# РОЗДІЛ V. ПРОБЛЕМИ ПОРІВНЯЛЬНОЇ ПЕДАГОГІКИ

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## CONTENT-PROCEDURAL FOUNDATIONS OF STEM EDUCATION IN THE USA

*The article reveals content-procedural foundations of STEM education in the USA. On the basis of using a number of theoretical research methods (analysis, synthesis, generalization, comparison) the essence of the studied phenomenon was revealed. The types of high schools, that provide educational services in the field of STEM, are characterized, namely: selective schools, which admit gifted students who have outstanding abilities in the field of STEM; inclusive schools that serve students from all backgrounds, targeting low-income youth, minorities and other traditionally under-represented categories of student youth; STEM-Focused Career and Technical Education (CTE) Schools, which help a wide range of high school students gain insight into the practical application of knowledge in STEM disciplines and prepare for work in the field of STEM.*

***Key words:*** *STEM education, STEM schools, selective schools, inclusive schools, vocational schools, USA.*

**Introduction.** Recently, development of STEM education has become a priority of the national educational policy of Ukraine, which is proved by the provisions of such normative documents as “Action Plan on introducing STEM education in Ukraine for 2016-2018” (2016), “The concept of Science and Mathematics Education (STEM Education) development” (2020) and so on. These documents emphasize the necessity of providing STEM education services in all types of education institutions. In order to solve this task, it is expedient to study best international practices, in particular the USA as one of the leaders in this field.

**Analysis of relevant research.** Different aspects of STEM education have been revealed in the studies of native and foreign researchers. Among Ukrainian scientists deserve attention the works 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, S. Podliesnyi, I. Savchenko, A. Sbruieva, S. Sioma, I. Slipukhina, H. Skrypka, O. Stryzhak, O. Tarasov, V. Zaiarna and others.

Literature review on the issue of STEM education have shown that Ukrainian scientific discourse lacks studies focused specifically on content-procedural foundations of STEM education in the USA. In view of this, the

article is **aimed** at revealing content-procedural foundations of STEM education in the USA.

To achieve the goal, the following **research methods** have been used: theoretical – analysis, synthesis, generalization, comparison – to reveal the essence of the studied phenomenon; structural-logical method – to highlight the current trends in STEM education services provisions.

**Research results.** Considering the content-procedural foundations of STEM education in high school in the United States, we'd like to note that the vast majority of American high school students receive STEM education in traditional public high schools. Along with general secondary schools, the number of such STEM education service providers as specialized STEM schools is growing. These education institutions usually offer a more in-depth STEM curriculum, more qualified STEM teachers, more time to teach STEM subjects and more resources than traditional high schools. Despite the fact that the share of specialized STEM schools is still insignificant among all public general secondary education institutions in the United States, such institutions not only perform better than traditional schools; they can also serve as a model for schools seeking improvement.

According to a study conducted with the financial support of the National Science Foundation, there are three categories of STEM-oriented schools in the United States, namely:

- *selective schools*, which admit gifted students who have outstanding abilities in the field of STEM;
- *inclusive schools* that serve students from all backgrounds, targeting low-income youth, minorities and other traditionally under-represented categories of student youth;
- *STEM-Focused Career and Technical Education (CTE) Schools,* which help a wide range of high school students gain insight into the practical application of knowledge in STEM disciplines and prepare for work in the field of STEM.

Below we'll consider content and procedural foundations of functioning of the above institutions in more detail.

*Selective schools.* This type of education institutions attracts the most talented students in the field of STEM. To enter these small elite public schools, children must pass a written exam. One of the most outstanding selective schools is Stuyvesant High School (New York), whose graduates include four Nobel Prize winners and numerous STEM leaders.

