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L. V. BATYUK[1], PhD (Biological Science), Associate Professor,
Associate Professor of the Department of Physics and Chemistry
e-mail: l.batyuk@hnpu.edu.ua ORCID ID: https://orcid.org/0000-0003-1863-0265
V. V. MASYCH[1], DSc (Pedagogy), Professor,
Head of the Department of Physics and Chemistry
e-mail: masych@hnpu.edu.ua ORCID ID: https://orcid.org/0000-0002-8943-7756
[1]*H. S. Skovoroda Kharkiv National Pedagogical University*,
29, Alchevskykh Str., Kharkiv, 61002, Ukraine

A REVIEW OF THE IMPLEMENTATION OF STEM EDUCATION IN THE USA BASED ON ROBOTICS

The article provides an overview of the implementation of STEM education in the United States based on robotics, as part of the latest innovations in the educational environment of the United States. STEM education is important for the development of basic, professional and social skills that are key to academic achievement and readiness for work in the 21st century. Technology in teaching STEM subjects refers to tools that make abstract ideas more concrete and accessible through experiential learning. These robotic technologies provide a dynamic presentation of STEM systems to improve students' mastery of complex concepts.

Based on a thorough analysis of scientific, pedagogical and regulatory sources, key periods of development of the use of technology in education and the related processes of building the STEM education industry in the United States are highlighted.

It was found that the emergence of technologies involves their introduction into the learning process of the lesson, and requires a profound change in the provision of education, a new concept regarding the “role of technology in education”, which defines a constructivist view of learning as “building knowledge structures” by creating new knowledge. Educational robotics in STEM education is considered cross-thematic and facilitates the assimilation of educational material by students in the field of science, technology, engineering and mathematics. Educational robotics provides schoolchildren and students with the opportunity to explore how virtual and engineering technologies work in real life, find new ways of working together, develop cooperation skills, express themselves using a technological tool, introduces students to a part of mathematical scientific thinking and can be a gateway to the study of applied mathematical disciplines and scientific concepts.

It was determined that robotic technologies provide a dynamic presentation of the STEM system to improve students' assimilation of complex concepts, and help optimize the educational process. The US government's support for integrating technology into robotics STEM education plays a key role in providing practical knowledge and preparing students for future careers in the global job market.

KEY WORDS*:* *STEM education, R-STEM education, educational robotics, Lego, K-12, school, university, higher education institution, USA.*

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Problem statement

STEM education plays a crucial role in preparing students for future career choices and successful professional activities in the human community. Nearly 80% of future careers in industrial sectors in the modern world will require some STEM skills and competence [8], [45], [14]. Therefore, STEM education is essential for developing basic, professional, and social skills that are keys to academic achievement and job readiness in the 21st century. Technology in STEM education refers to tools that make abstract ideas more concrete and accessible through experiential learning. These robotic technologies provide a dynamic presentation of STEM systems to enhance students' understanding of complex concepts. Robotic equipment and supplies are increasingly entering classrooms and university auditoriums, and educational robotics or R-STEM education [33], [48], [21], [10], [64] is seen as a transformative tool for teaching students computational thinking, teaching students the ability to code and develop projects of the future, and is also a successful and effective tool for acquiring professional competence by future professionals, where STEM education fulfills the duties of a part of project-based learning in integrated coding, computational thinking, and engineering education. Regardless of whether robots are fully autonomous or part of the lives of individuals and society, robots are becoming increasingly common in people's lives, ranging from performing certain operations on the factory floor or in the operating room in a hospital, to exploring space.

In the United States of America, STEM education is seen as an important and inevitable step necessary to ensure a successful and stable future for the country [58], [47]. The need for STEM education is based on the need for specialists who can combine with professional duties such skills as critical thinking and creativity, innovation, and information and technological literacy.

Interest in R-STEM education has grown at an astonishing rate over the past few years, not only in society at large, but in school and university courses teaching STEM subjects. American researchers taking a comprehensive approach to school STEM education in the American school education system known as K–12, argue that teaching STEM from a robotics perspective, especially in the context of real-world problems, can make STEM subjects more relevant to students and teachers [38]. Robots can replicate the physical movements of humans and allow students to develop mental representations of abstract mathematical ideas [30], [36]. Classes on the basics of educational robotics in US higher education institutions increase student interest and motivation, facilitating the learning process [50], and support teachers in their efforts to make their lessons easier and more enjoyable [18], [52]. Robotics provides students with the opportunity to explore how virtual and engineering technologies work in real life, find new ways to work together, develop collaboration skills, and express themselves using technological tools. In the American education system, Robotics is promoted as an important part of STEM education, as it introduces students to a part of mathematical scientific thinking and can be a gateway to studying applied mathematical disciplines and concepts. Therefore, there is a need to study the implementation and current state of STEM education in the United States based on educational robotics in schools and higher education institutions in the United States, which occupy the highest positions in the ranking of the best higher education institutions in the world [63], [65], in order to modernize the higher education system of Ukraine and direct it to the training of classified future specialists capable of innovations in the scientific and technical field.

Methods of Research

The specificity, subject and purpose of the study determined the choice of a set of scientific methods, namely, the analysis of scientific and pedagogical, methodological, historical and pedagogical literature, the legislative framework of the USA and international organizations in the field of STEM education in order to study the implementation of STEM education in the USA based on educational robotics; the use of modeling methods to clarify the features and generalize the experience of implementing STEM education in the USA based on educational robotics; the use of the scientific extrapolation method, which helped to determine the possibilities of applying the positive experience of the USA in domestic pedagogical theory and practice.

The purpose of the article is a theoretical overview of the implementation of STEM education in the USA based on the development of robotics. The objectives of the study are: 1) highlighting the key stages of technology development in the USA from 1920 to the present; 2) achievements and regulatory framework of the USA, which became the basis for the use of technologies in the STEM educational process; 3) achievements and trends of robotics, as part of STEM education, and the integration of technologies into the educational process of educational institutions in the USA at the current stage of its development.

The statement of the main material

Since the emergence of the concept of STEM education in the 1960s and 1970s, the central idea of this educational system in the United States has been the important concept of the "learning process", especially experience and learning in practice [20], [5]. To navigate well in practice, it is important for students to face a problem arising from a real situation, it is important to have the elements necessary to solve problems, to be able to develop solutions that they could test in real or virtual conditions. To acquire professional competence, students must actively participate in the learning process. Technologies and technological tools can be included in the lesson, to gain experience, and be part of the lesson, where the classroom becomes a learning environment, but the inclusion of technological tools in the lesson does not mean that you need to simply purchase new materials for the class or the audience. Each new technology or technique involves its implementation in the learning process of the lesson, and requires a profound change in the provision of education, a new concept regarding the "role of technology in education", which defines a constructivist view of learning as "building knowledge structures", through the creation of new knowledge, which encourages thinking about the process of creation as a manipulative version of knowledge construction, and reflecting on the tradition of co-construction of knowledge [20], [53], [21]. In response to these challenges, the introduction of robotics into the STEM education system is a necessary part of innovation in the educational environment [7], [26]; the use of robots in school settings affects students' curiosity [2], arts and crafts [57] and logic [12]. In the United States, the development of artificial intelligence has become a lever for the development of robotics and tools for their application in the context of the design of educational activities [61]. The McKinsey Global Institute predicts that artificial intelligence (AI) is likely to automate between 400 and 800 million jobs in the United States by 2030. This is approximately 22% of all currently available jobs, including government positions in the country [25].

The development of the use of technology in education can be divided into four periods.

