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IMPLEMENTATION OF STEM EDUCATION IN GENERAL EDUCATION INSTITUTIONS

IMPLEMENTAÇÃO DA EDUCAÇÃO STEM NAS INSTITUIÇÕES DE ENSINO GERAL

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ABSTRACT

The article investigates the fundamental characteristics of contemporary STEM education, encompassing integrated learning, critical thinking, problem-solving skills, as well as active communication and teamwork abilities. It presents a novel and imaginative strategy for project development, which aims to equip students with the necessary skills to engage in lifelong technological innovation by applying scientific and technological knowledge to real-world scenarios. Furthermore, the article sheds light on the core components of STEM education, drawing from the US government's initiatives aimed at integrating STEM approaches into the national education system. In addition, the article underscores the imperative to reassess the underlying philosophy of STEM education and the need for its actualization. This is accomplished through the introduction of a STEM education model that facilitates the seamless integration of STEM subjects with all other academic disciplines. Moreover, the article addresses crucial aspects of the US national policy on arts education. It delves into the development and implementation of the National Core Arts Standards and the National Visual Arts Standards, which play a pivotal role in supporting arts education initiatives. The article delves into an analysis of the theoretical and methodological principles underpinning the development of a STEM education model. This includes an examination of project-based and practice-oriented learning, as well as the utilization of flipped and blended learning approaches, alongside cloud technologies, to facilitate the transformation of traditional education into an innovative learning environment. Furthermore, the article outlines the anticipated steps involved in the implementation of STEM education, with a focus on fostering career autonomy and empowering students to make informed choices about their professions. These steps encompass the promotion and popularization of STEM specialties, the provision of support for gifted students, and the encouragement of youth engagement in creative and research-oriented activities. Expanding on the understanding of how STEM education can be effectively implemented, the article enriches the information field with innovative methods, tools, and organizational forms for the educational process. These include hackathons, marathons, online experiments, e-virtual laboratories, science museums, and platforms designed to facilitate the organization of research activities and international projects. It is noteworthy that the successful implementation of these innovations will not only enhance the quality of foreign literature courses within the New Ukrainian School but also serve as a significant catalyst for the development of competitive and creative graduates.

Keywords: STEM education. STEM training. STEM education model. STEM competencies. Secondary education institution.

RESUMO

O artigo investiga as características fundamentais da educação STEM contemporânea, abrangendo aprendizagem integrada, pensamento crítico, habilidades de resolução de problemas, bem como comunicação ativa e habilidades de trabalho em equipe. Apresenta uma estratégia nova e imaginativa para o desenvolvimento de projetos, que visa dotar os alunos das competências necessárias para se envolverem na inovação tecnológica ao longo da vida, aplicando conhecimentos científicos e tecnológicos a cenários do mundo real. Além disso, o artigo esclarece os componentes principais da educação STEM, com base nas iniciativas do governo dos EUA destinadas a integrar abordagens STEM no sistema educativo nacional. Além disso, o artigo sublinha a necessidade de reavaliar a filosofia subjacente à educação STEM e a necessidade da sua atualização. Isto é conseguido através da introdução de um modelo de educação STEM que facilita a integração perfeita das disciplinas STEM com todas as outras disciplinas académicas. Além disso, o artigo aborda aspectos cruciais da política nacional dos EUA em matéria de educação artística. Ele se aprofunda no desenvolvimento e implementação dos Padrões Nacionais de Artes Básicas e dos Padrões Nacionais de Artes Visuais, que desempenham um papel fundamental no apoio a iniciativas de educação artística. O artigo analisa os princípios teóricos e metodológicos que sustentam o desenvolvimento de um modelo de educação STEM. Isto inclui uma análise da aprendizagem baseada em projetos e orientada para a prática, bem como a utilização de abordagens de aprendizagem invertidas e combinadas, juntamente com tecnologias de nuvem, para facilitar a transformação da educação tradicional num ambiente de aprendizagem inovador. Além disso, o artigo descreve as etapas previstas envolvidas na implementação da educação STEM, com foco na promoção da autonomia profissional e na capacitação dos alunos para fazerem escolhas informadas sobre as suas profissões. Estas etapas abrangem a promoção e popularização de especialidades STEM, a prestação de apoio a estudantes sobredotados e o incentivo ao envolvimento dos jovens em atividades criativas e orientadas para a investigação. Expandindo a compreensão de como a educação STEM pode ser implementada de forma eficaz, o artigo enriquece o campo da informação com métodos, ferramentas e formas organizacionais inovadoras para o processo educacional. Estas incluem hackathons, maratonas, experiências online, laboratórios virtuais eletrónicos, museus de ciência e plataformas concebidas para facilitar a organização de atividades de investigação e projetos internacionais. É digno de nota que a implementação bem-sucedida destas inovações não só melhorará a qualidade dos cursos de literatura estrangeira na Nova Escola Ucraniana, mas também servirá como um catalisador significativo para o desenvolvimento de graduados competitivos e criativos.

