

# Advancements in STEM education and the evolution of game technologies in Ukrainian educational settings



Inna Pavlenko<sup>a</sup>   | Oksana Boiko<sup>b</sup>  | Dmytro Mykolaiets<sup>c</sup>  | Olena Moskalenko<sup>d</sup>  |  
Tetiana Shrol<sup>e</sup> 

<sup>a</sup>Department of Sports and Physical Education, Sumy State A. S. Makarenko Pedagogical University, Sumy, Ukraine.

<sup>b</sup>Chair of English Philology and Linguodidactics, Foreign Language Department, Zaporizhzhia National University, Zaporizhzhia, Ukraine.

<sup>c</sup>Interregional Academy of Personnel Management, Kyiv, Ukraine.

<sup>d</sup>Department of Foreign Philology and Translation, Faculty of Humanities and Pedagogy, National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine.

<sup>e</sup>Department of Information and Communication Technologies and Methods of Teaching Informatics, Faculty of Mathematics and Informatics, Rivne State University of Humanities, Rivne, Ukraine.

**Abstract** Modern trends in education are manifested in the integration of STEM education, gamification and the use of game technologies, which are key to the development of innovative approaches in education. The approaches provide an active and motivating learning environment, which is important for preparing students for the challenges of the modern world. The purpose of this article is to analyze the implementation of these innovations in the educational system of Ukraine based on the experience of European countries, with an emphasis on the challenges and opportunities they create. The article examines the peculiarities of the application of gamification and game technologies in education in Europe, which can serve as a source of inspiration for Ukraine. The analysis shows that the implementation of these approaches in Ukraine requires significant efforts in terms of teacher training, investments in technical equipment and the development of a national strategy for the integration of innovative technologies in education. The results of the analysis indicate the potential of increasing the effectiveness of education and the development of key competencies of students through the use of these innovations. The main conclusion of the study is the need to modernize the educational system of Ukraine, adapt to modern requirements and actively introduce innovative approaches into the educational process. The article emphasizes that the success of the implementation of gaming technologies depends to a large extent on a systemic approach to education, as it includes changes in curricula, teaching methods, and knowledge assessment. The recommendations given in the article offer specific strategies for the effective implementation of these innovations, which can significantly strengthen the quality of education and the readiness of students to solve current and future challenges. The study sets Ukraine the task of ensuring equal access to quality education and readiness for the integration of modern educational technologies.

**Keywords:** virtual communication, social network, gamification, contests, tests, teenagers

## 1. Introduction

The modern development of STEM education, gamification and the use of game technologies in education in Ukraine opens new horizons in the understanding of modern educational approaches. Under the conditions of globalization and rapid technological development, education faces the need to adapt to the changing demands of society and the labor market. The integration of gamification and gaming technologies into the educational process should significantly improve the quality of learning, providing an active and motivating learning environment. Using such approaches allows the development of students' critical thinking, creativity and innovation, which are key competencies in today's world. This study focuses on the analysis of modern trends and the identification of strategies for the effective integration of these innovations into the Ukrainian educational system. The features of the implementation of innovations in education in Europe make it possible to understand the potential opportunities and challenges for Ukraine. The experience of European countries, where gamification and game technologies are already actively used in the educational process, can serve as a guide for the development and implementation of similar programs in Ukraine. An analysis of the European experience, including its successes and challenges, will be an important component of our research. Existing practice will help to understand how best to adapt and implement these innovative approaches in Ukrainian educational institutions, taking into account local characteristics and needs (Cavus et al., 2023). This study focuses on the need to modernize the educational system of Ukraine so that it meets the requirements of the modern world. Modern education requires not only the integration of the latest technologies but also the creation of



conditions in which students can develop important skills such as critical thinking, creativity and the ability to innovate. There is a need to update curricula but also to provide teachers with the necessary resources and support to implement these innovations. This research is aimed at identifying the key factors for the successful integration of games and innovative approaches into the educational process, as well as at developing recommendations for improving the educational system in Ukraine.

