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Preparing Future Educators of Primary School for Implementing STEM Education Elements and the Use of Artificial Intelligence (AI) in the Field of Education

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Abstract: *This article examines ways of preparing future educators to work within the digital transformation context in modern schools. Our authors explore the role of STEM technology and the use of Artificial Intelligence (AI) in developing professional competencies among undergraduate education students, which are essential for working in today's schools. The study highlights key trends in higher pedagogical education, which are emphasised through the STEM approach application. The contemporary school is viewed as a space that nurture individuals prepared to acquire an integrated knowledge system and apply it within a dynamically changing social and educational environment. The article demonstrates the effectiveness of applying the STEM approach and the use of Artificial Intelligence (AI) in primary education, which is associated with the real synergy between different fields of knowledge in the educational process. We believe that teachers can incorporate project-based learning plans into STEM lessons. Technologies as modern teaching tools expand students' professional opportunities in the job market, guiding them towards designing and exploring scientific and technical activities. This article defines the role of the education of STEM in the modern world, emphasises the importance on preparing teaching staff for STEM implementation, and explores the significance of introducing STEM education in primary school. Modern AI capabilities in the context of primary education are analysed, including personalised learning, automated assessment, digital assistants, and intelligent decision support systems.*

Keywords: *STEM learning; STEM methodology; STEM innovations; AI; contemporary school; digital evolution; educator preparation; advanced teacher education.*

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1. Introduction

Today, educational institutions are experiencing global change, primarily due to rising demands for teachers' professional competence. The teacher's role is less about passing on knowledge to the next generation and more about cultivating students' abilities to adapt flexibly, respond swiftly, and think creatively to societal changes.

For years, schools have served as custodians of tradition, but they are increasingly becoming a space where teachers must foster innovative thinking in future generations. Achieving this challenging and ambitious goal requires new approaches to preparing personnel for modern schools.

A contemporary teacher must operate within a digital educational environment, possess innovative education methods, and adapt traditional pedagogical techniques to distance learning. Additionally, educators should utilise the learning space for diverse project-based activities, and create decision-making scenarios for students. Such an expansion in the competency profile of a pedagogical bachelor's degree graduate requires new approaches to organise the process of educating and integrating contemporary technologies in the practical training of university lecturers.

Overall, our research focuses on preparing future educators to work within the digital transformation of modern schools, in which we see the STEM approach as an effective tool.

The relevance of the study lies in the fact that many innovations have emerged in the past decade, playing a significant role in knowledge-based education sectors related to cognitive-intensive disciplines. Information and communication technologies, as well as creative industries, serve as drivers of national economic development in many countries, leading to changes in these areas. Global educational systems have influenced the development of education systems, demanding global changes. While traditionally, mathematics and technology have taken the lead, there is a growing imperative to integrate arts and creative disciplines into the curriculum. Throughout history, humans have developed technologies to meet their needs and desires, with most modern technologies being products of engineering, science, and applied technical tools.

According to Atamanchuk & Atamanchuk (2021b, p. 4), "STEM technologies first appeared in the USA. Some schools decided to integrate natural sciences, mathematics, technical sciences, and engineering. Later, the field of art was also added." American teachers believe that subject-matter expertise in these disciplines will help students become highly skilled professionals.

Banada (2018) argues: "Students now have access to additional areas of education, such as programming, robotics, and modelling. However, researchers in this field believe that knowledge of engineering and natural sciences is sometimes insufficient, requiring interdisciplinary interaction with other fields of education." Students operate in hybrid learning environments, where they are immersed in science and learn scientific methods in practical applications. Borrego & Henderson (2014) believe that "the primary goal of traditional school education is to provide knowledge and apply it in the processes of thinking and creativity. Learning in the context of STEM technologies means combining acquired knowledge with practical skills." As a result, students' ideas not only remain in their minds but can be applied practically in their lives. The knowledge tested through practical application is the most valuable. Gokbulut (2020) argues that "in the modern world, students must acquire many skills rightly called 21st-century skills". The essence of this concept is that people in today's world must think critically. Hence, the 21st-century skills emerged: creativity, collaboration, communication, and critical thinking. However, these skills cannot be acquired in a laboratory or through mathematical algorithms alone. Therefore, modern specialists need to engage more deeply in mastering new technologies, with STEM technologies occupying a prominent place.

