

## РОЗДІЛ І. ПРОБЛЕМИ ПОРІВНЯЛЬНОЇ ПЕДАГОГІКИ

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### STEM EDUCATION IN THE USA AND UKRAINE: COMPARATIVE ANALYSIS

*In the article a comparative analysis of theoretical and content-procedural foundations of STEM education development in the USA and Ukraine is conducted. The nature of the phenomenon under study is revealed. The regulatory basis of STEM education in the USA and Ukraine is characterized. It is proved that STEM education is a priority direction of national education policy in both countries. The similarities and differences in STEM educational services provision in the USA and Ukraine are found out. The prospects for further research are seen in the developing guidelines for STEM education implementation in the secondary education institutions based on the positive conceptual ideas of American experience.*

**Key words:** *STEM education, gifted and talented children and youth, USA, Ukraine.*

**Introduction.** Nowadays, development of STEM education is a priority area of education policy in many countries. For example, in Ukraine, the Ministry of Education and Science recognizes the need to promote development of STEM education by analyzing the effectiveness of the process and dynamics of development, finding ways to improve the efficiency of innovations implementation, identifying problems and predicting further trends in the development of STEM education (*НУШ: Нова українська школа*). At the same time, in determining trends of STEM education development, we consider it expedient to focus on the positive conceptual ideas of foreign experience, first of all, the USA as one of the world leaders in this field.

**Analysis of relevant research.** The current interest of domestic researchers in STEM education is caused by the need to modernize the content, forms and methods of teaching STEM disciplines in Ukrainian education institutions at different levels in order to prepare new national intellectual elite, competitive at the world labor market. For this purpose in 2016 in Ukraine a working group on implementation of STEM education was created. The working group meeting held

in 2019 approved the report on implementation of the Action Plan for STEM education development in Ukraine for 2016–2018 and discussed and approved the Action plan of the Ministry of Education and Science of Ukraine on STEM education development for 2019–2022. The meeting was attended by representatives of the Ministry of Education and Science of Ukraine, SSI “Institute of Education Content Modernization”, Institute of Pedagogy of the National Academy of Sciences of Ukraine, National Center “Minor Academy of Sciences of Ukraine”, regional institutes of postgraduate pedagogical education. During the discussion, the members of the working group presented the experience of implementing STEM education in the regions. The reports were presented by O. Patrykeieva, I. Vasylyashko, O. Buturlina, O. Barna, S. Ivanov, N. Polykhun (*STEM coalitions. STEM – освіта в Україні активно розвивається*).

Besides, different aspects of STEM education development in Ukraine and abroad have been revealed in the studies of V. Andriievskaya, 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.

Despite considerable interest in STEM education of domestic policy-makers, education theorists and practitioners, there are only few studies on STEM education development abroad, which could provide perspectives for the development of this field in Ukraine.

In the light of the above mentioned the **aim of the article** is to compare theoretical and content-procedural foundations of STEM education development in the USA and Ukraine.

**Research methods:** analysis, synthesis, comparison, generalization, concretization, classification, systematization – in order to study the sources on STEM education and divide them according to their direction; comparative analysis – for revealing similarities and differences in STEM education development in the USA and Ukraine; scientific extrapolation – in order to find out positive conceptual ideas of US experience that can be implemented in Ukraine.

**Research results.** In order to reveal peculiarities of STEM education development in the United States and Ukraine, we find it necessary to define the nature of the phenomenon under study. The term “STEM” is an acronym for the first letters of such disciplines as Science, Technology, Engineering, and Mathematics. In this context we’d like to emphasize, that Science refers to the natural sciences, not science as a whole, as it is interpreted by Ukrainian researchers.

This term was proposed by the National Science Foundation (NSF) to refer to these disciplines instead of the acronym SMET. For the first time the term STEM is found in the text of the NSF project entitled STEMTEC (Science, Technology, Engineering and Math Teacher Education Collaborative) in 1997.