Palavras-chave: Educação STEM. Formação STEM. Modelo de educação STEM. Competências STEM. Instituição de ensino secundário.

Introduction

One of the contemporary challenges in the field of education is to unlock the full potential of all participants engaged in the educational process and to provide them with ample opportunities to express their creativity. Addressing these challenges necessitates a recognition of the dynamic nature of the educational process, wherein a diverse range of modern activities takes place, demanding rigorous and critical evaluation. A promising approach to enhancing modern educational institutions involves fostering a culture of improved activities, wherein educators are encouraged to create and disseminate new educational products. These innovative learning products are expected to yield tangible outcomes. The introduction of any novel educational approach requires well-defined plans for implementation and rigorous evaluation of its results, particularly under specific contextual conditions. STEM education stands out as a prominent driver for the incorporation of innovative activities within general secondary education institutions. Its holistic approach integrating science, technology, engineering, and mathematics creates an environment conducive to fostering innovation and addressing the challenges of the modern educational landscape. STEM is an educational discipline that encompasses science, technology, engineering, and mathematics, emphasizing an interdisciplinary and hands-on approach to learning. Educational programs within STEM are designed to bolster natural sciences and incorporate emerging technologies. By integrating scientific and technological concepts, STEM aims to equip students with the knowledge and skills required to navigate the complexities of the modern world effectively. An essential objective of STEM education is to establish a sustainable connection between general secondary education institutions and society, thereby fostering the practical application of acquired knowledge. The primary focus of this study is to investigate the specificities of teaching in general education institutions with the incorporation of new educational technologies within the STEM framework. The significance of this research lies in addressing the contemporary challenge faced by schools to unlock the potential of all participants and foster an environment that encourages creativity in the educational process.

Literature Review

The works of several researchers who have explored the theoretical and practical aspects of informatization in education, with a specific focus on the integration of information technologies as a facet of implementing STEM education, have been identified. Among these researchers are N. Morze, O. Patrikeeva, N. Balyk, I. Dychkivska, O. Kovalenko, O. Kurnosenko, and others. Their studies are centered on addressing the challenge of nurturing innovative and scientific-research thinking among both teachers and students, serving as a foundational element of STEM education. Notably, the following scholars have contributed to this area of research: Barna O., Vashchenko L., Honcharova N., Zhuravel T., Kovbasenko Yu., Kornienko O., Lozova O., Gorbenko S., and others.

The majority of scientists emphasize that the successful implementation of STEM education necessitates interdisciplinary and project-based approaches. Through scientific and practical endeavors, researchers have elucidated the substantive content and conceptual framework underpinning the implementation of STEM education. The introduction of STEM education to students entails acquainting them with various cutting-edge concepts and technologies, including but not limited to innovations, creative industries, nanotechnology, scientific literacy, and project activities. This exposure to diverse domains of knowledge empowers students to engage with the dynamic world of modern science and technology.