The first period, 1920–1950s of the 20th century had covered the stage from the appearance of electromechanical computers to the widespread introduction of electronic computers. This stage is characterized by the use of various mechanical, electromechanical and electronic individualized devices, with the help of which educational material was presented and knowledge control and self-control were carried out.

The second period, 1950–1980s of the 20th century had covered the period of time associated with the military development of electronic computers during the Second World War and the widespread introduction of these machines into everyday life. The key terms of this period were intelligent learning systems, computer-oriented learning systems, computer support of the educational process, computer knowledge control systems. During this period, a large number of specialized software was created - automated learning systems PLATO, Coursewriter, Tutor and others [31]. This was facilitated by the obvious advantages of electronic computers over electromechanical ones. Electronic computers had the presence of memory for storing educational materials, high speed of processing and calculations, wider means for viewing educational materials and many others. The disadvantage of the developments of this period was their stationarity and autonomy, associated with the use of «large» computers or terminals connected to them. It was also difficult to implement the exchange of educational resources and services between a large numbers of users. By the beginning of 1965, the US education system had a sufficient number of computer facilities of various levels, equipped with high-level languages. In 1965, the DEC (Digital Equipment Corporation) company released the first commercially successful minicomputer PDP-8, which was used in mathematics classes at mathematics faculties [9], [24], [54], [16].

The development of the field of STEM education related to educational robotics (ER) began in the 1960s with the work and research of Seymour Papert. In 1967, at the Massachusetts Institute of Technology, S. Papert, not entirely related to instructionalism, was able to pioneer a new concept as known as the language LOGO, which is based on constructivist approaching initial activity [51]. The scientist suggested that learning becomes more effective when students take an active part in creating concrete, meaningful objects. Later, Papert's ideas formed the basis for the first commercially successful robots that appeared in classrooms in schools and universities, developed by Lego and the MIT Media Lab. The essence of this approach can best be expressed by the phrase "I can learn this myself if I teach it others". Inside the LOGO program, its user, namely the programmer, acted as a "teacher" for the main object of the LOGO microworld (it was a robotic turtle), this teacher taught the robot turtle through programming it to perform certain actions. The goal that S. Papert wanted to achieve by developing the LOGO programming language that it language are be accessible for children and to simply determine the procedure for solving simple tasks. S. Papert used LOGO to teach mathematics, and LOGO soon became the language of computer literacy in elementary school. The design of the LOGO environment had a significant impact on the further development of teaching aids and teaching concepts. Thus, one of the friends and colegy-scientists of S. Papert, who today is considered the father of object-oriented programming, as known as Alan Curtis Kay in 1968 was launched the Dynabook, a personal computer for children , equipped with the core of the Smalltalk language (www.smalltalk.org/main) [40], [35], [37]. Smalltalk was the first high-level language that supported experimentation with a wide range of mathematical objects, from numbers from different sets to geometric objects. Today, Dynabook has found its embodiment in software the Squeak environment (www.squeak.org) and hardware (laptops and tablet computers), and the object-oriented approach is the basis for building user interfaces [35], [3].

Over the past few decades, educational robotics has attracted the interest of both teachers and researchers, as educational robotics is one of the best teaching tools that supports learning and allows developing students' cognitive and social skills [13]. Educational robotics is aimed at developing high-level intellectual skills and knowledge, where the mechanism of cooperation is at the heart of problem solving [51], [59]. Educational robotics is a tool for hands-on learning. This teaching tool allows students to express their ideas by designing simple or complex mechanisms and robotic objects, making connections between play and fun, rewarding children, and thus providing them with intrinsic motivation, especially in elementary grades [59].

The third period, 1980–2000s of the 20th century is the period associated with the emergence of computer networks and personal computers. Is the period has development of modern technologies in connection of with had development the global Internet and are use of shared and distributed resources, Web technologies, and remote access to primary materials, ensuring a consistent increase in the effectiveness of professional training, accessibility and mass availability. Advanced hardware security made it possible to create professional middleware and systems for the provision of public services and the implementation of various types of formal (organized) and informal activities. The key goals of development of this period are the Internet, Web courses, virtual learning, virtual university, continuing education, lifelong learning, distance learning, learning with help Internet and multimedia and mobile technology.

The fourth period, 2000–2030s of the 21th century includes powerful Internet, online platforms, the use of blogs, social measures and multimedia, the use of distance learning courses, the use of artificial intelligence and automated bots. Robotics education focuses on the exploration and analysis of a simple or complex real-world problem, allowing students to directly observe the results of their solution and efforts, promoting creativity and problem-based learning by integrating abstract design ideas into a single design, allowing students to move from “learning technology” to “learning with technology”. Nowadays, mechanical structures of automated robots are combined with simple, physically tangible environments supported by special programming environments that allow students to transform the structures into intelligent objects that interact with the environment and respond to external stimuli. Educational robotics in STEM education is seen as cross-thematic and facilitates the assimilation of educational material by students in the field of science, technology, engineering and mathematics [51], [37].

Worcester Polytechnic Institute (WPI is a private research university in Worcester, Massachusetts; founded in 1865) was one of the United States’ first engineering and technology universities (WPI has 14 academic departments with over 50 bachelor's, master’s, and Ph.D. degree programs). WPI known by the slogan «R2: Doctoral Universities – High research activity») was the first university in the USA to offer a bachelor's degree in engineering robotics. At one time, he studied at WPI known inventor Dean Kamen, founder of For Inspiration and Recognition of Science and Technology, or FIRST [23]. FIRST is one of the most prominent organizations in the field of robotics STEM education, aimed at developing and supporting young people in mastering science, technology, engineering, and mathematics, and is the world's leading organization of school robotics competitions. Kamen was a WPI student in the early 1970s when he invented the first portable infusion pump, for use in chemotherapy, neonatology, and endocrinology. Kamen founded FIRST «to create a world where science and technology are celebrated… where young people dream of becoming heroes in science and technology» [27]. The organization offers a variety of programs for students of all ages and now has 460,000 students participating in 2,600 STEM-related activities worldwide. In 2015, WPI President Laurie Leshin was appointed to the FIRST Board of Directors [27]. After founding FIRST in 1989, Dean Kamen invited his WPI mentors to join the team of inventors and leaders. WPI helped write and develop the FIRST Robotics software library, and university members serve on the judging panel and are an integral part of the control system used by teams at the annual competition.

The most important development in modern robotics in STEM is a software library called WPILib, which includes a wide range of modules that allow teams to easily and quickly develop the programs that stand behind the kernel system for them robots; these programs include programs written for handle sensors, motors, water stations and other components that ensure synchronization of the robot. WPILib is supported by two thirds of over 84,000 students around the world who create robots for the extremely popular FIRST Robotics Competition (FRC), and participate in one of the largest STEM programs that helps students evaluate and continue your career in STEM fields.

In 1992, WPI had a small team at the first robotics competition, FIRST Robotics competition in Manchester, New York, and sponsored teams therefrom. In addition, the WPI Robotics Resource Center has created the FIRST online resource that promotes everything, starting with shared robots and ending with team robots. The work of the center is not only the sponsorship of teams, but also the promotion of other participants, but also the demonstration of their robots; the center was conduct nearly 50 demonstrations in libraries and schools across the region, expanding STEM awareness in both schools and universities [1].

In 1996, WPI was one of the first to provide to students a FIRST scholarship, one of the fifth currently available at the university. This FIRST scholarship consists of two scholarships that pay for your undergraduate studies, totaling approximately US $190,000. One of these scholarships is awarded for innovation in design; second scholarship is awarded for the demonstrated potential leadership qualities of a student who is a Native American, African American, Hispanic, or Hispanic student. Three additional $5,000 scholarships are also available as FIRST Scholarships for the WPI Frontiers Summer Program for early career scientists and engineers. Scholarships and the university's unique commitment to FIRST have brought more students to WPI, with in-depth knowledge of mathematics, technology, and science, with the goal of furthering their careers. The university is currently accepting applications from hundreds of scholarship participants, and in some cases, students who, for various reasons, were unable to qualify for FIRST scholarships, come before WPI and apply for other scholarships.