In modern conditions the synonyms of STEM are:

- eSTEM (environmental STEM);
- METALS (STEAM + Logic), where the acronym STEAM stands for the first letters of such disciplines as Science, Technology, Engineering, Art, Mathematics, and also Logic is added;
- MINT is a less used term with the same meaning that is most commonly used in Germany to refer to such disciplines as Mathematics, Information Sciences, Natural Sciences and Technology;
- STREM – covers Science, Technology, Robotics, Engineering and Mathematics;
- STREM – is similar to the previous acronym, but instead of Mathematics, the letter M stands for Multimedia;
- STREAM – includes Science, Technology, Robotics, Engineering, Art and Mathematics;
- STEAM – unlike the previous acronyms where the letter A is used to denote Art and letter M – Mathematics, in this case AM is Applied Mathematics;
- GEMS (Girls in Engineering, Math, and Science);
- STEMM – is used to refer to Science, Technology, Engineering, Mathematics, and Medicine;
- AMSEE – includes Applied math, Science, Engineering, and Entrepreneurship (Wikipedia).

According to American scientists H. B. Gonzales and J. J. Kuenzi, the concept of “STEM education” covers teaching and learning in the field of Sciences, Technology, Engineering and Mathematics. STEM education includes educational activities at all levels of education – from preschool to doctoral, both formal and informal (Gonzales & Kuenzi, 2012).

Although most scholars link emergence of STEM education phenomenon with the launch of the Soviet satellite in 1957, US researchers H. B. Gonzales and J. J. Kuenzi insist that the federal government’s attention to scientific and technological literacy is much longer and has its roots in the first Congress. For example, in his first address, President J. Washington urged members of the Congress to develop such field of knowledge as natural sciences for the sake of the Republic’s development.

After World War II, there was an increase in interest in STEM education as a pledge of national welfare and state power. As noted, the launch of the artificial

Soviet satellite in 1957 was the impetus for the government to take action to find the “best and smartest”, who will in the future make up the next generation of leaders and innovators in Science and Engineering (S&E). This event, according to American researchers (*Preparing the next generation of STEM innovators*), was the beginning of a new era of unprecedented scientific and technological growth of the Nation, which resulted in the creation of new businesses and jobs, improving national security and quality of life for citizens. The Government’s main objective was to achieve high results in such areas as STEM education and talent development, along with research and development (R&D).

Unlike the USA, in Ukraine the interest to STEM education at the national level arose in late 2010s. In particular, MES of Ukraine together with SSI “Institute of Education Content Modernization” designed Action Plan for STEM education development in Ukraine for 2016–2018, in the frames of which were defined priority directions of STEM education development in Ukraine, namely:

- development of regulatory, scientific-methodological foundations of STEM education implementation;
- promotion of STEM education development: analysis of the effectiveness of the process and development dynamics, ways to increase the efficiency of innovation implementation;
- identifying problems and predicting further trends in STEM education development;
- conducting experimental work at the national level on the topic “Scientific-methodological foundations of creation and operation of Ukrainian scientific-methodological virtual STEM center (USMV STEM-center) for 2017–2021 (MES order No. 708 of May 17, 2017);
- implementation of the Innovative educational project program of the national level “I am a researcher” for 2018–2021 (MES order dated April 13, 2018, No. 366);
- conducting educational and guidance work among young people to get acquainted with STEM careers;
- organizing and conducting educational events aimed at popularization of STEM learning: competitions, contests, STEM festivals, scientific picnics, STEM tours, etc;
- dissemination of experience and achievements in the field of STEM education through publications, presentations during various educational events: international, national, regional scientific-practical conferences, seminars, webinars, trainings, roundtables, competitions, hackathons, etc;
- initiating, fundraising and coordinating innovative educational projects;

- raising the level of professional skills of scientific-pedagogical workers and presentation of pedagogical work experience, in particular within STEM schools (*Методичні рекомендації щодо розвитку STEM-освіти...*).

Taking into account the fact, that STEM education in Ukraine is a new field (though in Ukrainian SSR as a part of USSR, Science, Technology, Engineering and Mathematics separately were taught at a high level), we consider it necessary to turn to foreign experience.

It should be also stressed, that despite the fact, that *all students* can be involved in STEM education, the target category of most STEM programs are gifted and talented.

There are numerous special STEM education programs for children and youth in the United States. At the same time, as NSF experts note, performance standards for gifted and talented should be raised, which will best meet their needs and reach their potential.