Methodology

The research materials utilized in this study comprise scientific articles authored by researchers (see References) who have extensively investigated the subject matter. The article was developed employing various theoretical methods, including:

1. Analysis and synthesis of the researched material: This involved segregating essential and general information from specific and less significant details.
2. Axiomatic approach: Logical proofs were applied to substantiate statements concerning the significance of implementing the STEM model in general educational institutions.
3. Systemic and structural considerations: STEM education was examined as a comprehensive system, with its functions and roles elucidated in comparison to other educational models. This identification was based on an analysis of prevailing patterns and developmental trends within the STEM system.

Through an in-depth examination of foreign experiences in implementing the STEM learning model in education, this study seeks to identify the potential prospects for the advancement of science and education in this direction within Ukraine. These prospects include but are not limited to:

1. Supporting STEM education at the national level to foster a conducive environment for the growth of STEM disciplines.
2. Encouraging mutual development among scientific organizations, universities, and centers to attract students of various age groups, stimulating their interest in science and scientific research.

3. Promoting participation in internationally recognized competitions that allow students to showcase their talents and achievements, thereby emphasizing their personal development within the STEM field.

4. Enhancing STEM teacher training programs to ensure the availability of well-qualified educators who can effectively impart STEM knowledge.

Moreover, a comprehensive analysis of relevant scientific works has identified significant factors influencing the strategy for engaging young individuals in STEM education. These factors include:

- Role models who inspire and serve as examples for aspiring STEM learners.
- Practical experiences that provide hands-on exposure and understanding of STEM principles.
- Motivation to pursue STEM studies, which fuels curiosity and interest in the subjects.
- The practical significance of STEM technologies, emphasizing the real-world applications and relevance of STEM disciplines.

Results

Education plays a pivotal role in aligning with the prevailing trends in societal development and catalyzes enhancing the competitive edge of national science.

The term STEM is an acronym derived from the English words: Science, Technology, Engineering, and Mathematics. STEM education serves as the cornerstone of contemporary didactics, emphasizing interdisciplinary subjects (Balyk N.R., 2016). Moreover, STEM actively incorporates creative and artistic disciplines, which are further elaborated in Table 1. Particularly, industrial design, architecture, and industrial aesthetics emerge as pertinent areas within the STEM domain.

Table 1 – Various options for STEM education.

№	Concept	Subjects
1	STEM	Science + Technology + Engineering + Mathematics
2	ESTEM	STEM + Environment
3	STREM	STEM + Robotics
4	STEMM	STEM + Medicine
5	STEAM	STEM + Arts
6	STREAM	STEM + Religion + Arts
7	METALS	STEM + Arts + Logic (Mathematics + Engineering + Technology + Arts + Logic + Science)

STEM education exhibits dynamic growth within the creative realm, encompassing various artistic disciplines such as industrial design, architecture, industrial aesthetics, and more. Scholars in the United States assert that a sole focus on scientific education without parallel development in artistic disciplines may result in a deficiency of creativity among the younger generation. As a proactive response to this concern, several countries, including China, the UK, Israel, Korea, Singapore, and the USA, have established national STEM education programs.

STEM education in the United States is founded on collaborative efforts involving numerous organizations, including government departments, agencies, state institutions, public and volunteer enterprises, scientific societies, research laboratories, universities, school education institutions, after-school creativity centers, and technical centers. A key coordinator in this landscape is the U.S. Department of Energy, which spearheads the STEM-rising program. This initiative offers a range of ready-made developments for diverse projects targeted at kindergarteners, students in grades 1-12, college students, and teachers with a vested interest in STEM education. For instance, the project "Saving Electricity" invites elementary school students to engage in a series of experiments aimed at cultivating an understanding of their dependence on electricity and exploring effective methods for regulating energy consumption. Through such participatory projects, students are encouraged to develop critical thinking and problem-solving skills while actively immersing themselves in practical STEM concepts. This comprehensive approach to STEM education nurtures a generation of scientifically literate and technologically adept individuals, fostering innovation and progress in various spheres of society. High school students can actively participate in the project "Energy of the Ocean," which involves simulated activities such as "drilling" an oil well and "constructing" a floating oil platform. Through this project, students delve into the study of energy resources present in the ocean, including oil, natural gas, and other relevant sources. Teachers, on the other hand, are provided with sets of instructional materials on various subjects, one of which is the "Harnessed Atom" program. This educational package elucidates fundamental principles of energy science, offering up-to-date information on nuclear energy. The sets also encompass experimental studies and practical exercises, such as modeling lithium and hydrogen atoms, thereby enabling teachers to effectively deliver engaging lessons in the classroom (Peters-Burton E. & others, 2014).