The purpose of the article is to determine the role of STEM education in the modern world, emphasise the importance of preparing teaching staff for STEM education implementation, and examine the synergistic potential of Artificial Intelligence and neuroscience in STEM education in enhancing learning effectiveness.

2. The Role of the Education of STEM in the Modern World

Today's schools serve as a space focused on preparing future-oriented individuals who are ready to master and apply an integrated system of knowledge in a dynamically changing social and educational reality. Modern children are immersed in a fast-moving flow of information that is growing in both speed and volume every day. A teacher's important task is not only to help students "catch" the seeds of knowledge within this flow, but also to guide them in managing it, including by contributing their own discoveries using innovative technological solutions (Polikhun et al., 2019).

Many researchers note the growing interest among students in natural sciences, physics, mathematics, information technology, and science-related subjects. This trend is unsurprising in an era of high-tech industries and complete computerisation. The lives of modern children are filled with gadgets and introduce them to technological solutions for everyday problems. Many students dream of becoming part of a world where they can not only use innovative solutions but also create them. They aspire to connect their lives with the information flow management, exact sciences, and high-tech industries.

Traditional educational technologies help students reveal their intellectual and creative abilities. For this reason, contemporary education is increasingly turning to a new approach known as STEM. Within this framework, teachers organise student interaction in an educational environment to create the conditions necessary for project activities and productive research, integrated into a global interdisciplinary picture of holistic knowledge.

Most school educators have, at best, a limited understanding of what the STEM approach is, and at worst, they may not even be aware of its existence. This presents a significant challenge for modern education: how can an educator prepare a person for the future if they are not equipped with the necessary technological tools themselves?

Andrievskaya & Bilousova (2017) suggest that the solution for practicing teaching lies in familiarising themselves with the basics of STEM, STEAM, and STREAM pedagogy, through additional professional development programs.

The authors highlight the main benefits of STEM education, including the ability to study not only single subjects, but holistic themes in all their variety; the demonstration of "live" scientific and professional knowledge, where students understand not only its purpose but actively apply it. Additional benefits include enhanced problem-solving and critical thinking that arise during project-based tasks; the awareness of one's own potential and a brand new perspective on the individual assets, and the formation of effective communication proficiency.

According to researchers, it is crucial for teachers participating in these training programs to take an active role in an educational process that employs STEM technologies. Essentially, they must become students themselves for a time to understand how this technology works. This hands-on experience enables teachers to design future lesson scenarios, discuss them with colleagues, share insights, and create educational products that can be effectively applied in practical classes.

3. Training Pedagogical Staff for Implementing STEM Education

Balyk et al. (2018) emphasise the comprehensive nature of training for future primary school teachers, who will be responsible for ensuring the quality of education in future schools. Training programs for future primary school educators need to be updated to enhance competency outcomes, particularly given the lack of contemporary educational programs that develop skills in areas like programming, mechatronics, electronics, robotics, and other fields of technical ingenuity.

Langdon et al. (2011) present an interesting example of implementing a “Robotics” course into the training of future primary educators. Students have the opportunity to broaden their competency profile by acquiring knowledge, skills, and abilities in ICT, basic programming, and firmware compilation, as well as experience collaborative activities in a cloud-based STEM environment, while working on joint online projects. As a result, the future primary school teachers demonstrate not only elementary engineering and technical competencies, but also an ease in developing similar competencies in their future students using contemporary educational technologies.

Zavalevskyi, Gorbenko, & Lozova (2022) also address the issue of training pedagogical staff for STEM education, showcasing the experience of implementing it within the program for preparing bachelor-level pedagogues specialising in "Informatics and Technology." The authors note that the existing school method of teaching STEM subjects, with an emphasis on lecture-based content and prioritising rote memorisation, fails to inspire genuine interest in STEM professions among students. Consequently, this leads to a shortage of qualified specialists in this field.