There are now about 90 selective STEM public high schools in the United States, most of which were established after publication in 1983 of the historic Nation at Risk report. By focusing on one or more STEM disciplines, selective schools aim to prepare gifted students to enter prestigious STEM institutions of higher education and build successful STEM careers in the future. Selective schools usually involve experienced highly qualified STEM teachers, work on specially designed curricula, have access to high-tech laboratory equipment and the opportunity to undergo research under the guidance of renowned scientists in the field of STEM.

Most selective public STEM schools are located in cities and attract the best students from across the school district. Fifteen states offer boarding schools that host talented students from across the state. In some states, such as Virginia and Michigan, low-income students from rural areas are transported by special bus to regional centers (Means et al., 2008).

One more example of an effective selective high school is the Illinois Mathematics and Science Academy (IMSA), which ranks second in the US schools ranking. The state pays for tuition and most of the expenses of students at the Illinois Academy of Mathematics and Science, which offers an internationally recognized three-year residential program for students in grades 10-12. Requirements for admission to this education institution are high and include testing in Mathematics, Science and English; high grades during previous academic years; letters of recommendation; increased demonstrated interest in STEM disciplines and the potential for significant contribution to the STEM industry.

The mission of the institution is to nurture creative, ethical and scientific potential of talented students. The mission is concretized in the belief that “all people have equal intrinsic value; all people have a choice and are responsible for their actions; belonging to the community requires a commitment to the common good; diverse perspectives enrich understanding and inspire discovery and creativity; honesty, trust and respect are vital for the development of any relationship; learning never ends; the meaning is constructed by the student; no person’s way of life is predetermined; the ability to distinguish and make connections is the essence of understanding; we are all responsible for our planet and we can significantly improve life on our planet” (*Illinois Mathematics and Science Academy (IMSA)*).

650 students of this high school study according to the individual curricula that take into account their interests and future goals. The central element of the curriculum is research, in the process of which students work together with each other and with scientists from around the world. Many

students publish the results of their research in scientific journals and speak at scientific conferences.

According to the institution's website (https://www.imsa.edu/discover-imsa/profile-mission-beliefs/), more than 99 % of the 4,350 IMSA graduates since 1985 have enrolled in higher education institutions. Nearly two-thirds have a degree in Math or Science – far more than the total number of American high school graduates, and more than four times the average for girls. Graduates of the Illinois Academy of Mathematics and Science are leading researchers, engineers, educators, and entrepreneurs (*Illinois Mathematics and Science Academy (IMSA)*).

According to research, it is specialized STEM schools that train future specialists in this field. After all, their graduates study in higher education institutions in STEM specialties almost 50 % more often than graduates of other general secondary education institutions. Compared to the national average, almost 20 % more graduates of selective STEM schools receive a degree in STEM within four years of graduating from high school.

Researchers explain the above facts by a number of reasons: mathematically and scientifically gifted students are more likely to enter STEM higher education institutions if they are offered higher-level curricula, highly qualified teaching, and peer encouragement. Participation in original research is perhaps the most powerful tool, especially for young women. Internships and mentoring play an important role. Although no single factor can have a profound impact, curricula that combine these factors can open up further prospects for high school students in the field of STEM.

However, according to R. Subotnik, student youth who attend specialized STEM schools not because of a deep interest in STEM, but for other reasons, in most cases do not receive STEM degrees (Subotnik, 2011). Researchers also emphasize the importance of early involvement in the study of STEM disciplines, which increases the chances of choosing a future profession in the field of STEM.

*Inclusive schools.* Despite the fact that selective STEM schools play an important role in the development of gifted students, in American society there is a growing interest in expanding intensive STEM education for the general population. This role is played by inclusive STEM schools, which are open to all. These education institutions seek to provide the same educational experience as selective schools but involve in the STEM field young people from low-income families and under-represented groups of population.

Based on the idea that giftedness in Mathematics and Science can be developed (instead of the previously held view that mathematical and scientific

abilities are innate, i.e. a person either has them or not), inclusive schools tend to select students by lottery and provide support to those with less academic experience. Tutoring, counseling and other services help prepare students for entering higher education institutions in STEM specialties.