FIRST also sponsors programs for young children students and in 2000, WPI became an operating partner with the state of Massachusetts for the FIRST LEGO League, where students between the ages of 9 and 14 uses LEGO Mindstorm sets to create robots the size of a palm. One of the largest FIRST LEGO programs in Massachusetts is led by Colleen Shaver, assistant director of the university's Robotics Resource Center [28]. This program enrolls 460 teams with approximately 2,500 students and organizes 13 events and two championships, including one event and one championship, held on campus directly for high school students on the High School future career in a STEM field. In addition to the creation of robots, scientists and students complete projects, create presentations on a specific topic, collaborating with scientists, engineers and other professionals in the process. Colleen Shaver has said: "The aim is to get to know children and young people from a career in science and technology and and given them role models and goals to work towards. We cheered for our participants and were able to see them ten years later. They came here when they were nine years old, and if that influenced them, they stayed connected to WPI." [19].

The U.S. National Science Foundation has invested of money some decades in fundamental robotic research, continuously developing cross-border research, innovation and productivity [60] and its Fundamental Research Program Robotics (FRR) NSF NSF's Foundational Research in Robotics (FRR) program promotes the research of robotic systems, which accommodates the development of both the computational complexity and the physical complexity of autonomy.

Robotics is a deeply interdisciplinary field that combines advances in technology with innovations in physics, mathematics and computer science. For the purposes of the NSF's Foundational Research in Robotics program, a robot is defined as having the intelligence, design, and ability to process information, perceive, plan, and move between work environments and significantly change the environment of their existence.

In 2001, the American Association for the Advancement of Science (AAAS) published its two volumes Atlas of Science Literacy as a part of Project 2061, which mapped the K–12 science curriculum. The Atlas includes themes, standards, benchmarks, instructional design, instruction, learning engagement resources, and assessment criteria [4], and emphasizes the dynamic nature of science and its interdisciplinary relationship with technology and mathematics. The National Science Education Standards [44] and mathematics, along with the Curriculum and Assessment Standards for School Mathematics, have supported the integration of these subjects [42], [37]. In April 2013, the Next Generation Science Standards (NGSS) published their vision standards, which aimed to encourage students to think critically, collaborate, and solve real-world problems using artificial intelligence and technology, and use evidence to justify their reasoning to apply their knowledge [43].

In 2015, with the STEM Education Act, the concept of STEM education was standardized and defined, with the development and addition of disciplines defined in the acronym STEM [56]. In the process of developing the STEM Education Act, the National Science Education Standards National Science Education Standards were presented in such a way as to serve as a theoretical foundation and indicate technology as an integral part of K–12 education, where recommendations for the use of technology, technical design, and programming were first included in the science curriculum [62], [55]. The Standards for Technological Literacy: Technology Research Content were published around the same time as the Atlas of Science Literacy was proposed by the AAAS in 2001 [34]. The standards emphasize the integration of technology into the STEM educational environment, and occupy the same important part as mathematics and science, emphasizing the study of the basics of technology concepts and their application in engineering design, helping students in the design experience, in the process of modeling, testing, research, analysis and decision-making. According to the STEM Education Act, the relationship between the four disciplines can be characterized as follows: mathematics and science provide a contextual basis for technology; technology supports engineering design and implementation of new developments, and plays a key role in the integration of relevant STEM disciplines [56].

Regarding the educational purposes of research and study of robots in R-STEM education, the study showed that 29.82% of primary school teachers responsible for core subjects in grades 1-4 use educational robots in their teaching methodology. This indicates a relatively high level in this category. In higher education institutions in the United States, studies show that most robots are used for teaching and transferring skills (58.97%, or 23 out of 39 studies) to improve the learning process for schoolchildren and students [22].

Educational robots are specialized devices used in education to engage students and facilitate learning. Especially in the fields of science, technology, engineering, and mathematics (STEM). These robots are programmable, equipped with sensors, and often mobile, allowing them to interact with their environment. They come in a variety of forms, from do-it-yourself robotic kits to pre-programmed and remotely controlled robots that serve as hands-on learning aids. Educational robots are widely used in STEM education, coding education, and problem-solving and providing practical knowledge and preparing students for future careers in technology professions.

The educational goals of research in R-STEM education directed to he ability to transfer scientific and engineering knowledge gained through scientific experiments and aim to learn practical learning experiences with robots. Creativity and motivation have been recognized as key educational goals in R-STEM education that can develop students' scientific knowledge [46]. Other educational goals of R-STEM education include confidence and the ability to present research [29], passion for STEM education [17] and future career choices [41], active learning and improving students' learning experiences through social interaction [6] and collaborative science projects as well as professional development for teachers on the use of robots to improve teaching effectiveness [32]. Teachers in R-STEM education are trained to develop meaningful instructional instructions [11] and lesson materials as well as to develop more sustainable professional effectiveness [49] but R-STEM education also considers issues such as cost for teacher training [39].

In 2022, the market generated approximately $1.2 billion in revenue; in 2023, the educational robots market generated approximately $1.4-1.6 billion in revenue in the US. In 2028, the revenue from humanoid robots is expected to double, as opposed to the revenue from avtobot robots. The global educational robots market is experiencing steady growth, and revenue growth is projected to continue over the coming years. The trend continues with an estimated revenue of $1.9 billion in 2025. As we move into the future, the market is expected to witness even more significant growth. Reaching approximately $2.3 billion in 2026 and $2.6 billion in 2027. The growth trajectory remains positive, with revenues projected to reach US$2.8 billion in 2028, US$3.3 billion in 2029, and US$3.7 billion in 2030. The global educational robots market is expected to exceed US$4.3 billion by 2031, with further growth to reach US$5.1 billion in 2032. This upward trend highlights the growing importance of educational robots in today's learning environment [39].

Conclusions

Having analyzed the sources on the research problem, it can be argued that at each stage of the development of STEM education, the use of technologies in education, and the introduction of robotics into the educational environment system, is a necessary development trend that takes into account the scientific and technical achievements of its time, theories and methods of using technologies in education. Over the past few decades, educational robotics has attracted the interest of both teachers and researchers, since the introduction of technologies into the educational process is one of the best learning tools that supports and allows the development of cognitive and social skills of students, aimed at the development of intellectual skills and knowledge, where the basis of problem solving is the mechanism of cooperation.

Educational robotics is a tool for practical learning that allows you to express your ideas, developing simple or complex mechanisms and robotic objects, forming connections between play and pleasure, encouraging students and thus ensuring their internal motivation.

As a result of the study, the main key stages of technology development in the USA from 1920s to the present were identified; the achievements and trends of robotics as part of STEM education and the integration of technology into the educational process of US educational institutions at the current stage of its development were highlighted; it was shown that educational robotics has been part of STEM education research for many years, and the current status of the development and use of technological achievements of robotics in lessons leads to increased student motivation and encouragement of perseverance in learning, the development of mathematical and scientific thinking.

Conflict of interest

The authors declare that there are no conflicts of interest in the publication of this manuscript. In addition, the authors fully complied with ethical standards, including plagiarism, data falsification, and double publication.