STEM education primarily aims to raise the profile of engineering and technological professions rooted in disciplines like Physics, Chemistry, Mathematics, Technology, and others.

Researchers Atamanchuk & Atamanchuk (2022) rightly argue that schools urgently need a new approach to education, one that enables the new generation to develop a deeper perception of natural and physical-mathematical sciences through the interconnectedness of natural sciences, mathematics, engineering, and technology.

Erdogan & Stuessy (2015) discussed the design of an educational program in the United States, the birthplace of the STEM approach, for training future educators. The curriculum aligns with the expanded STEAM approach (Science, Technology, Engineering, Art, Mathematics). The imbalance among these components, in the authors' view, highlights the need to reconsider the curriculum's focus on certain topics and to strengthen the art component, particularly through design and creative problem-solving methods (TRIZ).

The approach proposed by Jang (2016) for designing an educational program for bachelor's training significantly broadens the horizons of practical preparation for future graduates.

Researcher Semenikhina, Drushlyak, & Shishenko (2022) argue that bachelor's programs for pedagogical education should include a module that prepares future educators to incorporate STEM technologies into the primary school learning process. The authors developed a module titled "Information Foundations of STEM Technologies in Primary School Education," comprising three core and two elective courses, with a total workload of 16 credits. While supporting the inclusion of such a module, the authors question the minimal contact hours (64 out of 576 total module hours) dedicated to direct student-teacher interaction. They advocate for structuring self-guided student work by assessment types linked to specific sections (teacher-led, peer-led, self-assessment, and possibly even expert assessment by prospective employers). This approach would clarify the teacher's and other educational actors' roles in assessing student competencies.

The following recommendations are proposed to support the integrating modules aimed at building competencies in future educators for STEM-based work:

- University educators should receive at least basic training in STEM education and in using STEM technologies in the classroom.
- Universities should serve as hubs for implementing, scaling, and replicating promising STEM projects.
- Accessible content-sharing platforms should be created for sharing current STEM-based teaching methods and equipment use.
- Practitioners, including representatives of potential employers, should be involved in building STEM competencies in future educators.
- Classes should emphasise interdisciplinarity, openness, and innovation, which align with STEM methodology.
- Practical training, including peer-assessment, self-assessment, and expert evaluation of module completion, should combine guided independent work with contact hours.
- Effective completion of the module requires specialised equipment to expand students' competencies, such as in modelling, programming, and robotics, as well as through ICT.

Preparing future primary school teachers for STEM implementation is a crucial aspect of teacher education. Teachers should possess foundational knowledge in natural sciences, technology, engineering, and mathematics to integrate these elements in the classroom. Importantly, teachers must be proficient in interactive teaching methods, project activities, and collaboration, which are the essence of STEM education. They should also be open to new approaches, willing to experiment and modify traditional teaching methods, and ready to use modern technologies and materials essential for STEM, including labs, software, and experiment kits.

Despite the numerous benefits of STEM education, teachers often face several challenges during its implementation. The primary barriers and potential strategies to overcome them through professional development and support (Gokbulut, 2020).

1. **Lack of Resources and Equipment**
   A lack of necessary equipment (robotics kits, computers, software) and limited funding for STEM initiatives.
2. **Lack of Confidence in Teaching STEM Subjects**
   Primary school teachers often do not have a technical education, which makes them hesitant to work with programming or robotics. They may fear they will not be able to answer all students' questions.
3. **Lack of Time for Integrating STEM into the Curriculum**
   Teachers are overwhelmed with the requirements of the standard curriculum and do not have time for additional STEM lessons. There are also difficulties in combining STEM with core subjects.
4. **Resistance from Administration or Parents**
   The administration may see STEM as a secondary subject in the curriculum. Parents may not understand the benefits of STEM education or may fear that it will replace core subjects.