The department is actively engaged in promoting STEM education through collaborative educational initiatives with national laboratories. This partnership offers students a unique opportunity to engage in authentic scientific research, conduct experiments, report their findings, and even provide real consulting services. Notably, NASA actively supports STEM education and hosts a plethora of projects tailored to students of all age groups (grades 1-4, 5-8, 9-12), teachers, college students, and homeschoolers. These projects are intricately linked to the exploration of outer space, encompassing topics such as the Earth, Moon, Mars, constellations, airplanes, and more. Participants are encouraged to explore an array of resources, including video materials, games, and puzzles. Additionally, they partake in physical exercises aimed at enhancing lung and heart health, engage in experimental research and measurements, and even learn how to construct equipment relevant to their scientific pursuits. This holistic approach to STEM education empowers learners to acquire hands-on experience, critical thinking skills, and a deeper understanding of various scientific disciplines, fostering their passion for exploration and discovery.

The "Family" portfolio of subjects, encompassing Engineering, Natural Sciences, Technology, and Informatics, as well as Mathematics, holds a particular allure in the context of STEM education. Within this portfolio, various stimulating tasks are presented to contestants, such as designing a parachute to ensure a slow and gentle landing of cargo. Participants are encouraged to conduct tests with different materials, select optimal shapes and designs for the parachute, and optimize the landing route, among other factors. One prominent national center dedicated to STEM education is Washington STEM. Established in 2011 as an independent nonprofit organization, its primary objectives include introducing students to diverse STEM professions, fostering each child's skills to manifest their ideas within their chosen profession, and equipping them with essential skills for their future careers. Over time, Washington STEM has evolved into a robust network of regional partner centers, uniting an extensive array of teachers, business leaders, experts, and organizations. Together, they work collaboratively to promote professional development opportunities for all participants, irrespective of gender, race, or initial professional experience.

Concurrently with the introduction of STEM education in the United States, there emerged a significant discourse regarding the incorporation of arts within science programs and the imperative to transition towards STEM education. This necessity finds validation in the outcomes of a collaborative study conducted by The Conference Board and the American Association of School Administrators (AASA). The study highlights that contemporary industries seek professionals equipped with creative and artistic abilities, deeming them more essential than mere mathematical or scientific skills. Moreover, employers are keen on individuals capable of generating innovative ideas, collaborating effectively within teams, and possessing strong communication acumen. Support for STEM education is further buttressed by the fact that creative skills extend their relevance to the broader workforce. America's competitive edge lies in its commitment to fostering creative industries, ranging from film, television, and computer games to architecture, design production, graphics, and beyond.

The national program aims to foster the training of skilled personnel in high-tech fields, and in line with this goal, Ukraine has recently intensified efforts toward the development of STEM education. A notable milestone in this direction is the establishment of the STEM Education Department at the Institute of Modernized Education. The department is entrusted with the following responsibilities:

1. Formulating a comprehensive regulatory framework encompassing documents, scientific resources, and methodological materials to facilitate the effective implementation of STEM education.

2. Exercising scientific and methodological oversight over innovative activities, specifically those incorporating STEM technologies within general secondary education institutions.

3. Providing practical assistance to educational institutions and local education departments in the adoption and execution of STEM education initiatives.

4. Conducting thorough research and analysis to identify challenges and opportunities for the advancement of STEM education.

5. Coordinating the collaboration of working groups composed of scientists, teachers, and experts in the field of STEM technologies.

6. Establishing communication channels with relevant services and educational institutions in the sector.

7. Initiating and supervising innovative educational projects to enhance STEM learning experiences.

8. Organizing and conducting scientific and practical seminars and events, aimed at the training and professional development of teachers across various disciplines, with a specific focus on issues related to innovative educational practices within the domain of STEM technologies.