A number of states are creating innovative educational networks to encourage creation of inclusive STEM schools and exchange of best practices between these institutions and with traditional public schools. For example, at the initiative of the T-STEM innovation network (Texas), more than 50 secondary schools have been opened since 2006. The Ohio STEM Learning Network has helped create 10 inclusive STEM schools in different economic regions of the state. The experience of this innovative educational network is also implemented by the states of California, New York and North Carolina.

Given the innovativeness of the studied education institutions, we consider it appropriate to provide a definition of inclusive STEM high school (ISHS), proposed by a group of scientists led by B. Means (Means, 2016). Researchers interpret an inclusive STEM high school as an education institution that accepts students based on their interests rather than abilities or past achievements and provides all students with the opportunity to study Mathematics and Science in depth, as opposed to regular high schools, in order to prepare them for further study in higher education institutions in this field. ISHS enrolls students on the basis of application, it does not require high scores to enter such a school. These schools are designed to develop students' STEM competences, rather than select gifted students in the field of STEM.

An example of an inclusive school is Delta High School, Washington. With the help of local business leaders, the school opened in 2009, enrolling about 100 high school students selected through a lottery. The Delta High School contingent reflects the demographics of Kennewick, Richland and Pasco. Already in the fall of 2012, 400 students were studying in grades 9-12 of this institution.

Delta High School became one of the state's first STEM-oriented schools and a pilot project of the Washington State STEM Education Foundation. Funding comes from each of the three school districts and is complemented by grants from the foundation and many other partners, including the Battelle Research Institute, the University of Washington and Columbia Basin College, which provides learning space on its campus.

The central element of the Delta High School curriculum is the combination of Science, Technology, Engineering, Mathematics and Humanities in the process of practical problem-based learning. The curriculum includes 90-minute classes, counseling on learning and admission to higher education

institutions, career guidance for STEM professionals, internships, supervision of STEM professionals in the workplace and seminars for senior students. The education institution emphasizes the need to provide personalized educational services, especially individual interaction of students and teachers, taking into account the strengths and interests of students and implementation of careful monitoring of their performance.

It should be noted that studies on the effectiveness of inclusive STEM schools are still being conducted, although the results of testing that have been already obtained in several states show some positive effects. For example, Texas High School STEM (T-STEM) students get higher in state Math and Science tests, miss fewer classes, and choose higher-level courses than their peers compared to high schools of the same state (Young et al., 2011).

We also consider it appropriate to refer to the characteristics of inclusive STEM schools, obtained as a result of quantitative research conducted by American scientists. In particular, the researchers have found that inclusive STEM schools, compared to selective schools, serve more African Americans, Hispanics and low-income students. Moreover, inclusive schools offer a higher level of personalization through strategies such as “assigning” teachers to the same students for several years and assigning professional mentors to students who reflect their race and ethnicity.

Noteworthy is the study of the effectiveness of inclusive high schools (Means, 2016), conducted in 20 education institutions in seven states (Ohio (4), Texas (4), Washington (4), California (3), North Carolina (2), Tennessee (2), New York (1)), on the basis of which the authors identified eight key elements of these institutions, which included:

- basic (related to learning and not related learning);
- auxiliary.

Elements related to learning include pedagogical strategies and students’ achievement of academic goals. Elements not related to learning include students’ social and emotional well-being, as well as improvement of the STEM education system outside the school. Auxiliary elements include strategies and external factors that support the main elements (see Fig. 1).

*STEM-Focused Career and Technical Education (CTE) Schools* provide training to students within the practice-oriented programs for technologically experienced workers. In this context, it should be noted that in modern conditions it is difficult to draw a clear line between STEM-oriented vocational schools and other STEM education programs, as almost all vocational education institutions are to some extent related to STEM industries.