Possible solutions to these problems include using free digital resources (Scratch, Tynker, Code.org), collaborating with local organisations (grants, sponsorship, partnership programs), working on projects with available materials (creating models from cardboard, using simple kits), as well as professional development and training for teachers on how to use accessible alternatives (such as virtual labs and online simulations). Additionally, participation in STEM training and webinars with minimal resource costs can help address these challenges (Erdogan & Stuessy, 2015).

STEM education in primary schools faces many challenges, but solutions exist. The key to successful implementation lies in teachers' professional development and confidence. Through training, collaboration, and integrating STEM into daily lessons, technological education can become accessible even with limited resources.

Continuous professional development, training, and support from educational institutions will help teachers enhance their skills and stay up-to-date with new STEM teaching trends.

4. The Importance of Implementing STEM Education in Primary Education

Integrating STEM into the educational process involves gradually providing access to technologies that enable the organisation of learning according to modern children's needs. A distinctive feature of STEM education is that all lessons in this approach involve applying theoretical knowledge in practice, allowing students to reinforce the material and grasp the core of the topics being studied.

The learning process with STEM involves establishing sustainable connections between individual subjects at the primary level, where mathematics and computer science are just beginning to be introduced (Atamanchuk & Atamanchuk, 2021b).

STEM education is an innovative approach that elevates the skill development of primary school students. It comprises a series of programs that harmoniously blend natural sciences, innovative technology, and applied learning. STEM lessons are designed to allow students to analyse authentic problems and devise their own solutions.

STEM education is a specialised field that focuses on the study of exact and natural sciences, complemented by a strong innovation and technological component (Sheremet et al., 2019).

One of the main goals of STEM education is to develop students' systems of thinking. STEM learning teaches children to adapt quickly to new technologies and trends in a rapidly evolving world. STEM enables children to more effectively absorb educational material, gain a comprehensive understanding of topics and processes, experience an engaging learning process with motivation to learn, develop original thinking, formulate research questions, and systematically explore solutions in STEM for primary school, showcasing and explaining the interconnections between processes and encouraging independent learning.

By integrating new technologies from an early age, STEM education helps students understand the underlying logic of the phenomena and explore the relationships between them. This contributes to developing curiosity, technical thinking, teamwork skills, and more, thus facilitating a new level of personal development (Means et al., 2016).

Engaging children in STEM should begin at an early school age, as it enables them to delve into the logic of phenomena and systematically study the world with curiosity, technical thinking, and collaborative skills.

The experience in using new technologies in various countries shows that practical classes in school are as important as theoretical ones. Traditional classroom learning often lacks the time to keep up with the fast-changing world. With STEM, students engage with diverse disciplines, gaining hands-on knowledge through experience, rather than merely intellectual exercises (Honchar et al., 2021).

At the methodological level, alongside acquiring theoretical skills and solving technical problems, STEM also promotes group work skills, constructive criticism and opinion defense, language proficiency, and creative use of technologies across various fields.

Compared to traditional school systems, STEM focuses on experiments, model-building, independent creative work, and implementing personal ideas in reality (Banada, 2018). Hence, STEM education links theory to practice and is essential across all educational levels, from preschool to vocational training, often in close collaboration with formal and informal educational organisations.

Through project-based activities, students acquire foundational skills in designing and programming models. Teachers create favorable conditions for students to demonstrate and develop their abilities. Moreover, STEM education helps identify highly gifted students and provides necessary conditions for their further development.

One of STEM's specific educational aims is to cultivate new ways of thinking in children. Unlike traditional school systems, STEM fosters analytical and creative abilities, encourages teamwork, and develops autonomy in learning (Nerubasska, Palshkov, & Maksymchuk, 2020).

Using a theoretical analysis of STEM education sources, three key characteristics can be identified that distinguish STEM education from traditional education systems. These characteristics are as follows: first, STEM education provides students with more opportunities and time for independent learning, teaches them to spot problems, and encourages them to find solutions independently through purposeful and conscious active engagement; second, by participating in teamwork, students have the opportunity to make creative discoveries (children overcome problems together and develop projects); and third, within STEM learning, collaboration and mutual assistance in overcoming learning problems are cultivated and encouraged.