References

1. A Long History with FIRST Robotics Competition. (2017). https://www.wpi.edu/news/long-history-first-robotics-competition
2. Adams, R., Evangelou, D., English, L., De Figueiredo, A. D., Mousoulides, N., Pawley, A. L., Schiefellite, C., Stevens, R., Svinicki, M., Trenor, J. M., Wilson, D. M. (2011). Multiple perspectives on engaging future engineers. *Journal of Engineering Education*, 100(1), 48–88. https://doi.org/10.1002/j.2168-9830.2011.tb00004.x
3. Alimisis, D. (2013). Educational robotics: open questions and new challenges. *Themes in Science and Technology Education*, 6(1), 63–71. https://www.researchgate.net/publication/284043695_Educational_robotics_Open_questions_and_new_challenges
4. American Association for the Advancement of Science (AAAS). (2001). *Atlas of Science Literacy*, Washington, DC: AAAS. https://www.aaas.org/search?searchTerm=Atlas+of+Science+Literacy+2001&sort_by=relevance
5. Association for Educational Communications and Technology (AECT). The Rise of Robotics in STEM Education. AECT Publications, (2021). Teachers College Press. https://vapstech.com/the-rise-of-robotics-in-education/
6. Ayar, M. C. (2015). First-hand experience with engineering design and career interest in engineering: An informal STEM education case study. *Educational Sciences: Theory & Practice*, 15(6), 1655–1675. https://doi.org/10.12738/estp.2015.6.0134
7. Bargagna, S., Castro, E., Cecchi, F., Cioni, G., Dario, P., Dell'Omo, M., Di Lieto, M. C., Inguaggiato, E., Martinelli, A., Pecini, C., Sgandurra, G. (2019). Educational robotics in down syndrome: A feasibility study. *Technology, Knowledge and Learning*, 24(1), 315–323. https://doi.org/10.1007/s10758-018-9366-z
8. Batyuk, L., Zhernovnykova, O. (2022). Modern educational digital competence of future doctors of Poland as a European state. *New Collegium*, 3(108), 55–65. https://doi.org/10.30837/nc.2022.3.55
9. Bell, G. (2014). Stars: rise and fall of minicomputers. *Proceedings of the IEEE*, 102(4), 629–638. https://doi.org/10.1109/JPROC.2014.2306257
10. Belpaeme, T., Kennedy, J., Ramachandran, A., Scassellati, B., Tanaka, F. (2018). Social robots for education: A review. *Science Robotics*, 3(21), eaat5954. https://doi.org/10.1126/scirobotics.aat5954
11. Bernstein, D., Mutch-Jones, K., Cassidy, M., Hamner, E. (2022). Teaching with robotics: Creating and implementing integrated units in middle school subjects. *Journal of Research on Technology in Education*, 54(2), 161–176. https://doi.org/10.1080/15391523.2020.1816864
12. Bers, M. U. (2008). Blocks to robots learning with technology in the early childhood classroom. Teachers College Press. https://www.daneshnamehicsa.ir/userfiles/files/1/17-%20Blocks%20to%20Robots_%20Learning%20with%20Technology%20in%20the%20Early%20Childhood%20Classroom%20(2007,%20Teachers%20College%20Press).pdf
13. Blanchard, S., Freiman, V., Lirrete-Pitre, N. (2010). Strategies used by elementary schoolchildren

solving robotics-based complex tasks: innovative potential of technology. *Procedia–Social and Behavioral Sciences*, 2(2), 2851–2857. https://doi.org/10.1016/j.sbspro.2010.03.427
14. Boichenko, V. (2020a). Genesis and current state of STEM education development: U.S. experience. *Pedagogical sciences: theory, history, innovative technologies, 8 (102)*, 410–418. https://doi.org/10.24139/2312-5993/2020.08/410-418
15. Brown, A. L., Campione, J. C. (1994). Guided discovery in a community of learners. In: McGilly, K. (ed.). *Classroom Lessons: Integrating Cognitive Theory and Classroom Practice*, MIT Press/Bradford Books, Cambridge, MA. https://psycnet.apa.org/record/1994-98346-008
16. Campbell-Kelly, M., Aspray, W., Ensmenger, N., Yost, J. R. (2014). Computer: A history of the information machine (3rd ed.), Routledge. https://www.taylorfrancis.com/books/mono/10.4324/9780429495373/computer-martin-campbell-kelly-william-aspray-jeffrey-yost-nathan-ensmenger
17. Chiang, F. K., Liu, Y. Q., Feng, X., Zhuang, Y., Sun, Y. (2023). Effects of the world robot Olympiad on the students who participate: A qualitative study. *Interactive Learning Environments*, 31(1), 258–269. https://doi.org/10.1080/10494820.2020.1775097
18. Chiazzese, G., Arrigo, M., Chifari, A., Lonati, V., Tosto, C. (2019). Educational Robotics in Primary School: Measuring the Development of Computational Thinking Skills with the Bebras Tasks. *Informatics*, 6(4), 43. https://doi.org/10.3390/informatics6040043
19. Colleen Shaver. Director, Robotics Resource Center. (2025). https://www.wpi.edu/people/staff/colleen
20. Collins, A., Halverson, R. (2009). Rethinking Education in the Age of Technology: The Digital Revolution and Schooling in America, Teachers College Press. http://ektr.uni-eger.hu/wp-content/uploads/2015/11/rethinking-education-in-the-age-of-technology.pdf
21. Conde, M. A., Rodriguez-Sedano, F. J., Fernandez-Llamas, C., Goncalves, J., Lima, J., Garcia-Penalvo, F. J. (2021). Fostering STEAM through challenge based learning, robotics, and physical devices: A systematic mapping literature review. *Computer Applications in Engineering Education*, *29(1)*, 46–65. https://doi.org/10.1002/cae.22354
22. Darmawansah, D., Hwang, G.-J., Chen, M.-R.A., Liang, J.‑C. (2023). Trends and research foci of robotics‑based STEM education: a systematic review from diverse angles based on the technology‑based learning model. *International Journal of STEM Education, 10(12),* 1–24. https://doi.org/10.1186/s40594-023-00400-3
23. Dean Kamen: U.S. Must Focus on STEM to Regain Innovative Spirit. (2012). https://www.usnews.com/opinion/articles/2012/06/21/without-focus-on-stem-fields-us-is-losing-its-innovative-spirit
24. Digital Equipment Corporation (DEC) PDP-8 Minicomputer Collection. (2024). https://www.rrauction.com/auctions/lot-detail/349021906984242-digital-equipment-corporation-dec-pdp-8-minicomputer-collection/EXCEEDAcademy .
25. EXCEED Academy. Preparing Our Children for future technologic world. (2025). https://www.myexceedacademy.com/preparing-our-children-for-future-technologic-world/
26. Ferreira, N. F., Araujo, A., Couceiro, M. S., Portugal, D. (2018). Intensive summer course in robotics – Robotcraft. *Applied Computing and Informatics, 16(1/2)*, 155–179. https://doi.org/10.1016/j.aci.2018.04.005
27. FIRST. (2025). https://www.firstinspires.org/
28. FIRST LEGO League Divisions. (2025). https://www.firstinspires.org/robotics/fll?__hstc=208832909.7c06ef6cc1a37061d8865a54ee23a6a4.1488899663438.1488899663438.1488899663438.1&__hssc=208832909.2.1488899663438&__hsfp=3760882989
29. Guven, G., Kozcu Cakir, N., Sulun, Y., Cetin, G., Guven, E. (2022). Arduino-assisted robotics coding applications integrated into the 5E learning model in science teaching. *Journal of Research on Technology in Education*, 54(1), 108–126. https://doi.org/10.1080/15391523.2020.1812136
30. Han, J., Jo, M., Hyun, E., So, H. J. (2015). Examining young children's perception toward augmented reality-infused dramatic play. *Educational Technology Research and Development*, 63(3), 455–474. https://doi.org/10.1007/s11423-015-9374-9