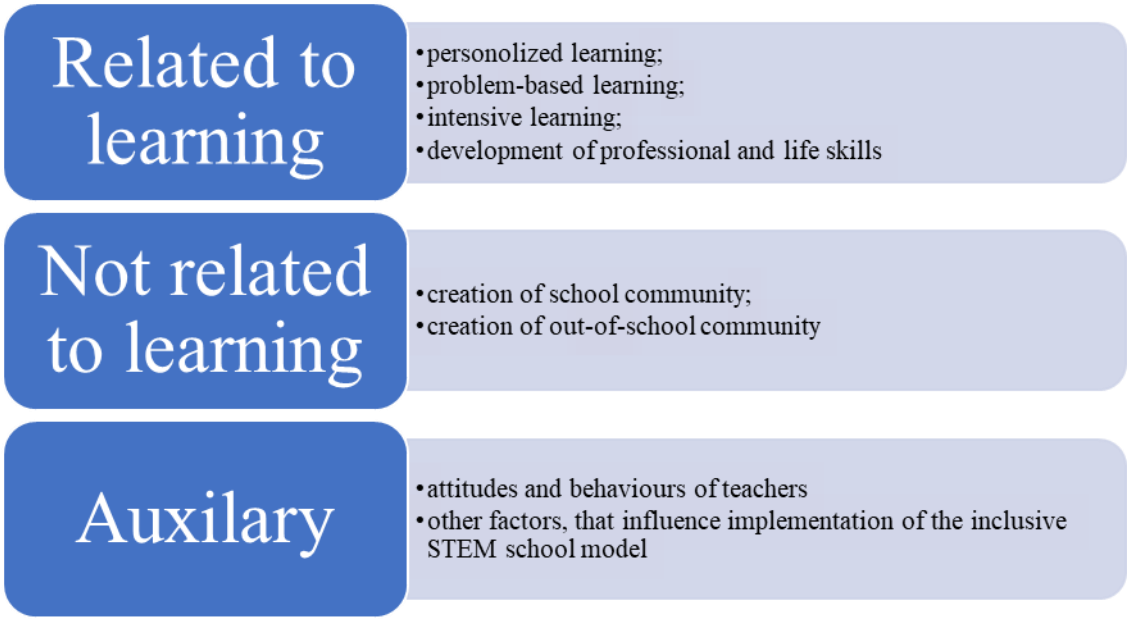


Fig. 1. Key elements of inclusive STEM schools

STEM disciplines can be included in any model of vocational education organization, including regional vocational centers, vocational secondary schools or career academies in senior secondary schools.

A striking example of a STEM-oriented vocational school is Sussex Technical High School (Delaware). Founded in 1961 as a part-time school, Sussex Technical High School now serves more than 1,300 full-time students, that have been admitted by lottery. Almost a third of students come from low-income families. Among its achievements, the institution has the highest rating in the country – "the best school" – based on the results of tests in Mathematics, Reading, Science and Social Sciences. It is also important to note that 98 % of students graduate from high school (*Delaware Department of Education*).

The school provides a comprehensive educational program that combines technical education with basic academic courses and is called "techademia". Each student receives educational services in one of 15 technical fields that meet local business needs (automotive technology, healthcare/service technology, communications/information technology, industrial/engineering technology, etc.).

During the first year of study, the students of the above-mentioned high school study the basic academic courses and get acquainted with various technical fields in order to choose a future profession. Then students choose one curriculum for grades 10-12. In the graduating class, students participate in an "exhibition of skills" in the field of STEM, for which everyone creates an important technical product, prepares a research paper and makes an official presentation, which is evaluated by administration, teachers and business/industry representatives.

Students also have many opportunities to study in the workplace in their chosen profession (*Delaware Department of Education*).