A key distinction between STEM education and traditional education lies in its focus on cultivating learning skills rather than relying on the rote memorisation of material, which is prevalent in many educational systems. STEM emphasises independent work, the ability to generate innovative ideas, collaborate with peers, tackle cognitive challenges, and identify and rectify mistakes in the learning process. These principles form the core of STEM education, positioning it as one of the most innovative educational paradigms in contemporary education. Through effective and comprehensive implementation, STEM learning has become a catalyst of successful lifelong learning and professional development in many fields. The feature and main idea of STEM learning is that both theoretical and practical knowledge are essential for learning and development, as well as autonomy in acquiring this knowledge. Therefore, this method is both a specific method of learning and a specific way of thinking (Gokbulut, 2020).

The primary focus of STEM education is children's independence in gaining new knowledge. This self-directed learning approach strengthens students' will for teamwork and fosters creativity and communication skills, essential attributes for well-rounded individuals who are prepared to address any challenges and problems they may encounter. A key feature of STEM is its focus on teamwork and project work, which allows students to activate their creative and emotional potential.

Here are several examples of successful STEM integration in primary schools, focusing on robotics and coding for children without deep technical knowledge (Zavalevskyi, Gorbenko, & Lozova, 2022):

Case 1: "Coding with LEGO WeDo"

Objective: introduce 1st-3rd grade students to basic programming and technology through robot creation.

Students work with LEGO WeDo 2.0 kits, building simple robots (e.g., a mechanical frog or a car) and programming them using the Scratch block-based coding environment.

Children develop logical thinking, learn teamwork, and experiment with algorithms.

Case 2: "Stories in Code: Programming with Scratch Junior"

Objective: use coding to enhance creative thinking and connect it to other subjects.

1st-3rd grade students create interactive stories or animations where characters perform specific actions (e.g., moving or changing facial expressions).

They use the free Scratch Junior app to work visually with coding blocks.

Outcome: improved storytelling skills, enhanced algorithmic thinking, and imagination development.

Case 3: "Smart Home: Introduction to Automation"

Objective: demonstrate robotics and programming principles through real-life applications.

2nd-4th grade students develop smart home models using Arduino kits and simple sensors (e.g., a light sensor to turn on a lamp).

The task is split into steps, and programming is done through visual block-based tools.

Outcome: development of interdisciplinary knowledge (electronics, physics, programming) and analytical thinking.

Case 4: "Coding with Bee-Bot Robots"

Objective: introduce young students (1st-2nd grade) to the concept of algorithms.

Using Bee-Bot robots, which move according to programmed commands (e.g., step forward, step backward, turn), students complete tasks such as creating mazes, maps, or math games.

Outcome: children learn to create simple algorithms, predict command results, and work in groups.

Case 5: "Mathematics and Coding: Graphic Patterns in Tynker"

Objective: integrate coding into math lessons.

Students use the Tynker platform to create symmetrical drawings and shapes using simple commands (e.g., movement and rotation in a certain direction).

They explore basic geometry and coordinate planes.

Outcome: improved math skills through interactive activities.

STEM in primary schools does not require complex programming - visual environments and physical models are sufficient. The focus is on gamified learning and integration with other subjects. Simple robotics kits and educational platforms enable easy technology integration into classrooms, without requiring technical training (Zavalevskyi, Gorbenko, & Lozova, 2022).

STEM education offers far more than just discipline-specific competence. Integrating STEM with other subjects, including humanities, and focusing on social and emotional skills can make learning more comprehensive and effective.

STEM can contribute to the cognitive and emotional development of primary school students. Cognitive skills are developed through the enhancement of critical thinking (tasks involving data analysis from experiments or observations, formulating and testing hypotheses, discussing different perspectives and seeking compromises), creativity (designing models, prototypes, and innovative solutions, developing personal experiments and research, using unconventional problem-solving approaches), problem-based learning (creating real-life situations where students must apply knowledge from various subjects to find solutions, collaborating with others to solve problems), and problem-solving.