9. Investigating and implementing international best practices in the realm of STEM education to incorporate global insights and advancements into the national context (Honcharova N., 2019).

Presently, discussions surrounding STEM education in Ukrainian schools remain premature, as only certain elements of STEM technologies have been introduced thus far. The full-fledged development of STEM education within the educational process of general secondary education institutions in Ukraine is envisioned to cultivate a host of advantageous outcomes. Most notably, it will facilitate the nurturing of students' abilities to experiment, design, and innovate, thereby fostering a high level of qualification among specialists in the realm of innovation. The primary objectives of these technologies encompass:

- Fostering the comprehensive development of key professional, social, and personal competencies among young individuals, thereby bolstering their competitiveness in the labor market.
- Cultivating the readiness to tackle complex problems, instilling in students the ability to formulate research questions and devise effective solutions.
- Nurturing flexibility, enabling students to embrace new ideas and articulate and defend their positions coherently.
- Encouraging originality and breaking free from conventional templates.
- Cultivating the capacity for idea recombination, abstraction, analysis, concretization, and synthesis.
- Developing a sense of harmony in the organization of ideas, fostering a holistic approach to understanding and problem-solving.
- Nurturing critical thinking, creativity, management skills, and an innovative mindset among students (Kurnosenko O. V.,2018).

In the process of implementing STEM education in educational institutions, teachers play a pivotal role in actively incorporating innovative teaching methods such as programming, interactive, and problem-based learning. Among the various problem-based learning approaches, project-based learning occupies a significant position, enabling students to acquire knowledge, competencies, and skills through engaging in research activities. These research activities revolve around complex real-world technical problems, supported by meticulously crafted tasks. Consequently, students undergo a comprehensive technical algorithm, spanning from the inception of an innovative idea to the development of a viable commercial product, and learning the art of presenting it to potential investors. This immersive approach allows students to garner both theoretical knowledge and practical expertise, positioning them effectively to address real-world challenges and contribute to the development of innovative solutions. In the national methodology, the definition of the concept of "model" encompasses diverse perspectives and opinions, reflecting the multifaceted nature of STEM education and the varied approaches undertaken in its implementation.

One of the approaches employed in understanding the innovation process involves highlighting specific properties, emphasizing the analogy to the original model. V. Shtoff characterizes the model as "...a mentally represented or materially realized system that, by reflecting or reproducing the object of study, can replace it so that its study gives us new information about the functions of this object" (Harrison, M., 2015). Several scholars have contributed to the conceptualization of the innovation process through diverse models. R. Normann's perspective views the model as a two-stage process, comprising initiation and implementation. G. Khage and M. Eiken's model offers a more comprehensive approach, dividing the innovation process into four stages: assessment, initiation, implementation, and routinization. On the other hand, S. Mayers and D. Margis propose a five-stage model: understanding the problem, generating an idea, finding a solution to the problem, implementing the solution, and using it. In a similar vein, G. Vilson identifies three stages: conceptualization, proposal, adoption, and implementation. L. Cummings and M. O'Connell distinguish five phases of the innovation process: searching for the "germ" of the problem, proposing innovation, evaluating all possible solutions, selecting the best option, and approving and implementing it. An additional aspect of the innovation process involves integrated learning through "topics" rather than traditional subjects (Barna O. V., 2017).

STEM education is characterized by the integration of project-based and interdisciplinary approaches, effectively combining natural sciences, technology, engineering, creativity, and mathematics. Through hands-on courses, STEM education seeks to demonstrate to students the tangible and practical application of scientific and technological knowledge in real-world scenarios. Engaging in specific projects, students actively participate in the creation of prototypes for real products, thereby honing critical thinking and problem-solving skills (Zhuravel T.O., 2016).