**Conclusions and prospects for further research.** Summarizing the above mentioned we'd like to conclude, that in the USA there are wide opportunities for high school students to study STEM disciplines. Furthermore, STEM is no longer the field for elite – recently there have been created inclusive schools for under-represented categories of student youth: low-income families, minorities, girls and so on. STEM services provision takes into account, primarily, interest in STEM, not high scores. Positive experience of creating STEM high schools should be implemented in Ukraine in conditions of further realization of the Concept of the New Ukrainian School and creating profile high school. One more important conceptual idea of U.S. experience is popularization of STEM education and STEM careers among schoolchildren and creating the opportunities for their self-realization in this field.

The prospects for further research are seen in the study of the effective forms and methods of STEM education, which are used in the American STEM high schools.

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## РЕЗЮМЕ

**Бойченко Виталий.** Содержательно-процессуальные основы STEM-образования в США.

*В статье раскрываются содержательно-процессуальные основы STEM-образования в США. На основе использования ряда теоретических методов исследования (анализ, синтез, обобщение, сравнение) раскрыта сущность изучаемого явления. Охарактеризованы типы школ, которые предоставляют образовательные услуги в области STEM, а именно: селективные школы, в которых обучаются одаренные ученики, обладающие выдающимися способностями в*

*области STEM; инклюзивные школы, которые обслуживают учащихся-выходцев из всех слоев населения и ориентированы на молодежь с низкими доходами, меньшинства и другие традиционно недостаточно представленные категории ученической молодежи; школы профессионального и технического образования, ориентированные на STEM, которые помогают широкому кругу старшеклассников получить представление о практическом применении знаний по STEM-дисциплинам и подготовиться к работе в области STEM.*

***Ключевые слова:*** *STEM-образование, STEM-школы, селективные школы, инклюзивные школы, профессиональные школы, США.*

## АНОТАЦІЯ

**Бойченко Віталій.** Змістово-процесуальні засади STEM-освіти в США.

*Стаття розкриває змістовно-процесуальні засади STEM-освіти в США. На основі використання низки теоретичних методів дослідження (аналіз, синтез, узагальнення, порівняння) було розкрито сутність досліджуваного феномену. Схарактеризовано типи середньої школи, які надають освітні послуги в галузі STEM, а саме: селективні школи, що приймають на навчання обдарованих учнів, які мають визначні здібності в галузі STEM; інклюзивні школи, що обслуговують учнів-вихідців із усіх верств населення, орієнтовані на учнівську молодь із низьким рівнем доходу, меншини та інші традиційно недостатньо репрезентовані категорії, школи кар'єри та технічної освіти, орієнтовані на STEM, що допомагають широкому колу старшокласників отримати уявлення про практичне застосування знань зі STEM-дисциплін та підготуватися до майбутньої професійної діяльності в галузі STEM.*

*На основі аналізу діяльності окреслених STEM-шкіл зроблено висновок, що в США є широкі можливості для старшокласників щодо вивчення STEM-дисциплін. Крім того, STEM більше не є прерогативою еліти, що унаочнилося в нещодавно створених інклюзивних школах для недостатньо репрезентованих категорій студентської молоді в галузі STEM: малозабезпечених сімей, меншин, дівчат та ін. Під час надання STEM-послуг ураховується, насамперед, наявність інтересу до STEM, а не високі бали. Наголошено, що позитивний досвід створення старших середніх STEM-шкіл має бути впроваджений в Україні в умовах подальшої реалізації Концепції Нової української школи та створення профільної старшої середньої школи. Не менш важливою концептуальною ідеєю досвіду США є популяризація STEM-освіти та STEM-кар'єри серед школярів та створення можливостей для їх самореалізації в цій галузі.*

*Перспективи подальших наукових розвідок вбачаємо у вивченні ефективних форм та методів STEM-освіти, які застосовуються в американських старших середніх школах STEM.*

***Ключові слова:*** *STEM-освіта, STEM-школи, вибіркові школи, інклюзивні школи, професійно-технічні школи, США.*