STEM also fosters emotional development in primary school students, influencing empathy by helping to design projects aimed at solving social issues, developing an understanding of others' needs, showing empathy and compassion, self-regulation, managing emotions while working on challenging tasks, building resilience to failure, and enhancing self-esteem.

On a global scale, contemporary pedagogical systems increasingly integrate STEM into traditional curricula because it actively involves students in science, equipping future professionals for a rapidly advancing technological world. The interdisciplinary nature of STEM education makes this integration possible, diversifying the educational process and preparing students to independently explore information, use new technologies, and creatively solve problems.

5. Artificial Intelligence and Neuroscience in the Service of STEM Education: Synergy for Effective Learning

AI-based platforms open new horizons in education, particularly in STEM. They provide teachers with powerful tools for individualised instruction and enhancing instructional efficacy, as AI systems analyse data on student performance, learning styles, and interests to create individual learning paths. This allows each student to learn at their own pace and according to their own characteristics. AI can create realistic virtual environments for experiments that enable students to explore phenomena that are difficult or impossible to study in real life. AI can also automate the assessment process, providing teachers with detailed feedback on each student's work. This allows teachers to focus on the creative aspects of their work (Honchar et al., 2021).

Neuroscience enhances educational practices by studying neurocognitive processes during the learning process. This knowledge can be used to enhance the instructional architecture of learning materials and teaching methods. Neurobiology has shown that emotions play a crucial role in memory formation. Therefore, it is important to create a learning environment that evokes positive emotions in students. Research has shown that regular repetition of information improves knowledge consolidation. AI systems can automate this process by selecting the optimal time for material repetition. The use of various sensory channels (sight, hearing, touch) enhances the learning process and promotes better memory retention. AI can help create learning materials that appeal to different sensory systems.

STEM education impacts the development of cognitive skills by combining science, technology, engineering, and mathematics. It provides an ideal environment for developing cognitive skills such as problem-solving: STEM projects often require students to find unconventional solutions to complex problems, critical thinking, data analysis, information evaluation, and hypothesis formulation - all of them encourage critical thinking; creativity: STEM projects encourage students to seek new ideas and unconventional approaches; collaboration: working in teams on common projects develops communication skills and teamwork abilities.

The combination of AI, neuroscience, and STEM education creates novel pedagogical opportunities for creating an effective and personalised learning environment. AI systems based on neuroscience principles can adapt the learning process to each student's individual needs, promoting the development of both cognitive and emotional skills (Nerubasska, Palshkov, & Maksymchuk, 2020).

AI, neuroscience, and STEM education are three powerful tools that can be used to create a more effective and personalised learning environment. The combination of these approaches allows for personalised learning, instructional enhancement of the educational process, development of key competencies, and fostering critical thinking, creativity, collaboration, and other essential skills.

The future of education is tied to the use of technology, and AI plays a key role in this. Together, AI, neuroscience, and STEM education open new opportunities for constructing inclusive, data-informed, and cognitively attuned learning ecosystems.

6. Modern Capabilities of Artificial Intelligence in the Context of Primary Education

At the current stage of digital transformation in education, artificial intelligence (AI) is not only a technological tool but also a catalyst for profound changes in the learning paradigm. The implementation of AI is particularly relevant in primary school, where basic competencies, critical thinking, self-organisation, and motivation for learning are formed. AI enables the shift from a mass, standardised approach to individualised learning, providing a more flexible, adaptive, and efficient educational process (Anderson, Rainie, & Luchsinger, 2023). In this context, several key areas of application should be highlighted, as presented in Table 1.

Table 1. Applications of AI in Education: Areas, Effects, and Tools

Application Area	Description	Expected Effect	Examples of Tools
Personalised Learning	Adapting content and delivery methods to the individual level, pace, and learning style of the student	Increased student engagement, reduced anxiety, improved learning outcomes	Knewton, Smart Sparrow
Automated Knowledge Assessment	Using AI to check tests, written answers, detect common errors, and create recommendations	Time savings for teachers, instant feedback, and formative assessment	Gradescope, Century Tech
Digital Educational Assistants	Interactive assistants in the form of chatbots or virtual mentors that support real-time learning	Support for self-education, development of independent learning skills	Duolingo, Google Assistant for Edu
Decision Support Systems for Teachers	Analytics of student progress, identifying risk areas, and recommendations for differentiated learning	Improved lesson planning, prevention of student underperformance	Squirrel AI, IBM Watson Education
Adaptive Game-Based Platforms	Combining gamification elements with intelligent analysis of student actions to increase motivation	Improved emotional background, stimulation for learning	Kahoot!, Classcraft