STEM projects play a crucial role in bolstering self-confidence among young individuals. Through the process of creating diverse products and independently resolving challenges, participants progressively gain confidence in their abilities. This heightened sense of self-assurance is further reinforced through active communication and teamwork, essential components of STEM projects. During the discussion phase of STEM projects, an atmosphere conducive to open and free expression of opinions is fostered. This encourages participants to engage in constructive discussions, where ideas and perspectives are exchanged without hesitation. Continuous communication with mentors and teammates throughout the project duration further enhances the participants' interpersonal skills and teamwork abilities. Notably, the dynamic and collaborative nature of STEM projects instills a growing interest in technical subjects among the participants. As they immerse themselves in the problem-solving process and see tangible results from their efforts, the allure of technical disciplines becomes increasingly apparent.

The primary objective of incorporating STEM technologies in general secondary education is to foster and nurture students' interest in natural and technical disciplines. Lessons infused with elements of STEM technologies are characterized by their captivating, dynamic, creative, and innovative nature. STEM learning follows a structured sequence of stages, which include questioning (assignment), discussion, design, creation, testing, and implementation. These stages form the foundation of the project-based approach in STEM education. By immersing students in the simultaneous study and practical application of science and technology, numerous innovative projects can be conceived and realized. These projects may encompass diverse areas such as connecting education with career prospects, as well as preparing students for the challenges and opportunities presented by technological advancements in their lives (Patrikeeva O. O., 2016).

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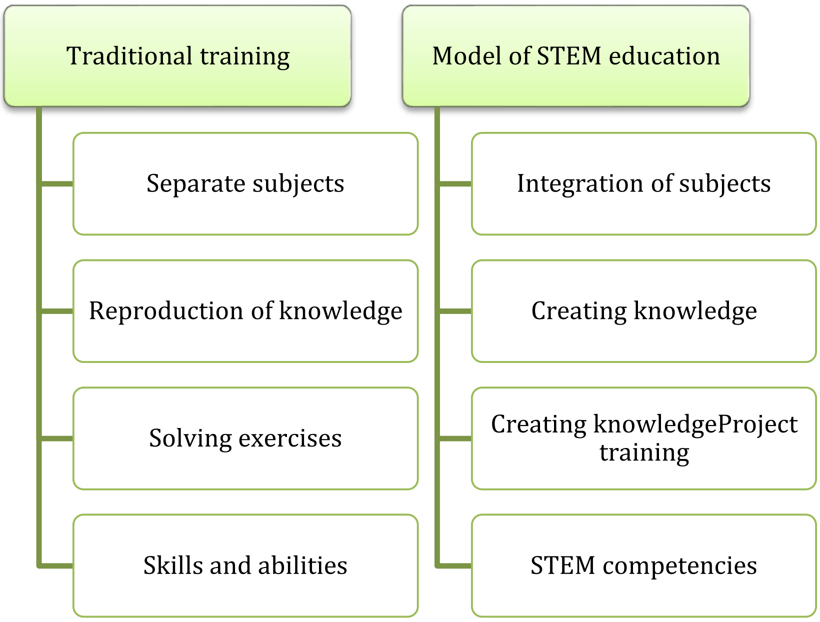
Figure 1 – Comparison of traditional and STEM education



In recent times, it has become evident that conventional teaching methods no longer align with the demands of our rapidly evolving society. While traditional universities excel at producing skilled teachers in disciplines such as philosophy or history, the training of machinists, engineers, and inventors requires a different approach—one that starts from childhood and emphasizes the acquisition and application of new information. This early exposure not only enables young innovators to showcase their talents and abilities promptly but also fosters a greater affinity towards the natural sciences, dispelling any apprehension towards complex subjects. The increasing demand for technical specialists presents a pressing concern as we already face shortages in this domain. Consequently, the time has come to sow the seeds of progress that will burgeon shortly, meeting the surging demands of science and technology. By conducting an analysis of the theoretical and methodological underpinnings for an innovative model of STEM education, we can discern the principal distinctions from traditional educational paradigms.

The efficacy of STEM education and the successful implementation of an innovative approach in the new Ukrainian school hinge upon two crucial factors: the modernization of the subject component within the science and mathematics cycle and the critical element of material and technological support for educational institutions.