The problems of STEM education, gamification and the use of game technologies in education under the conditions of war and the need for development in Ukraine are the subject of intensive research and discussions in scientific circles. Scientists and analysts consider digital aspects to be key factors in the modern development of educational systems. The researcher Buturlina et al. (2021) emphasized the importance of integrating STEM disciplines into school programs, pointing to the positive impact on the development of analytical thinking and creative abilities among students. An important aspect that draws attention to Camacho-Sánchez et al. (2023) is the need to adapt educational programs to the needs of the modern labor market, which requires flexibility and innovation from the educational system.

The hypothesis of Patrikeeva et al. (2021) indicates the high effectiveness of gamification as a means of motivating and engaging students in the learning process, especially in complex STEM fields. Khaldi (Khaldi et al., 2023) analyzed the use of game technologies, particularly virtual and augmented reality, which allow the creation of an interactive and exciting learning environment. Research (Astashova et al., 2023) emphasizes the potential of game technologies and gamification in improving the educational process, especially in increasing the interest and motivation of students. The researcher Hevko (Hevko & Savchenko, 2022) points to the importance of taking into account the specifics of the Ukrainian educational context when integrating game technologies, emphasizing the need to ensure access to modern technical equipment and teacher training. Additionally, Ovchatova (2021) analyzed the impact of the COVID-19 pandemic on education in Ukraine, pointing to the growing role of digital technologies and distance learning. The author emphasized the importance of developing flexible and adaptive educational approaches capable of responding to the challenges of the modern world. Shapovalov et al. (2020) examined the impact of early involvement of schoolchildren in STEM disciplines and showed that such an approach contributes to the development of logical thinking and interest in scientific research.

On the other hand, research (Hope et al., 2023) has focused on the challenges of implementing STEM education in schools, particularly the need for highly qualified teachers and appropriate technical equipment. Regarding Ukraine, the analysis indicates a gradual increase in interest in STEM education but emphasizes the need for further support and development in this field, especially in view of global educational trends (Nikitina & Ishchenko, 2022). Gamification and game technologies in education are also at the center of scientific discussions. Cavus et al. (2023) emphasized the importance of gamification, as it can increase the motivation of students and improve the process of learning complex material, making learning more interactive and exciting. Research (Irwanto et al., 2023) in the field of game technologies includes virtual and augmented reality, indicating their potential in creating realistic simulations that allow students to better understand complex scientific concepts. The conducted analysis demonstrated that the introduction of game technologies can be an important step in modernizing the education system but noted that this requires significant investment in infrastructure and teacher training (Pinchuk & Prokopenko, 2022). Korshunova et al. (2018) notes that currently, within the framework of STEM education, there is an innovative educational project at the all-Ukrainian level called "I am a researcher". Developed and approved by the Ministry of Education and Science of Ukraine, the project aims to stimulate students' interest in research and develop their scientific abilities. Furthermore, as part of the educational initiative for which I am a researcher, the "Singapore Math" and "I Explore the World" initiatives have already been launched, aiming to foster the growth of ingenuity, logical thinking, and a broad understanding of scientific research in children in schools (Korshunova et al., 2018). Therefore, the development of STEM education, gamification and game technologies in Ukraine opens up new opportunities for improving the quality of education and adapting it to the requirements of the modern world, but it poses new challenges and tasks to the educational system. The literature review emphasized that the development of gaming technologies is key to the modernization of the educational system of Ukraine, ensuring its compliance with modern global trends and challenges.

The purpose of this research is to study the process of integrating STEM education, gamification and game technologies into the education system of Ukraine, with an emphasis on the analysis of problems and the identification of the main challenges and opportunities. The issues of the research include the assessment of the current state of educational innovations in Ukraine, particularly the effectiveness of the introduction of STEM disciplines, gamification methods and game technologies into the educational process. The main tasks are the analysis of the European experience of applying similar approaches, the assessment of the need for the training and development of teachers' qualifications, and the determination of the necessary changes in educational programs. This research is aimed at identifying the features and unique opportunities that game technologies and gamification can bring to the Ukrainian educational sphere, with the aim of developing recommendations for modernization and improving the quality of education.