AI platforms are increasingly capable of recognising not only academic performance, but also the affective condition of students, opening new opportunities for developing emotional intelligence in schools. For example, systems based on facial expression or voice recognition can alert teachers when a student is cognitively disengaged or experiencing affective dysregulation.

Another promising area is inclusive education, where AI helps adapt learning materials for children with special educational needs, from automatic text reading to visualising complex information (Pinchuk, 2022). At the same time, the risks of implementing AI must be considered: excessive automation may reduce pedagogical interaction, distort assessments, or neglect cultural responsiveness. Therefore, it is essential not to replace teachers but to enhance their roles through new technologies.

7. Conclusion

This article highlights STEM as one of the 21st century's most transformative approaches, combining innovative pedagogy, arts education, and modern teaching technologies. The success of this approach depends on creating synergy between different fields of knowledge within the educational process.

Synthesising the above, we can underline key trends in the pedagogical education system that have been actualised through the application of the STEM approach. The update of existing and development of new pedagogical programs for bachelor's and master's degrees in pedagogical education, which are focused on mastering competencies required to teach in modern schools in the logic of STEM education. The development of experiential training programmes for the professional retraining and development of teachers working within STEM disciplines. The revision of school STEM curricula and the search for evidence-based methodologies for teaching STEM areas at all levels of education. The creation of a continuous professionalisation network within the "school-college-university" framework, aiming at preparing future school graduates for STEM careers. The expansion of infrastructure and technological capacuty in vocational education organisations and institutions to ensure the implementation of educational programs for the training of teaching STEM specialists. The implementation and development of new school programs that align with the goals of preparing individuals for the future, in the context of the modern school, based on the STEM method.

In general, the readiness of prospective primary school teachers to implement STEM education requires a comprehensive approach, including training, the development of personal skills, and support from educational institutions.

The article demonstrates that the use of artificial intelligence in primary education opens up new horizons for enhancing the quality, individualisation, and efficiency of the educational process. Personalised learning, automated assessment, digital assistants, and analytical decision-support systems help create a more flexible, accessible, and adaptive learning environment. At the same time, the implementation of AI must consider ethical aspects, the need to preserve a humanistic approach to education, and the strengthening of the teacher's role as a mentor. A comprehensive, critical, and responsible use of AI tools will contribute to the development of competent, motivated, and creative students who are prepared to face future challenges.

References

Anderson, J., Rainie, L., & Luchsinger, A. (2023). The future of learning: AI in education. *Pew Research Center.* https://www.pewresearch.org

Andrievskaya, V. M., & Bilousova, L. I. (2017). BYOD concept as a tool for implementing STEAM education. *Physics and Mathematics Education: Scientific Journal*, *4*(14), 13–17. https://cyberleninka.ru/article/n/kontseptsiya-byod-yak-instrument-realizatsiyi-steam-osviti

Atamanchuk, V. P., & Atamanchuk, P. S. (2021a). Standard criteria for monitoring predicted results of educational and cognitive activities. Collection of materials of the International Scientific and Practical Online Conference "Global Educational Trends: Creating a Creative Environment for STEAM Learning", 6–11. *Kyiv: Publishing House of M. P. Dragomanov National Pedagogical University.* https://enpuir.npu.edu.ua/handle/123456789/37637?show=full&locale-attribute=uk

Atamanchuk, V. P., & Atamanchuk, P. S. (2021b). STEM-integratory educational innovations in formation of natural science competency. *Scientific Journal of the National Center "Minor Academy of Sciences of Ukraine"*, *(42)*, Article 45. https://doi.org/10.32843/2663-6085/2021/42.45