31. Heilmann, T. A. (2023). The Beginnings of Word Processing: A Historical Account. In: Kruse, O., et al. Digital Writing Technologies in Higher Education. 3–14. Springer, Cham. https://doi.org/10.1007/978-3-031-36033-6_1
32. Hennessy, E. C. (2020). Run it through me: Positioning, power, and learning on a high school robotics team. *Journal of the Learning Sciences, 29(4–5),* 598–641. https://doi.org/10.1080/10508406.2020.1770763
33. Huang, H.-Y., Shih, J.-L. (2022). Integrating Design Thinking into Interdisciplinary Course with STEM-based Robotic Game. *American Journal of Educational Research,* 10(10), 599–611. https://doi.org/10.12691/education-10-10-3
34. International Technology Education Association. (2000). Standards for technological literacy: Content for the study of technology. Reston, VA: ITEA. http://www.iteawww.org/TAA/STLstds.htm
35. Kay Alan C. (1981). Generic programming: APL and Smalltalk. *ACM SIGAPL APL Quote Quad*,12(1), p. 180. https://doi.org/10.1145/390007.805355
36. Kennedy, J., Baxter, P., Belpaeme, T. (2015). Comparing robot embodiments in a guided discovery learning interaction with children. *International Journal of Social Robotics*, 7(2), 293–308. https://doi.org/10.1007/s12369-014-0277-4
37. Kiyanovska, N. M. (2014).The development of Information and communication technologies in teaching engineering students in universities of the United States: diss. ... candidate of pedagogical sciences: 13.00.10, Kryvyi Rih. https://elibrary.kdpu.edu.ua/handle/0564/1595?mode=full https://doi.org/10.31812/0564/1595
38. Kopcha, T. J., McGregor, J., Shin, S., Qian, Y., Choi J., Hill R., Mativo, J., Choi, I. (2017). Developing an Integrative STEM Curriculum for Robotics Education Through Educational Design Research. *Journal of Formative Design in Learning,* 1*(2),* 31–44. https://doi.org/10.1007/s41686-017-0005-1
39. Leonard, J., Mitchell, M., Barnes-Johnson, J., Unertl, A., Outka-Hill, J., Robinson, R., Hester-Croff, C. (2018). Preparing teachers to engage rural students in computational thinking through robotics, game design, and culturally responsive teaching. *Journal of Teacher Education, 69(4),* 386–407. https://doi.org/10.1177/0022487117732317
40. Maxwell, J. W. (2006). Tracing the Dynabook: a study of techno cultural transformations. A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in The Faculty of Graduate Studies (Curriculum and Instruction). University of British Columbia, 311 p. https://worrydream.com/refs/Maxwell_2006_-_Tracing_the_Dynabook.pdf
41. Meyers, K., Goodrich, V. E., Brockman, J. B., Caponigro, J. (2012). I2D2: Imagination, innovation, discovery, and design. *In 2012 ASEE annual conference & exposition*, San Antonio, Texas. https://doi.org/10.18260/1-2--21464
42. National Council of Teachers of Mathematics, & (NCTM). (1989). Curriculum and evaluation standards for school mathematics. Reston, VA: NCTM. https://www.scirp.org/reference/referencespapers?referenceid=883118
43. National Research Council. (2013). Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press. 532 p. https://doi.org/10.17226/18290
44. National Research Council (NRC). (1996). National science education standards. National Committee on Science Education Standards and Assessment, Board on Science Education, Division of Behavioral and Social Science and Education. Washington, DC: National Academies Press. https://doi.org/10.17226/4962
45. National Training, Education, and Workforce Survey (NTEWS) Pilot. (2022). *National Center for Science and Engineering Statistics*. https://ncses.nsf.gov/surveys/national-training-education-workforce/2022#tableCtr12925
46. Pangarkar, T. (2025). Educational Robots Statistics 2025 By Great Learning Tech. *Educational Technology and Online Learning. Market.us Scoop*. https://scoop.market.us/educational-robots-statistics/
47. Presidential Actions. President's Council of Advisors on Science and Technology. (2025). https://www.whitehouse.gov/presidential-actions/2025/01/presidents-council-of-advisors-on-science-and-technology /
48. Robotics in STEM Education. Redesigning the Learning Experience. Myint Swe Khine., Ed.

Springer International Publishing AG. (2017). 260 p. https://doi.org/10.1007/978-3-319-57786-9
49. Ryan, M., Gale, J., Usselman, M. (2017). Integrating engineering into core science instruction: Translating NGSS principles into practice through iterative curriculum design. *International Journal of Engineering Education*, 33(1), 321–331. https://mspnet-static.s3.amazonaws.com/05_ijee3374ns--IJEE_2017_article.pdf
50. Sapounidis, T., Alimisis, D. (2021). Educational Robotics Curricula: Current Trends and Shortcomings. In: Malvezzi, M., Alimisis, D., Moro, M. (eds). *Education in & with Robotics to Foster 21st-Century Skills*. EDUROBOTICS 2021. Studies in Computational Intelligence, Vol. 982. Springer, Cham. https://doi.org/10.1007/978-3-030-77022-8_12
51. Sapounidis, T., Alimisis, D. (2020). Educational robotics for STEM: A review of technologies and some educational considerations. In book: *Science and Mathematics Education for 21st Century Citizens: Challenges and Ways Forward*, Chapter: 9, Publisher: Nova science publishers: Hauppauge, NY, USA, 167–190. https://www.researchgate.net/publication/346588762_Educational_robotics_for_STEM_A_review_of_technologies_and_some_educational_considerations
52. Sapounidis, T., Stamelos, I., Demetriadis, S. (2016). Tangible User Interfaces for Programming and Education: A New Field for Innovation and Entrepreneurship. *Innovation and Entrepreneurship in Education (Advances in Digital Education and Lifelong Learning, 2),* Emerald Group Publishing Limited, Leeds, pp. 271-295. https://doi.org/10.1108/S2051-229520160000002016
53. Scardamalia, M., Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In K. Sawyer (Ed.), Cambridge Handbook of the Learning Sciences (pp. 97-118). New York: Cambridge University Press. https://ikit.org/fulltext/2006_KBTheory.pdf .
54. Small computer handbook. (1973). Digital Equipment Corporation. 591 p. http://vandermark.ch/pdp8/uploads/PDP8/PDP8.Manuals/DEC-S8-OSSCH-A.pdf
55. Standards for Technological Literacy: content for the study of technology. (2007). Third Edition. International Technology Education Association and its Technology for All American Project. 260 p. https://wwwcp.umes.edu/tech/wp-content/uploads/sites/94/2021/09/xstnd.pdf
56. STEM Education Act of 2015. (2015). LEGISLATIVE HISTORY – H.R. 1020: SENATE REPORTS: No. 114–115 (Comm. on Commerce, Science, and Transportation). CONGRESS.GOV. https://www.congress.gov/114/plaws/publ59/PLAW-114publ59.pdf
57. Sullivan, A., Bers, M. U. (2016). Robotics in the early childhood classroom: Learning outcomes from an 8-week robotics curriculum in pre-kindergarten through second grade. *International Journal of Technology and Design Education*, 26(1), 3–20. https://doi.org/10.1007/s10798-015-9304-5
58. Theodosios, S., Demetriadis, S. (2013). Tangible versus graphical user interfaces for robot programming: exploring cross-age children's preferences. *Personal and Ubiquitous Computing, 17(8)*, 1775–1786. https://doi.org/10.1007/s00779-013-0641-7
59. The NSTC's 2024 Report on the Committee on Science, Technology, Engineering, and Mathematics (CoSTEM) and CoSTEM-Related Agency Actions. (2025). 100 p. https://www.whitehouse.gov/wp-content/uploads/2025/01/2024-CoSTEM-Annual-Report.pdf
60. United State Government. U.S. National Science Foundation. Robotics. (2025). https://new.nsf.gov/focus-areas/robotics
61. Uslu, N. A., Yavuz, G. Ö., Usluel, Y. K. (2023). A systematic review study on educational robotics and robots. *Interactive Learning Environments, 31(9),* 5874–5898. https://doi.org/10.1080/10494820.2021.2023890
62. Wonacott, M. E. (2001). Technological Literacy. ERIC Digest. ERIC Clearinghouse on Adult Career and Vocational Education Columbus OH. 7 p. https://files.eric.ed.gov/fulltext/ED459371.pdf
63. World University Rankings 2025. (2025). *THE – Times Higher Education*. https://www.timeshighereducation.com/world-university-rankings/latest/world-ranking
64. Zhang, Y., Luo, R., Zhu, Y., Yin, Y. (2021). Educational robots improve K-12 students' computational thinking and STEM attitudes: Systematic review. *Journal of Educational Computing Research*, 59(7), 1450–1481. https://doi.org/10.1177/0735633121994070
65. 2024 Best STEM High Schools. (2025). U.S. News & World Report L.P.