## 2. Materials and Methods

To study the implementation of projects in the fields of STEM education, gamification and game technologies in Ukraine, various methods of data collection and analysis will be used. Quantitative data will be collected through questionnaires of

students, teachers and administrators of educational institutions to assess the effectiveness and impact of the introduced methods and technologies on the educational process. Data on the experience of European countries in this field will be used for comparative analysis and study of best practices. The key factors of success and possible challenges faced by Ukraine during the implementation of similar projects are identified.

The research methodology will include the stages of data collection, systematization and analysis and the use of statistical methods to assess the impact of innovative educational approaches on the quality of education. The use of linear regression methods and other statistical tools will help to identify trends and dependencies between the use of new methods and changes in educational indicators (Popovych et al., 2021). Case studies from European countries will also be analyzed to determine effective strategies for introducing STEM education and gaming technologies into the educational process.

The basis of the study was data on the highest education indices in the world, the growth rates of STEM education, and the approaches of European countries to STEM education. UNESCO reports, OECD studies and other international educational initiatives were used to process and analyze the statistical data of the indices. The interpretation made it possible to assess the general state and level of development of higher education at the international level and identify leaders. Considerable attention has been given to the analysis of support programs for young scientists and engineers aimed at attracting them to scientific activity. The procedural factor of the study was a comparative analysis of the approaches of European countries to the integration of STEM education. The study employed a statistical analysis technique to analyze data from diverse regions of Ukraine in order to ascertain trends in the number of participants in the STEM School educational program in the country.

The study of national strategies for the development of education, gamification programs and the use of game technologies in the educational process was carried out. The main trends of the formation and development of digital education in a constantly changing environment are determined by the method of forecasting. The use of the system method was carried out to outline the aspects of European educational transformation through the introduction of digital platforms and the creation of a unique resource for students to ensure quality education. By means of induction, the main prospective directions for the implementation of STEM education and the possibilities for its implementation in modern pedagogical practice are determined.

### 3. Results

Modern education has undergone a transformational period, especially during recent decades, due to the rapid development of technology. The essence of evolution lies in the integration of innovative technologies into educational structures, which has radically changed the approaches of teachers to teaching and the methods of learning material by students. Transformation occurs through the introduction of new tools, as they change approaches to the educational process, turning passive memorization into active, research-based learning. The importance of STEM education (science, technology, engineering and mathematics), which is gaining popularity worldwide, deserves special attention. Schools and universities are actively integrating STEM programs, which promote the development of critical thinking, creativity and innovative approaches. An important component is the development of partnerships between educational institutions and technology companies, which allows for the creation of interactive laboratories and the use of modern technologies, such as virtual and augmented reality, to improve the quality of education. Current trends open new horizons for the educational process, making it more effective and exciting.

Game technologies are becoming an important element in modern education, making a significant contribution to the development of innovative teaching methods. Gamification, the use of game elements in the learning process, has proven to be an effective means of engaging students and stimulating their motivation. From creating educational games to using gaming platforms, technology allows students to immerse themselves deeply in the learning process, turning it into an engaging and interactive activity. The organization of thematic workshops and environmental projects in schools and the development of mobile applications with augmented reality for studying natural sciences open up new opportunities for the use of game technologies in education, making learning more exciting and accessible to a wide range of students. The countries with the highest level of education for the available statistical period are shown in Table 1.

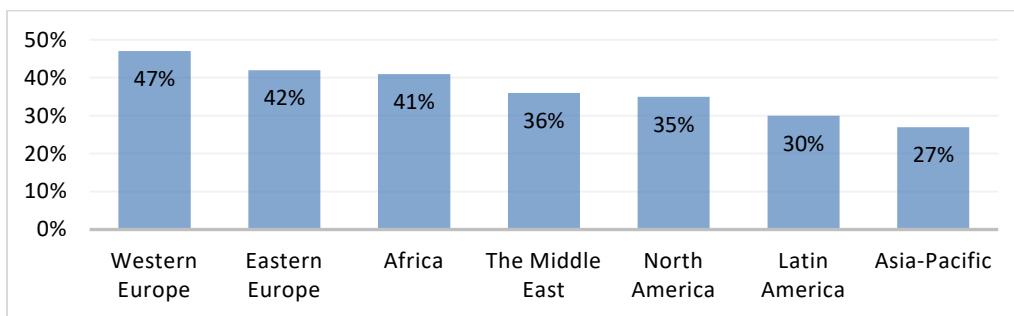
Countries with the highest level of education, such as Australia, New Zealand, Iceland, Finland, Sweden, Belgium, Denmark, Germany, the Netherlands and Norway, demonstrate high standards in the educational field, which is largely due to developed STEM education (science, technology, engineering and mathematics) and innovative approaches such as gamification. Finland and Sweden are known for their progressive education systems, with a strong emphasis on developing critical thinking and practical skills through STEM education.