In an analytical report “Preparing the next generation of STEM innovators: Identifying and Developing our Nation’s Human Capital”, NSF experts provide information on the current state of GT education, in particular:

- talented, motivated students are more likely to master the content of the curriculum, and some of them have already mastered 40–50 % of the course material during transition to the next class. The desire to receive new information and learn quicker can disappear if the necessary measures are not taken. Growing popularity among educational policy makers of such strategy as time on task that provides well-defined time limits for completing a certain type of educational work (if the student did the work faster, it was not done well, the material was not fully understood), has a negative impact on GT students’ development, as time is often allocated to the task that the student has long completed. Therefore, learning activities should be appropriate to the student’s learning style, his or her individual needs and abilities;
- survey shows that accelerated curriculum or accelerated learning is most appropriate for gifted students, as it allows matching the pace and level of learning of the material with intellectual readiness, emotional maturity and motivation of the student without developing a special curriculum;
- organization of accelerated learning does not require large financial costs, but it does require the flexibility of school administration, especially when it comes to junior pupils, where accelerated learning needs to be addressed at the state or district level. Similarly, the bureaucratic obstacles caused by the specificities of the state or local education policy prevent school students from moving to other classes/schools to meet their educational needs;

- in the field of STEM education, all students, including the most gifted, should be involved in experiential learning, collaboration with classmates, open-ended real-world problem solving, STEM-based training, engagement with scientists, engineers and other professionals. At the present stage of development of American education, such opportunities were realized mainly within the framework of informal, extracurricular activities (enrichment of the curriculum) (for example, summer camps, visits to science museums, mathematical circles), rather than as an integrated component of the STEM curriculum. Out-of-school enrichment of the curriculum is extremely valuable, mainly, in maintaining interest in STEM, but insufficient, as students spend most of their time in the school, so educational and extracurricular activities in this area should be synchronized;
- formal and informal enrichment of the curriculum is quite limited in poorly financed districts and schools. However, curriculum enrichment is an extremely effective measure and, together with accelerated learning, should be a must-have in teaching GT students. Content enrichment of STEM resources can be achieved with the help of the latest information and communication technologies. Using Internet GT students in deprived areas can take advantage of formal and informal opportunities and receive advice from STEM specialists, access online museum collections and a wide range of digital STEM content, and work in virtual laboratories;
- early involvement in STEM education is of utmost importance, as interest in STEM disciplines is most often manifested in junior pupils, and such an early immersion in STEM will make it possible to make a future choice of the career related to the subject of interest;
- engineering is an industry where innovations are being actively implemented, and therefore involving GT students in engineering (e.g., robotics, inventive competitions, etc.) can increase interest in STEM. However, involvement in engineering is not widespread in the junior and middle classes of general secondary schools;
- sometimes gifted and talented students are not sufficiently prepared for enriched content because they lacked access to the necessary resources or were not immersed in a stimulating learning environment. One of the ways to overcome this contradiction is the so-called bridge programming. Specially designed “bridge programs” help to increase the students performance in such a way that it corresponds to his/her personal potential, to increase the student’s confidence in his/her abilities, as well as to participate in the activity with the classmates who have high educational achievements (*Preparing the next generation of STEM innovators*).

Thus, in the United States STEM education is provided in secondary schools while in Ukraine the main emphasis is made on extracurricular activities. Furthermore, in the USA there is a tendency to creating STEM schools while in Ukraine – to enriching curriculum with STEM disciplines and developing STEM programs.

As Ukrainian STEM experts note, transition to a competence STEM learning model and application of new methodological approaches, above all, provides:

- fundamentally new goal setting in the pedagogical process, displacement of the accents in educational activities from narrow subject to general ones;
- updating the structure and content of academic subjects, special courses, etc.;
- identifying and evaluating learning outcomes through key and subject competences of the student;
- introducing end-to-end STEM training, competence oriented forms and methods of teaching, systems-activity approach;
- introduction of innovative, game learning and case study technologies, interactive group learning methods, problematic techniques aimed at development of critical and systemic thinking, etc.;
- correction of the content of some topics of subjects with emphasis on personal development, game teaching methods, value attitude to the issue under study;
- creation of pedagogical conditions for obtaining effective individual experience of project activity and startup development (*Методичні рекомендації щодо розвитку STEM-освіти*).