https://www.usnews.com/education/best-high-schools/national-rankings/stem

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Л. В. БАТЮК[1], кандидат біологічних наук, доцент,
доцент кафедри фізики та хімії
e-mail: l.batyuk@hnpu.edu.ua ORCID ID: https://orcid.org/0000-0003-1863-0265
В. В. МАСИЧ[1], доктор педагогічних наук, професор,
завідувач кафедри фізики та хімії
e-mail: masych@hnpu.edu.ua ORCID ID: https://orcid.org/0000-0002-8943-7756
[1]*Харківський національний педагогічний університет ім. Г. С. Сковороди,*
вул. Алчевських, 29, м. Харків, 61002, Україна

ОГЛЯД ВПРОВАДЖЕННЯ STEM-ОСВІТИ В США НА ОСНОВІ РОБОТОТЕХНІКИ

У статті наведено огляд упровадження STEM-освіти в США на основі робототехніки, як частини новітніх інновацій освітнього середовища Сполучених Штатів. STEM-освіта має важливе значення для розвитку базових, професійних та суспільних навичок, які є ключовими для академічних досягнень і готовності до роботи в 21-му столітті. Технологія у викладанні STEM-предметів відноситься до інструментів, які роблять абстрактні ідеї більш конкретними та доступними через експериментальне навчання. Ці роботизовані технології забезпечують динамічність представлення систем STEM для покращення засвоєння учнями складних понять.

На основі ґрунтовного аналізу науково-педагогічних і нормативно-правових джерел висвітлено ключові періоди розвитку застосування технологій у навчанні та пов'язані з ними процеси розбудови галузі STEM-освіти в США.

З'ясовано, що поява технологій передбачає впровадження їх у навчальний процес уроку та вимагає глибокої зміни надання освіти, нового поняття відносно «ролі технологій в освіті», що визначає конструктивістський погляд на навчання як на «побудову структур знань», шляхом створення нових знань. Освітня робототехніка в STEM-навчанні розглядається як крос-тематична та полегшує засвоєння навчального матеріалу учнями в галузі науки, технологій, інженерії та математики. Освітня робототехніка надає школярам та студентам можливість досліджувати, як віртуальні та інженерні технології працюють у реальному житті, знаходити нові способи спільної роботи, розвивати навички співпраці, виражати себе за допомогою технологічного інструменту, знайомити учнів із частиною математичного наукового мислення та може бути воротами до вивчення прикладних математичних дисциплін та наукових концепцій.

Визначено, що роботизовані технології забезпечують динамічність представлення системи STEM для покращення засвоєння учнями складних понять та допомагають оптимізувати освітній процес. Підтримка урядом США інтеграції технологій у робототехнічне STEM-освітнє середовище, відіграє ключову роль у наданні практичних знань і підготовки учнів до майбутньої кар'єри на світовому ринку праці.

КЛЮЧОВІ СЛОВА: *STEM-освіта, R-STEM-освіта, освітня робототехніка, Лего, К-12, школа, університет, заклад вищої освіти, США.*

Конфлікт інтересів

Автори заявляють, що конфлікту інтересів щодо публікації цього рукопису немає. Крім того, автори повністю дотримувались етичних норм, включаючи плагіат, фальсифікацію даних та подвійну публікацію.

Список використаної літератури

1. A Long History with FIRST Robotics Competition. 2017. URL: https://www.wpi.edu/news/long-history-first-robotics-competition
2. Adams, R., Evangelou, D., English, L., De Figueiredo, A. D., Mousoulides, N., Pawley, A. L., Schiefellite, C., Stevens, R., Svinicki, M., Trenor, J. M., Wilson, D. M. (2011). Multiple perspectives on engaging future engineers. *Journal of Engineering Education*. 2011. Vol. 100(1). Pp. 48–88. DOI: https://doi.org/10.1002/j.2168-9830.2011.tb00004.x
3. Alimisis, D. (2013). Educational robotics: open questions and new challenges. *Themes in Science*