The educational approach includes the integration of modern technologies and teaching methods, which makes the learning process more interesting and effective. Gamification involves the use of game elements in the educational process and is becoming increasingly popular in these countries, as it helps to increase the motivation of pupils and students and improves the process of assimilating complex material. In Germany and the Netherlands, educational institutions use gamified platforms for teaching technical and scientific disciplines, which allows students to experiment and solve practical problems in a game form. The dynamics of the development of gamification in recent years are shown in Figure 1.

**Table 1** Countries with the Highest Education Index Scores Worldwide.

Country	2021 Index
Australia	1.01
New Zealand	0.99
Iceland	0.99
Finland	0.96
Sweden	0.96
Belgium	0.96
Denmark	0.95
Germany	0.94
Netherlands	0.94
Norway	0.94

Source: World Population Review (2024).



**Figure 1** Growth Rates of Game-based Learning Worldwide, 2019-2024.

Source: FinanceOnline (2024)

European countries emphasize the development of technologies in education. They invest in updating the educational infrastructure and introducing interactive digital resources and tools for learning. This transformation increases the accessibility of education and promotes the development of skills needed in today's digital world. These factors form a solid foundation for a high level of education in these countries. Investments in education, combined with innovative approaches to learning, create conditions in which students not only acquire knowledge but also develop important life skills and competencies necessary for a successful future (Imanbazar & KimYe, 2023).

Finland, Germany, Italy and Sweden are vivid examples of a high level of integration of STEM education, gamification and game technologies into the educational system. In Finland, for example, innovative STEM teaching methods focus on hands-on learning, giving students the opportunity to apply theoretical knowledge to real-life situations. Practice contributes to better assimilation of material and the development of critical thinking skills. Gamification in education, in particular the use of gamified platforms for teaching mathematics, stimulates the interest of students and increases their motivation. The implementation of VR technologies in schools for the study of science opens up new opportunities for interactive learning, making the educational process more exciting and effective. More details about the most popular approaches among European countries that could be useful for Ukraine are shown in Table 2.