A special form of end-to-end STEM training is integrated lessons/classes aimed at establishing cross-curricular relationships that contribute to the formation of students' holistic, systemic outlook, actualization of personal attitude to the issues addressed at the lesson.

Action Plan for STEM education development in Ukraine envisages that STEM education in Ukrainian secondary schools must be provided in the framework of the special STEM curriculum – a normative document that defines the range of basic competences that students need to form in learning a particular subject (discipline) and the system of knowledge and skills they need to acquire.

The curriculum contains: explanatory note, list of topics of study material, recommendations on the number of hours for each topic, distribution of topics by year of study and time allocated to study the whole course, the amount of knowledge, skills and competences in the given discipline for each age category, list of literature sources for students, guidelines and manuals for teachers, criteria for assessing knowledge, skills and competences in each activity, etc.

The STEM program in Ukrainian schools should meet the following criteria: relevance and innovative content; understandability of the program

implementation process (what the students do, what conditions and equipment are needed for effective implementation); methodology that allows using the program in any education institution; achievement of educational and upbringing pedagogical result and availability of tools for its measurement (*Методичні рекомендації щодо розвитку STEM-освіти*).

According to the terms of implementation of STEM programs in Ukraine are divided into:

- short-term (2–24 hours);
- coursework (for summer schools, courses, etc.) (24–80 hours);
- medium-term (year) (80–120 hours);
- long-term, continuing education (300–600 hours).

STEM programs are developed in the following areas:

- integrated, interdisciplinary curricula;
- robotics and engineering;
- “Smart devices” of the Internet of Things;
- 3D modeling (*Програми STEM*).

In the United States today, there are approximately 100 public schools that specialize in STEM. The aforementioned schools create peer groups with a common interest in STEM; learners master in-depth STEM content; students are given the opportunity to engage in research and discovery; they can try their hand at real STEM jobs; students are introduced to role models of STEM careers. Such education institutions include charter schools, magnet schools, boarding schools, as well as programs for the transfer of students from the class in which they study to another during the school day in order to enrich the curriculum (pull-out programs). More than 47,000 American schoolchildren are educated in these institutions (*Prepare and inspire...*).

In Ukraine, in order to improve the quality of STEM educational services MES of Ukraine initiated creation of STEM laboratories/centers that provide in-depth, focused learning of profile subjects and acquisition of competences necessary for further experimental, design, inventive activities.

The purpose of the STEM laboratory/center is to create organizational-pedagogical conditions for advanced scientific and technical training of children and youth in accordance with priority areas of science and technology development; formation of competences that determine competitiveness of the personality in the labor market. Accordingly, the STEM laboratory/center must form STEM literacy of student youth, which characterizes the degree of mastery of both interdisciplinary knowledge and skills in using multidisciplinary approaches to solving practical problems.



It should be stressed that the main problems in implementing STEM education in Ukraine and creating STEM schools and laboratories/centers is inadequate financing of education in general and STEM education in particular. One more problem is lack of theoretical-methodological support of STEM educational services provision and lack of qualified STEM specialists (teachers, experts, etc.).

**Conclusions.** The results of the conducted comparative analysis of theoretical and content-procedural foundations of STEM education development in the USA and Ukraine have confirmed that this field is a priority direction of national education policy in both countries. To the similarities we can also refer deep historical roots of STEM education in the USA and Ukraine, where deep knowledge of STEM disciplines was considered to be the guaranty of competitiveness at labor market. In both countries STEM education is provided within the framework of formal and informal education. At the same time USA have significant positive experience of STEM education provision and sufficient financing of the field while Ukraine makes only first steps in this direction and lacks adequate financing and theoretical-methodological support.

Taking into account the above mentioned the **prospects for further research** are seen in the developing guidelines for STEM education implementation in the secondary education institutions based on the positive conceptual ideas of American experience.