Atamanchuk, V. P., & Atamanchuk, P. S. (2022). Educational and cognitive activities of future educators through the prism of worldview parameters (Category B). *Pedagogical Sciences:*

Theory and Practice, *2*(42), 139–146. *Odesa: Publishing House "Helvetika".* https://doi.org/10.26661/2786-5622-2022-2-21

Balyk, N., Barna, O., Shmyger, G., & Oleksiuk, V. (2018). Model of professional retraining of teachers based on the development of STEM competencies. *ICT in Education, Research and Industrial Applications*, 318–331. https://ceur-ws.org/Vol-2104/paper_157.pdf

Banada, O. S. (2018). Diversification of mathematics teaching forms in the context of STEM education. STEM education as a direction for modernizing teaching methods of natural and mathematical sciences in secondary and higher education institutions: Collection of materials of the All-Ukrainian Student Scientific and Practical Conference, 86–87. *Kherson.* https://doi.org/10.31812/123456789/4541

Borrego, M., & Henderson, C. (2014). Increasing the use of evidence-based teaching in STEM higher education: A comparison of eight change strategies. *Journal of Engineering Education*, *103*(2), 220–252. https://doi.org/10.1002/jee.20040

Erdogan, N., & Stuessy, C. (2015). Modeling successful STEM high schools in the United States: An ecology framework. *International Journal of Education in Mathematics, Science and Technology*, *3*(1), 77–91.

Gokbulut, B. (2020). The effect of Mentimeter and Kahoot applications on university students' e-learning. *World Journal on Educational Technology*, *12*(2), 107–116. https://doi.org/10.18844/wjet.v12i2.4814

Honchar, L., Derkachova, O., Shakhrai, V., Saienko, V., Hladoshchuk, O., & Voropayeva, T. (2021). Formation of psychological readiness of the teacher to implement information and communication technologies in professional activities. *International Journal of Education and Information Technologies*, *15*(38), 364–371. https://doi.org/10.46300/9109.2021.15.38

Jang, H. (2016). Identifying 21st century STEM competencies using workplace data. *Journal of Science Education and Technology*, *25*(2), 284–301. https://doi.org/10.1007/s10956-015-9593-1

Langdon, D., McKittrick, G., Beede, D., Khan, B., & Doms, M. (2011). *S*TEM: Good jobs now and for the future. *Washington, DC: U.S. Department of Commerce.*

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

Nerubasska, A., Palshkov, K., & Maksymchuk, B. (2020). A systemic philosophical analysis of the contemporary society and the human: New potential. *Postmodern Openings*, *11*(4), 275–292. https://doi.org/10.18662/po/11.4/235

Pinchuk, O. S. (2022). Artificial intelligence in the general secondary education system: Potential and challenges. *Information Technologies and Learning Tools*, *89*(1), 123–132.

Polikhun, N. I., Postova, K. G., Slipukhina, I. A., Onopchenko, G. V., & Onopchenko, O. V. (2019). Implementation of STEM education in the context of integrating formal and informal education for gifted students: Methodological recommendations. *Kyiv: Institute of Gifted Children of the National Academy of Pedagogical Sciences of Ukraine.* https://lib.iitta.gov.ua/id/eprint/718661

Semenikhina, O. V., Drushlyak, M. G., & Shishenko, I. V. (2022). STEM-project as a means of learning modeling for pre-service mathematics and computer science teachers. *Information Technologies and Learning Tools*, *90*(4), 46–56. https://doi.org/10.33407/itlt.v90i4.4946

Sheremet, M., Leniv, Z., Loboda, V., & Maksymchuk, B. (2019). The development level of smart information criterion for specialists' readiness for inclusion implementation in education. *Information Technologies and Learning Tools*, *72*(4), 273–285. https://doi.org/10.33407/itlt.v72i4.2561

Zavalevskyi, Y., Gorbenko, S., & Lozova, O. (2022). Psychological and pedagogical conditions for the development of STEM education. *Problems of Education*, *2*(97), 61–77. https://doi.org/10.52256/2710-3986.2-97.2022.04