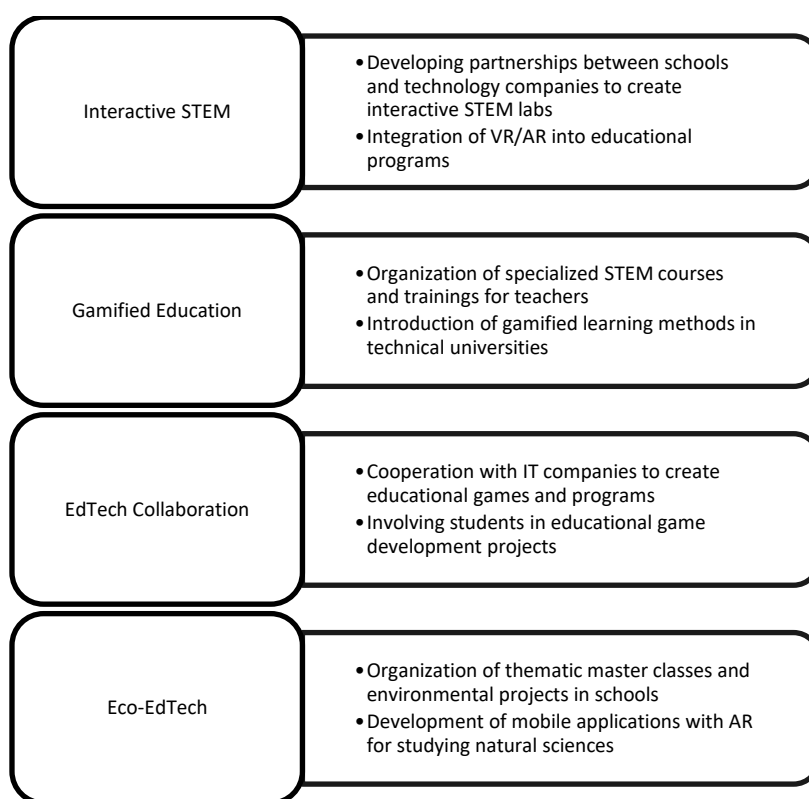
Countries also work in the field of strong support for technical education and the integration of STEM programs in schools, as there is a strategic approach to the development of the scientific and technical industry in the country. Game elements in educational programs, especially in professional training, ensure students' deeper involvement in the learning process. The development of educational games for learning engineering disciplines is one way to increase the effectiveness of education. Focusing on the development of STEM laboratories in schools and robotics in Italy supports students' interest in technical disciplines. Gamified applications for the study of history and culture, as well as the use of gaming platforms for language learning, show a flexible approach to education. In Sweden, special attention has been given to increasing interest in science among young people and an emphasis on environmental education. The use of gamification for motivation in learning and AR for interactive teaching of geography plays an important role in improving the quality of education (Boyko, 2023).

The use of game technologies radically changes education approaches in Ukraine. Technologies make it possible to create unique learning environments that can simulate real situations and processes, providing deep immersion in learning material. With VR, students can virtually visit historic sites, conduct complex science experiments, and immerse themselves in processes that are difficult to replicate in the classroom. Ukraine can use innovations to improve the quality of education and prepare young people for the challenges of the modern world. Following the example of Europe, game technologies should be used to stimulate interest in languages, history, geography and other humanities, turning traditional learning into a more exciting and interactive process. The main areas of experience implementation in Ukraine are shown in Figure 2.



**Table 2** Approaches of European countries to STEM education, gamification and the use of game technologies.

Country	STEM education	Gamification in education	Game technologies in education
Finland	Innovative STEM teaching methods, emphasis on hands-on learning	Using gamified platforms for teaching mathematics	Implementation of VR technologies in schools for science education
Germany	Strong support for technical education, integration of STEM programs in schools	Game elements in educational programs, especially in vocational training	Development of educational games for learning engineering disciplines
Italy	Development of STEM laboratories in schools, focus on robotics	Gamified applications for studying history and culture	Using game platforms for learning languages
Sweden	Projects to increase interest in science among young people, emphasis on environmental education	Using gamification for motivation in education	Using AR for interactive geography learning



**Figure 2** The main directions of gamification integration in Ukraine.

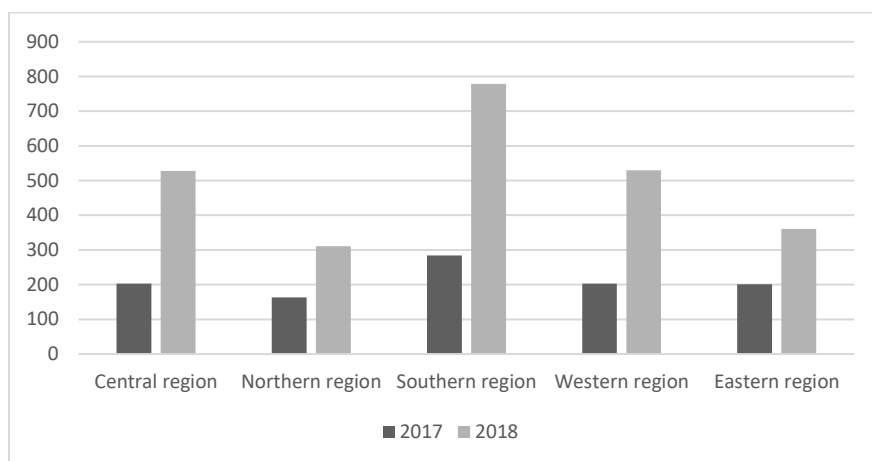
The implementation of educational game technologies is of great importance for the educational system of Ukraine, which is rapidly developing and seeks to integrate modern approaches to learning. The integration of STEM education into school and university programs can play a key role in preparing Ukrainian youth for the challenges of the modern technological world. These include separate courses in science, technology, engineering and mathematics and the creation of interactive laboratories where students can experiment and bring their ideas to life. Educational policy promotes the development of analytical skills, creativity and innovative thinking (Bakhov et al., 2021). Robotics and programming can be integrated into school curricula to stimulate interest in technical disciplines from an early age. European practice will help Ukraine train highly qualified specialists in the field of STEM, who will be able to ensure the country's competitiveness in the international arena.