Modern information support and the availability of measuring devices serve as motivational components for students' educational and research pursuits, fostering their intellectual and creative engagement. These resources play a pivotal role in the development of cognitive interests and the cultivation of disciplinary abilities, thereby creating an environment conducive to students' professional growth and development. Given the pressing need for the comprehensive development of STEM education, it is imperative to undertake a concerted effort at the state level. In line with this vision, the Institute for the Modernization of Educational Content (IMEC) was established to advance a contemporary approach to education in Ukraine. To bolster this initiative, leading foreign companies operating in Ukraine, including Ericsson, Intel, and Melexis, have pledged their support. In consequence, the Ukrainian STEM Education Alliance and the public organization "Center for the Development of Social Corporate Responsibility" have been established, bringing together a coalition of 38 companies (Khokhlina O.P., 2019). The STEM Education Alliance is an esteemed organization that unites companies, educational institutions, associations, specialized organizations, municipalities, and the media with a shared objective of enhancing the quality of STEM education in Ukraine. The mission of the STEM Education Alliance encompasses several vital goals:

1. Developing and presenting recommendations to the Ministry of Education and Science of Ukraine regarding the effective teaching of STEM subjects, thereby contributing to the continuous improvement of STEM education across the nation.

2. Initiating and coordinating projects aimed at guiding and inspiring young individuals towards meaningful employment opportunities within STEM fields, promoting the alignment of educational pursuits with the demands of the job market.

3. Facilitating the professional development of teachers by imparting innovative approaches to teaching STEM subjects, ensuring educators are well-equipped to deliver engaging and impactful lessons.

4. Paving the way for experimentation and research opportunities within general secondary education institutions, fostering an environment conducive to inquiry-based learning and scientific exploration.

5. Organizing and hosting technical competitions, olympiads, missions, hackathons, and similar events to stimulate the spirit of competition and innovation among students and educators alike.

6. Creating information platforms, such as websites and social media pages, to popularize and raise awareness about the significance of STEM education, thereby inspiring a wider audience of students, parents, and educators.

7. Promoting and fostering international collaboration in the field of STEM education, facilitating knowledge exchange and best practices sharing with global partners.

Modern STEM education methods have been widely adopted by schools throughout Ukraine. In addition to the regular curricular offerings, extracurricular STEM education also plays a crucial role in achieving the same educational objectives. Various extracurricular activities, such as clubs, competitions, and the Junior Academy of Sciences, actively engage students in STEM-related pursuits. Moreover, numerous projects and competitions dedicated to environmental education further reinforce the importance of STEM principles in addressing contemporary challenges. Looking ahead, the nationwide implementation of the STEM: Career in the Future project is scheduled for the forthcoming years. As part of this endeavor, the All-Ukrainian Scientific and Methodological Virtual STEM Center was established in 2016 to promote and facilitate the realization of this educational initiative. For the effective integration of STEM education and the successful implementation of innovative approaches in new Ukrainian schools, certain critical factors warrant attention.

The most prevalent teaching aids employed in STEM education encompass a wide range of tools and equipment, such as constructors, robotic systems, models, measuring systems, and sensors, along with laboratory instruments and electronic devices (3D printers, computers, digital equipment, various models of projection screens, codoscopes, scratchboards, interactive whiteboards, physical cameras, projection tables, etc., 2019). By utilizing these resources, students gain the opportunity to conduct experiments, undertake tasks using models of diverse processes and phenomena, and develop a comprehensive understanding at the interdisciplinary level. To optimize the educational experience, STEM laboratories should be equipped with state-of-the-art technological tools and equipment. These facilities should cater to scientific research across a broad spectrum of fields, including technical modeling, electrical engineering, information technology, biology, nano- and energy-saving technologies, automation, remote mechanics, robotics and intelligent systems, radio engineering and electronics, aeronautics, aerospace engineering, and more.