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## РЕЗЮМЕ

**Бойченко Марина, Бойченко Віталій.** STEM-образование в США и Украине: сравнительный анализ.

*В статье проведен сравнительный анализ теоретических и содержательно-процедурных основ развития STEM-образования в США и Украине. Раскрыта природа изучаемого явления. Охарактеризована нормативная база STEM-образования в США и Украине. Доказано, что STEM-образование является приоритетным направлением национальной образовательной политики в обеих странах. Выявлены общие черты и различия в предоставлении образовательных STEM-услуг в США и Украине. Перспективы дальнейших исследований видятся в разработке руководств по внедрению STEM-образования в средних учебных заведениях, основанных на позитивных концептуальных идеях американского опыта.*

**Ключевые слова:** STEM-образование, одаренные и талантливые дети и молодежь, США, Украина.

## АНОТАЦІЯ

**Бойченко Марина, Бойченко Віталій.** STEM-освіта у США та Україні: порівняльний аналіз.

*У статті здійснено порівняльний аналіз теоретичних та змістово-процесуальних засад розвитку STEM-освіти. За допомогою теоретичних методів аналізу, синтезу, порівняння, узагальнення, конкретизації, класифікації, систематизації розкрито природу окресленого феномену. З'ясовано, що термін «STEM» є акронімом, що позначає перші літери таких навчальних дисциплін, як природничі науки (Science), технології (Technology), інженерна справа (Engineering) та математика (Mathematics).*

*Результати проведеного порівняльного аналізу теоретичних та змістово-процедурних засад розвитку STEM-освіти в США та Україні засвідчили, що ця сфера є пріоритетним напрямом національної освітньої політики в обох країнах. До спільних рис віднесено глибоке історичне коріння STEM-освіти в США та Україні, де фундаментальні знання зі STEM-дисциплін вважалися запорукою*

конкурентоспроможності на ринку праці. В обох країнах STEM-освіта забезпечується в межах формальної та неформальної освіти. Зокрема, в закладах загальної середньої освіти створюються групи однолітків зі спільним інтересом до STEM; учні опановують поглиблений STEM-контент; школярам надається можливість займатися дослідницькою діяльністю й робити відкриття; вони можуть спробувати себе на справжніх робочих місцях у галузі STEM; учні знайомляться з рольовими моделями STEM-професій. Відмінним у досліджуваних країнах є те, що США мають значний позитивний досвід організації STEM-освіти та достатнє фінансування галузі, тоді як Україна робить лише перші кроки в цьому напрямку та не має достатнього фінансування й теоретико-методологічного забезпечення.

Ураховуючи вищезазначене, перспективи подальших досліджень полягають у розробці керівних принципів щодо впровадження STEM-освіти в закладах загальної середньої освіти на основі позитивних концептуальних ідей американського досвіду.

**Ключові слова:** STEM-освіта, обдаровані і талановиті діти та молодь, США, Україна.

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## **ФІНАНСУВАННЯ ВИЩОЇ ОСВІТИ У КРАЇНАХ ЄВРОПИ**

У статті з'ясовано роль освіти, зокрема вищої, у суспільстві та економіці країни. Інвестиції в освіту визnano одним із чинників, які визначатимуть майбутнє суспільства та економіки країни. Розкрито моделі та форми (модальності) фінансування закладів вищої освіти у країнах Європи. Визначено моделі фінансування закладів вищої освіти з орієнтацією на пропозицію і на попит та відмінності між ними. Наведено механізми розподілу блок-грантів у країнах Європи. Проаналізовано послуги освіти, у тому числі вищої, за джерелами її оплати в Україні та деяких країнах Європи.

**Ключові слова:** автономія закладів вищої освіти, блоковий грант, постатейний бюджет, фінансування вищої освіти, форми (модальності) фінансування, цільове фінансування.

**Постановка проблеми.** Інвестиції в людський капітал, і особливо в молодь, є ключовим пріоритетом для країн Європейського Союзу. У документі під назвою «Reflection paper on the social dimension of Europe» (Аналітичний доклад із соціального виміру Європи 2017 р.) (European Commission, 2017) зазначається, що освіта є одним із чинників, які визначатимуть майбутнє суспільства та економіки. Освіта також перебуває в центрі Порядку денного щодо сталого розвитку ООН на період до 2030 р. (United Nations, 2015), що виділяє освіту як окрему Ціль № 4 «Забезпечення всеохоплюючої і справедливої якісної освіти і заохочення можливості навчання впродовж усього життя для всіх» (United Nations) і містить завдання у сфері освіти в межах низки інших цілей, зокрема, у