and Technology Education. 2013. Vol. 6(1). Pp. 63–71. URL: https://www.researchgate.net/publication/284043695_Educational_robotics_Open_questions_and_new_challenges
4. American Association for the Advancement of Science (AAAS). *Atlas of Science Literacy*, Washington, DC: AAAS, 2001. URL: https://www.aaas.org/search?searchTerm=Atlas+of+Science+Literacy+2001&sort_by=relevance
5. Association for Educational Communications and Technology (AECT). The Rise of Robotics in STEM Education. AECT Publications, 2021. Teachers College Press. URL: https://vapstech.com/the-rise-of-robotics-in-education/
6. Ayar, M. C. (2015). First-hand experience with engineering design and career interest in engineering: An informal STEM education case study. *Educational Sciences: Theory & Practice*. 2015. Vol. 15(6). Pp. 1655–1675. DOI: https://doi.org/10.12738/estp.2015.6.0134
7. Bargagna, S., Castro, E., Cecchi, F., Cioni, G., Dario, P., Dell'Omo, M., Di Lieto, M. C., Inguaggiato, E., Martinelli, A., Pecini, C., Sgandurra, G. Educational robotics in down syndrome: A feasibility study. *Technology, Knowledge and Learning*.2019. Vol. 24(1). Pp. 315–323. DOI: https://doi.org/10.1007/s10758-018-9366-z
8. Batyuk, L., Zhernovnykova, O. Modern educational digital competence of future doctors of Poland as a European state. *New Collegium*. 2022. Vol. 3(108). Pp. 55–65. DOI: https://doi.org/10.30837/nc.2022.3.55
9. Bell, G. Stars: rise and fall of minicomputers. *Proceedings of the IEEE*. 2014. Vol. 102(4). Pp. 629–638. DOI: https://doi.org/10.1109/JPROC.2014.2306257
10. Belpaeme, T., Kennedy, J., Ramachandran, A., Scassellati, B., Tanaka, F. Social robots for education: A review. *Science Robotics*. 2018. Vol. 3(21). eaat5954. DOI: https://doi.org/10.1126/sciro botics.aat5954
11. Bernstein, D., Mutch-Jones, K., Cassidy, M., Hamner, E. Teaching with robotics: Creating and implementing integrated units in middle school subjects. *Journal of Research on Technology in Education*. 2022. Vol. 54(2). Pp. 161–176. DOI: https://doi.org/10.1080/15391523.2020.1816864
12. Bers, M. U. Blocks to robots learning with technology in the early childhood classroom. Teachers College Press, 2008. https://www.daneshnamehicsa.ir/userfiles/files/1/17-%20Blocks%20to%20Robots_%20Learning%20with%20Technology%20in%20the%20Early%20Childhood%20Classroom%20(2007,%20Teachers%20College%20Press).pdf
13. Blanchard, S., Freiman, V., Lirrete-Pitre, N. Strategies used by elementary schoolchildren solving robotics-based complex tasks: innovative potential of technology. *Procedia–Social and Behavioral Sciences*. 2010. Vol. 2(2). Pp. 2851–2857. DOI: https://doi.org/10.1016/j.sbspro.2010.03.427
14. Boichenko, V. (2020a). Genesis and current state of STEM education development: U.S. experience. *Pedagogical sciences: theory, history, innovative technologies*. 2020a. Vol. 8 (102). Pp. 410–418. DOI: https://doi.org/10.24139/2312-5993/2020.08/410-418
15. Brown, A. L., Campione, J. C. Guided discovery in a community of learners. In: McGilly, K. (ed.). *Classroom Lessons: Integrating Cognitive Theory and Classroom Practice*, MIT Press/Bradford Books, Cambridge, MA, 1994. URL: https://psycnet.apa.org/record/1994-98346-008
16. Campbell-Kelly, M., Aspray, W., Ensmenger, N., Yost, J. R. Computer: A history of the information machine (3rd ed.). Routledge, 2014. URL: https://www.taylorfrancis.com/books/mono/10.4324/9780429495373/computer-martin-campbell-kelly-william-aspray-jeffrey-yost-nathan-ensmenger
17. Chiang, F. K., Liu, Y. Q., Feng, X., Zhuang, Y., Sun, Y. Effects of the world robot Olympiad on the students who participate: A qualitative study. *Interactive Learning Environments*. 2023. Vol. 31(1). Pp. 258–269. DOI: https://doi.org/10.1080/10494820.2020.1775097
18. Chiazzese, G., Arrigo, M., Chifari, A., Lonati, V., Tosto, C. Educational Robotics in Primary School: Measuring the Development of Computational Thinking Skills with the Bebras Tasks. *Informatics*. 2019. Vol. 6(4). Pp. 43. DOI: https://doi.org/10.3390/informatics6040043
19. Colleen Shaver. Director, Robotics Resource Center. 2025. URL: https://www.wpi.edu/people/staff/colleen

20. Collins, A., Halverson, R. Rethinking Education in the Age of Technology: The Digital Revolution and Schooling in America. Teachers College Press, 2009. URL: http://ektr.uni-eger.hu/wp-content/uploads/2015/11/rethinking-education-in-the-age-of-technology.pdf
21. Conde, M. A., Rodriguez-Sedano, F. J., Fernandez-Llamas, C., Goncalves, J., Lima, J., Garcia-Penalvo, F. J. Fostering STEAM through challenge based learning, robotics, and physical devices: A systematic mapping literature review. *Computer Applications in Engineering Education.* 2021. Vol. 29(1). Pp. 46–65. DOI: https://doi.org/10.1002/cae.22354
22. Darmawansah, D., Hwang, G.-J., Chen, M.-R.A., Liang, J.‑C. Trends and research foci of robotics‑based STEM education: a systematic review from diverse angles based on the technology‑based learning model. *International Journal of STEM Education.* 2023. Vol. 10(12). Pp. 1–24. DOI: https://doi.org/10.1186/s40594-023-00400-3
23. Dean Kamen: U.S. Must Focus on STEM to Regain Innovative Spirit. 2012. URL: https://www.usnews.com/opinion/articles/2012/06/21/without-focus-on-stem-fields-us-is-losing-its-innovative-spirit
24. Digital Equipment Corporation (DEC) PDP-8 Minicomputer Collection. 2024. URL: https://www.rrauction.com/auctions/lot-detail/349021906984242-digital-equipment-corporation-dec-pdp-8-minicomputer-collection/EXCEEDAcademy .
25. EXCEED Academy. Preparing Our Children for future technologic world. 2025. URL: https://www.myexceedacademy.com/preparing-our-children-for-future-technologic-world/
26. Ferreira, N. F., Araujo, A., Couceiro, M. S., Portugal, D. (2018). Intensive summer course in robotics – Robotcraft. *Applied Computing and Informatics*. 2018. Vol. 16(1/2). Pp. 155–179. DOI: https://doi.org/10.1016/j.aci.2018.04.005
27. FIRST. 2025. URL: https://www.firstinspires.org/
28. FIRST LEGO League Divisions. 2025. URL: https://www.firstinspires.org/robotics/fll?__hstc=208832909.7c06ef6cc1a37061d8865a54ee23a6a4.1488899663438.1488899663438.1488899663438.1&__hssc=208832909.2.1488899663438&__hsfp=3760882989
29. Guven, G., Kozcu Cakir, N., Sulun, Y., Cetin, G., Guven, E. Arduino-assisted robotics coding applications integrated into the 5E learning model in science teaching. *Journal of Research on Technology in Education*. 2022. Vol. 54(1). Pp. 108–126. DOI: https://doi.org/10.1080/15391523.2020.1812136
30. Han, J., Jo, M., Hyun, E., So, H. J. Examining young children’s perception toward augmented reality-infused dramatic play. *Educational Technology Research and Development.* 2015. Vol. 63(3). Pp. 455–474. DOI: https://doi.org/10.1007/s11423-015-9374-9
31. Heilmann, T. A. The Beginnings of Word Processing: A Historical Account. In: Kruse, O., et al. Digital Writing Technologies in Higher Education. 3–14. Springer, Cham, 2023. DOI: https://doi.org/10.1007/978-3-031-36033-6_1
32. Hennessy, E. C. Run it through me: Positioning, power, and learning on a high school robotics team. *Journal of the Learning Sciences.* 2020. Vol. 29(4–5). Pp. 598–641. DOI: https://doi.org/10.1080/10508406.2020.1770763
33. Huang, H.-Y., Shih, J.-L. Integrating Design Thinking into Interdisciplinary Course with STEM-based Robotic Game. *American Journal of Educational Research.* 2022. Vol. 10(10). Pp. 599–611.DOI: https://doi.org/10.12691/education-10-10-3
34. International Technology Education Association. Standards for technological literacy: Content for the study of technology. Reston, VA: ITEA, 2000. URL: http://www.iteawww.org/TAA/STLstds.htm
35. Kay Alan C. Generic programming: APL and Smalltalk. *ACM SIGAPL APL Quote Quad.* 1981. Vol. 12(1). P. 180. DOI: https://doi.org/10.1145/390007.805355
36. Kennedy, J., Baxter, P., Belpaeme, T. Comparing robot embodiments in a guided discovery learning interaction with children. *International Journal of Social Robotics.* 2015. Vol. 7(2). Pp. 293–308. DOI: https://doi.org/10.1007/s12369-014-0277-4
37. Kiyanovska, N. M. The development of Information and communication technologies in teaching engineering students in universities of the United States: diss. ... candidate of pedagogical sciences: 13.00.10, Kryvyi Rih, 2014.

