.) MON Ukrayini, Hersonskij derzhavnij universitet. Klasichnij privatnij universitet. Zaporizhzhya. – (Diss. ... Doctor of Science in Education) Ministry of Education and Science of Ukraine, Kherson State University. Classical Private University. Zaporizhzhia. 2020. 510 p. [In Ukrainian].

36. Vasyutina, T.M. (2024). Osvitni mediaresursi ta cifrovi zastosunki yak zasobi realizaciyi STEM-tehnologij u pidgotovci majbutnih pedagogiv [Educational media resources and digital applications as means of implementing STEM technologies in the training of future teachers]. *Naukovi zapiski. Seriya: Pedagogichni nauki* – Scientific notes. Series: Pedagogical Sciences, 7, 18–24. DOI: https://doi.org/10.59694/ped_sciences.2024.07.018 [In Ukrainian].

37. Williams, M. K. (2017). John Dewey in the 21st Century. *Journal of Inquiry & Action in Education*, 9(1), 91–102.

38. Yamada, R., Yamada, A., Neubauer, D. E. (Eds). (2023). *Transformation of Higher Education in the Age of Society 5.0. International and Development Education*. Palgrave Macmillan, Cham. pp 159–167. https://doi.org/10.1007/978-3-031-15527-7_12

Стаття надійшла до редакції 28.04.2025.
The article was received 28 April 2025.