In practice, it becomes evident that easily accessible educational Internet resources serve as valuable supplements to traditional teaching methods. These resources offer equal learning opportunities for adolescents of all ages, including those with special needs, facilitating the attainment of quality education. Moreover, they provide a platform for various types of learning, such as individual learning, group learning, and project-based activities, enhancing the versatility of the educational experience. However, teachers must guide students in understanding the capabilities of these online resources and initiate discussions about important aspects of Internet safety, ethical conduct, and copyright compliance. By imparting such knowledge, educators ensure that students navigate the digital realm responsibly and ethically. An obstacle faced by many online resources supporting STEM education is the predominance of English-language interfaces. This limitation hampers their effective use without appropriate language proficiency among users (Kovalenko O., 2016).

The successful implementation of STEM education is contingent upon the competence and level of professional activity demonstrated by scientists and teachers. Utilizing the latest teaching methods to engage students is paramount in this process. Active involvement in various regional, national, and global events, including scientific and practical conferences, seminars, webinars, STEM festivals, competitions, and online STEM schools, contributes significantly to the development of teachers' professional competencies (Vashchenko L., 2003). Participation in such events not only equips educators with fresh knowledge and access to new resources, but also offers a platform to showcase their accomplishments and facilitates the exchange of novel ideas, insights, and experiences. To ensure comprehensive professional growth, teachers should proactively engage in projects not only facilitated by national educational institutions but also those sponsored by the state, international (grants), and commercial entities (Dychkivska I.M., 2004). Accessing relevant information about STEM education activities organized by the Ministry of Education and Science of Ukraine and the Institute for the Modernization of Education Content can be achieved through official websites and social media pages of pertinent institutions.

Discussion

The implementation of STEM education in secondary schools in Europe and the United States is extensively documented and disseminated on the Internet, aiming to promote exemplary STEM practices and showcase innovative STEM resources. Notably, the STEM Alliance plays a vital role in this regard, organizing an annual online hackathon to facilitate open discussions on the challenges and prospects of incorporating innovative STEM resources into European and global education. To further support STEM education, the Alliance conducts a series of webinars covering diverse topics, such as aerospace projects in the classroom, encouraging women in STEM fields, and utilizing educational materials from Lego. Additionally, the Alliance provides researchers and practitioners with complimentary access to valuable resources and materials designed for STEM classrooms and lesson planning. An example of such open educational STEM resources can be found within the Concorde Consortium's collection, featuring interactive simulators and virtual laboratories. Through these resources, students can actively engage in scientific research and experiments, exploring dynamic models of various mathematical concepts, definitions, and theorems, and delving into the modeling of diverse natural phenomena and processes. In conclusion, when summarizing the experience of implementing STEM technologies in education abroad, several key observations emerge:

- There exists a strong public interest in enhancing students' knowledge and skills in natural and mathematical subjects and technologies.
- Various organizations and companies are actively involved in promoting STEM education, aiming to educate future professionals who can collaboratively tackle emerging challenges, generate innovative ideas, and express themselves effectively.
- Government support for schools, centers, and organizations dedicated to STEM education is comprehensive and instrumental in driving progress in this field.
- Abundant opportunities are provided for students of all ages to engage in project-based work across a wide spectrum of public and private organizations, laboratories, and centers.
- Adequate funding for STEM development is available and can be further optimized, enabling continuous improvement, utilization, and implementation of STEM initiatives.
- Recognizing the significance of targeted training for future teachers in organizing STEM projects, efforts are being made to raise awareness about the importance of such training.
- Given these observations, it is evident that research in the specific areas of training future teachers to organize STEM projects in Ukraine, as well as the integration of STEM education into the educational process of the New Ukrainian School, holds considerable promise.

Conclusions

STEM education's most crucial aspect lies in its commitment to fostering comprehensive skills in applying scientific and technological knowledge to real-

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world situations. The transformation from traditional to innovative learning forms the scientific and methodological foundation for developing the STEM education model, predominantly relying on project-based learning methods. Various forms of engagement play a vital role in enticing young individuals to pursue STEM fields. These include competitions, Olympiads, science picnics, festivals, and the establishment of dedicated STEM schools. To further advance the field of STEM education, promising research avenues involve the collaborative efforts of scientists and educators from both formal and non-formal educational institutions. Their focus is on disseminating the most effective STEM educational practices and fostering strategic partnerships between general secondary education institutions and STEM-oriented institutes.

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