URL: https://elibrary.kdpu.edu.ua/handle/0564/1595?mode=full
DOI: https://doi.org/10.31812/0564/1595

38. Kopcha, T. J., McGregor, J., Shin, S., Qian, Y., Choi J., Hill R., Mativo, J., Choi, I. (2017). Developing an Integrative STEM Curriculum for Robotics Education Through Educational Design Research. *Journal of Formative Design in Learning.* 2017. Vol. 1(2). Pp. 31–44. DOI: https://doi.org/10.1007/s41686-017-0005-1
39. Leonard, J., Mitchell, M., Barnes-Johnson, J., Unertl, A., Outka-Hill, J., Robinson, R., Hester-Croff, C. Preparing teachers to engage rural students in computational thinking through robotics, game design, and culturally responsive teaching. *Journal of Teacher Education.* 2018. Vol. 69(4). Pp. 386–407. DOI: https://doi.org/10.1177/0022487117732317
40. Maxwell, J. W. Tracing the Dynabook: a study of techno cultural transformations. A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in The Faculty of Graduate Studies (Curriculum and Instruction). University of British Columbia, 2006. 311 p. URL: https://worrydream.com/refs/Maxwell_2006_-_Tracing_the_Dynabook.pdf
41. Meyers, K., Goodrich, V. E., Brockman, J. B., Caponigro, J. I2D2: Imagination, innovation, discovery, and design. *In 2012 ASEE annual conference & exposition*. San Antonio, Texas, 2012. DOI: https://doi.org/10.18260/1-2--21464
42. National Council of Teachers of Mathematics, & (NCTM). Curriculum and evaluation standards for school mathematics. Reston, VA: NCTM, 1989. URL: https://www.scirp.org/reference/referencespapers?referenceid=883118
43. National Research Council. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press, 2013. 532 p. DOI: https://doi.org/10.17226/18290
44. National Research Council (NRC). National science education standards. National Committee on Science Education Standards and Assessment, Board on Science Education, Division of Behavioral and Social Science and Education. Washington, DC: National Academies Press, 1996. DOI: https://doi.org/10.17226/4962
45. National Training, Education, and Workforce Survey (NTEWS) Pilot. *National Center for Science and Engineering Statistics*. 2022. URL: https://ncses.nsf.gov/surveys/national-training-education-workforce/2022#tableCtr12925
46. Pangarkar, T. Educational Robots Statistics 2025 By Great Learning Tech. *Educational Technology and Online Learning. Market.us Scoop*. 2025. URL: https://scoop.market.us/educational-robots-statistics/
47. Presidential Actions. President’s Council of Advisors on Science and Technology. 2025. URL: https://www.whitehouse.gov/presidential-actions/2025/01/presidents-council-of-advisors-on-science-and-technology /
48. Robotics in STEM Education. Redesigning the Learning Experience. Myint Swe Khine., Ed. Springer International Publishing AG, 2017. 260 p. DOI: https://doi.org/10.1007/978-3-319-57786-9
49. Ryan, M., Gale, J., Usselman, M. Integrating engineering into core science instruction: Translating NGSS principles into practice through iterative curriculum design. *International Journal of Engineering Education.* 2017. Vol. 33(1). Pp. 321–331. URL: https://mspnet-static.s3.amazonaws.com/05_ijee3374ns--IJEE_2017_article.pdf
50. Sapounidis, T., Alimisis, D. Educational Robotics Curricula: Current Trends and Shortcomings. In: Malvezzi, M., Alimisis, D., Moro, M. (eds). *Education in & with Robotics to Foster 21st-Century Skills*. EDUROBOTICS 2021. Studies in Computational Intelligence. 2021. Vol. 982. Springer, Cham. DOI: https://doi.org/10.1007/978-3-030-77022-8_12
51. Sapounidis, T., Alimisis, D. Educational robotics for STEM: A review of technologies and some educational considerations. In book: *Science and Mathematics Education for 21st Century Citizens: Challenges and Ways Forward*, Chapter: 9. Publisher: Nova science publishers: Hauppauge, NY, USA, 2020. Pp. 167–190. URL: https://www.researchgate.net/publication/346588762_Educational_robotics_for_STEM_A_review_of_technologies_and_some_educational_considerations
52. Sapounidis, T., Stamelos, I., Demetriadis, S. Tangible User Interfaces for Programming and Education: A New Field for Innovation and Entrepreneurship. *Innovation and Entrepreneurship*

in Education (Advances in Digital Education and Lifelong Learning, 2). Emerald Group Publishing Limited, Leeds, 2016. Pp. 271-295. DOI: https://doi.org/10.1108/S2051-229520160000002016

53. Scardamalia, M., Bereiter, C. Knowledge building: Theory, pedagogy, and technology. In K. Sawyer (Ed.), Cambridge Handbook of the Learning Sciences. New York: Cambridge University Press, 2006. Pp. 97-118. URL: https://ikit.org/fulltext/2006_KBTheory.pdf .
54. Small computer handbook. Digital Equipment Corporation, 1973. 591 p. URL: http://vandermark.ch/pdp8/uploads/PDP8/PDP8.Manuals/DEC-S8-OSSCH-A.pdf
55. Standards for Technological Literacy: content for the study of technology. Third Edition. International Technology Education Association and its Technology for All American Project. 2007. 260 p.URL: https://wwwcp.umes.edu/tech/wp-content/uploads/sites/94/2021/09/xstnd.pdf
56. STEM Education Act of 2015. *LEGISLATIVE HISTORY – H.R. 1020: SENATE REPORTS*. 2015. No. 114–115 (Comm. on Commerce, Science, and Transportation). CONGRESS.GOV. URL: https://www.congress.gov/114/plaws/publ59/PLAW-114publ59.pdf
57. Sullivan, A., Bers, M. U. Robotics in the early childhood classroom: Learning outcomes from an 8-week robotics curriculum in pre-kindergarten through second grade. *International Journal of Technology and Design Education.* 2016. Vol. 26(1). Pp. 3–20. DOI: https://doi.org/10.1007/s10798-015-9304-5
58. Theodosios, S., Demetriadis, S. Tangible versus graphical user interfaces for robot programming: exploring cross-age children’s preferences. *Personal and Ubiquitous Computing.*2013. Vol. 17(8). Pp. 1775–1786. DOI: https://doi.org/10.1007/s00779-013-0641-7
59. The NSTC’s 2024 Report on the Committee on Science, Technology, Engineering, and Mathematics (CoSTEM) and CoSTEM-Related Agency Actions. 2025. 100 p. URL; https://www.whitehouse.gov/wp-content/uploads/2025/01/2024-CoSTEM-Annual-Report.pdf
60. United State Government. U.S. National Science Foundation. Robotics. 2025. URL: https://new.nsf.gov/focus-areas/robotics
61. Uslu, N. A., Yavuz, G. Ö., Usluel, Y. K. A systematic review study on educational robotics and robots. *Interactive Learning Environments.* 2023. Vol. 31(9). Pp. 5874–5898. DOI: https://doi.org/10.1080/10494820.2021.2023890
62. Wonacott, M. E. Technological Literacy. ERIC Digest. ERIC Clearinghouse on Adult Career and Vocational Education Columbus OH. 2001. 7 p. URL: https://files.eric.ed.gov/fulltext/ED459371.pdf
63. World University Rankings 2025. *THE – Times Higher Education*. 2025. URL: https://www.timeshighereducation.com/world-university-rankings/latest/world-ranking
64. Zhang, Y., Luo, R., Zhu, Y., Yin, Y. Educational robots improve K-12 students’ computational thinking and STEM attitudes: Systematic review. *Journal of Educational Computing Research.* 2021. Vol. 59(7). Pp. 1450–1481. DOI: https://doi.org/10.1177/0735633121994070
65. 2024 Best STEM High Schools. U.S. News & World Report L.P. 2025. URL: https://www.usnews.com/education/best-high-schools/national-rankings/stem

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