In Ukraine, the potential of game technologies can be realized through cooperation with IT companies to create educational games and programs, as well as involving students in the development of educational game projects. As a result, it will increase interest in learning and promote the development of technical skills and creativity. Because of the war in Ukraine, STEM education is gaining strategic importance, as it is the foundation for training qualified specialists who will be able to develop innovative solutions for military defense, cybersecurity, infrastructure restoration and digitalization of the economy. The growing need for cyber security experts, developers of advanced software solutions, design engineers and



critical communication systems emphasizes the importance of integrating gamification and gaming technologies into the educational process.

The Web-STEM School is a new opportunity for professional growth in STEM education that has opened up for pedagogical staff. During the period of 2017-2018, three sessions of the STEM School were conducted in accordance with the approved programs of special courses of the University of Education Management. These sessions included two special courses for distance learning for 15 academic hours and one curriculum for full-time study for 30 academic hours. To date, STEM School 2018 has become virtually the only free resource with a certified professional development program for teachers in STEM education. Gradually, STEM School is turning into an alternative mass educational resource popular among the public (Fig. 2). During this period, more than 8000 participants from all over Ukraine had the opportunity to gain new knowledge and exchange thoughts, ideas, and experiences with 130 speakers (Korshunova, et al. 2018).



**Figure 2** Increase in the number of participants from the first to the second session.

Source: Korshunova, et al. (2018)

An example of a successful STEM education organization in Ukraine is the Tsarychany Lyceum, which launched the regional research and experimental project "Scientific and Methodological Principles for Creating an Innovative Model of STEM Education" in 2017 and has already achieved some success by 2020. For example, three female students of the lyceum won the regional STEM project competition and were recognized in the nominations "Industry Inspires" and "Best STEM Decoration." The lyceum was also provided with multimedia equipment and an electron microscope. The local community contributed to the purchase of five complexes for STEM projects. The lyceum has a mobile electrical laboratory that provides interesting and rich lessons where different subjects are combined, and there are technical opportunities for programming. Using a mobile platform with integrated manipulators, students implement various projects under the guidance of a computer science teacher (Osvita.ua, 2022).

Since not all educational institutions in Ukraine have the opportunity to raise additional funds for STEM education, STEM laboratories may become impossible. Therefore, for many schools, the best option would be to engage the Minor Academy of Sciences of Ukraine in a virtual STEM center, which provides remote and in-person professional methodological and technological assistance in organizing STEM education for students (MAS of Ukraine, 2018).

The results indicate the successful functioning of these methods, as they contribute to the involvement of students in the deep assimilation of complex engineering and technological concepts. Considerable attention should be given to the creation of specialized educational programs that combine theoretical knowledge with practical skills in areas critical to national security and recovery. The Ukraine has intensified international cooperation in the educational and scientific spheres, attracting global innovations and best practices for integration into the national education system. However, the transformation of education aims to ensure a technological breakthrough and the recovery of the country after the war, using the acquired knowledge to create a safe, sustainable and innovative society.

#### 4. Discussion

The practice of integrating STEM education, gamification and game technologies into education in Ukraine reflects global trends with certain local features. Research (Hellberg & Moll, 2023) confirms the importance of early involvement of students in STEM, which corresponds to our conclusions about the positive impact of such involvement on the development of logical thinking among Ukrainian schoolchildren. This article (Ovchatova, 2021) points to specific challenges that Ukraine faces in implementing STEM education due to funding limitations and the need for the professional development of teachers. According to Nikitina & Ishchenko (2022), this approach differs from the situation in more developed countries, where there is more stable support for STEM initiatives. Regarding gamification and gaming technologies, the results reflect a generally positive impact of the approaches on student motivation and engagement (Oliveira et al., 2023), which is in line with global

observations. The experience of Ukraine, according to the approach (Martyniuk et al., 2021), in the implementation of game technologies is limited due to the lack of technical infrastructure and high costs, which is emphasized in our own research. The current situation presents Ukraine with the task of finding effective and affordable ways to integrate gaming technologies into the educational process. The obtained results confirm the opinion (Nazarenko et al., 2021) that in Ukraine, there is significant potential for the development of gamification as a tool for increasing the effectiveness of education, especially in complex STEM disciplines. This view (Patrikeeva et al., 2021) corresponds to the general trend of using gamification to improve the educational process but requires adaptation to the specifics of the Ukrainian educational system. Our results support findings (Cavus et al., 2023) regarding the high effectiveness of gamification in learning, especially in the context of STEM subjects, demonstrating its positive impact on student engagement and motivation in Europe. The results are consistent with those of Hellberg & Moll (2023), which indicates the potential of game technologies in creating an interactive learning environment and engaging students in European and Ukrainian schools.

A comparison with a previous study (Yurchenko et al., 2023) demonstrated the similarities of challenges and opportunities in the implementation of STEM education in Ukraine, especially regarding the need to improve the qualifications of teachers and provide the necessary technical equipment. Therefore, the development of STEM education, gamification and gaming technologies in Ukraine has a lot in common with global trends but also includes unique challenges and opportunities. There is a need to develop specialized strategies and approaches that consider local characteristics and needs. It is also important to take into account current limitations and look for opportunities for innovation and improvement in the educational process to ensure quality and modern education for Ukrainian youth.

## 5. Conclusions

Thus, it can be concluded that the importance of the integration of STEM education, gamification and the use of game technologies in the educational system of Ukraine is greatest. The analysis showed that these approaches can significantly increase the interest and motivation of students and increase their critical thinking, creativity and readiness to solve complex problems. It is especially important to involve students in practical learning through STEM, which stimulates their understanding and application of scientific knowledge in real life. Gamification and game technologies make it possible to turn learning into an exciting and effective process, stimulating students to actively participate in the learning process. The implementation of gamification of education in Ukraine should be based on the experience of Europe, which includes the integration of game elements into the educational process, to increase the motivation and involvement of students. Finland and Germany are already showing success in using gamification to improve educational outcomes through the use of gaming platforms and e-learning tools.

The implementation of innovative approaches faces a number of problems and global challenges. One of the main challenges is the lack of qualified teachers who can effectively teach STEM subjects and use gaming technologies. Improving teachers' qualifications and solving problems related to innovative technologies are key challenges in the implementation of gamification and game technologies in education. To effectively use the latest approaches, teachers need to master new technologies and have the skills to integrate game elements into the educational process. A significant obstacle is the limited financial and technical resources needed to equip schools with modern equipment. There is a need to ensure access to quality internet and digital technologies for all students, especially in rural areas. These challenges require an integrated approach and the coordination of efforts between different stakeholders.

In view of the identified problems, several key measures are recommended to improve the situation in Ukraine. There is a need to invest in the training and professional development of teachers in the field of STEM and gaming technologies. It is important to involve the public and private sectors to finance educational programs and equip schools with the necessary equipment. Additionally, national strategies for the integration of digital technologies in the educational process should be developed and implemented, with a special emphasis on ensuring equal access to education for all students. Modernizing curricula, using digital technologies, and ensuring equal access to quality education for all students must become a priority for education systems to meet the needs of a rapidly changing world. The need to modernize the education system is important for responding to the modern challenges and needs of society. The implementation of these recommendations will help Ukraine to effectively integrate modern educational approaches and prepare the young generation for the challenges and opportunities of the modern world.

## Ethical considerations

Not applicable.

## Conflict of interest

The authors declare no conflicts of interest.

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