

Implementation of STEM Education in Distance Learning Conditions During Martial Law in Ukraine: Challenges, Tools and Prospects for Training Future Engineers

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Abstract— The paper considers the relevance of implementing STEM education in the context of distance learning caused by martial law in Ukraine. The main challenges associated with the lack of access to physical laboratories, technical inequality and insufficient digital competence of teachers are analyzed. The use of virtual simulators, in particular Tinkercad, Fritzing, Proteus, is proposed as effective tools for the formation of engineering skills. A comparative analysis of these environments is conducted from the point of view of their educational potential. The prospects for integrating the STEM approach into school and university education are outlined, taking into account the crisis conditions and the needs for the restoration of educational infrastructure.

Keywords— *STEM-Education, Distance Learning, Virtual Simulators, Martial Law, Engineering Training, Tinkercad, Digital Technologies.*

I. INTRODUCTION

The modern education system of Ukraine is under the influence of complex challenges caused by a full-scale war, which has radically changed the format of the educational process both in secondary education institutions and in higher education institutions. In conditions of constant danger, population displacement, limited access to resources and unstable Internet connection, the educational process has been forced to transform into a distance or blended format. Against this background, the implementation of STEM education (science, technology, engineering, mathematics), which is able to provide integrated training of pupils and students to solve complex engineering and technical tasks, is of particular relevance [1,2].

Given the rapid development of digital technologies and the need for highly qualified technical specialists, the STEM approach is strategically important for preserving the intellectual potential of the country. The implementation of such methods in a distance format requires the adaptation of educational tools, the development of digital infrastructure, innovative approaches to practical learning, as well as the new role of the teacher as a facilitator of an interactive, interdisciplinary educational process. In these conditions, the

study of the possibilities and mechanisms for implementing STEM education in school lyceums and universities of Ukraine is extremely relevant and has significant importance for improving the quality of training of future engineers during martial law and in the post-crisis period [3]. The implementation of STEM in distance education is not just a forced step, but a strategic investment in the future of the country's technical infrastructure.

II. MAIN CHALLENGES IN IMPLEMENTATION OF STEM EDUCATION DURING MARTIAL STATE

Under martial law in Ukraine, the education system is experiencing significant pressure and transformation, in particular, this concerns the implementation of STEM education, which faces a number of challenges. One of the main problems is the physical inaccessibility of laboratory equipment, which limits the ability of pupils and students to conduct practical experiments, assemble electronic circuits and work with microcontrollers [4,5]. Due to shelling, evacuations and destroyed infrastructure, the educational process often takes place in conditions of unstable communication, which reduces the effectiveness of learning. The distance learning form, which is the only possible in many regions, deepens the inequality of access to education between students with different levels of technical support. Some students do not have stable access to the Internet, modern computers or even electricity, which significantly complicates participation in full-fledged STEM education. In many cases, teachers, especially in secondary schools, do not have sufficient digital competence to work effectively with virtual simulators, platforms and online tools, which limits the potential for implementing innovative methods. Educators often work under conditions of stress, emotional exhaustion and lack of resources, which also affects the quality of knowledge transfer. On the other hand, a significant part of higher education teachers face difficulties in adapting curricula to new formats, in particular due to the lack of officially approved models for implementing STEM in distance education [6]. As a result, there is a decrease in

motivation among both students and teachers, especially when the educational process is interrupted due to air alarms or forced relocations. It is worth noting the lack of methodological support for teachers and lecturers who are trying to independently integrate new technologies and resources into teaching technical disciplines. Educational platforms that could become the basis for STEM education are not always adapted to the needs of Ukrainian users, and educational materials are often presented only in English. In addition, training using simulators requires not only technical training, but also an understanding of pedagogical approaches to the formation of practical skills through virtual means. Teachers often do not have experience in developing interactive courses or digital laboratory work, which limits their ability to effectively implement STEM components. Against this background, there is a growing need for a systemic approach to training personnel, updating curricula and state support for the digital infrastructure of education. Existing educational initiatives, despite their effectiveness at the local level, do not always have a large-scale impact due to limitations in funding and resources. In addition to technical difficulties, psychological factors are also a significant barrier - in particular, fear, anxiety and loss of learning motivation, which reduce the ability to concentrate and perceive complex information. As a result, despite the high potential of STEM education as a tool for improving the quality of technical training, its effective implementation during wartime requires overcoming many barriers. These include both institutional and personal challenges related to the adaptation of participants in the educational process to conditions of uncertainty and limited resources. Particular attention should be paid to the creation of unified methodological recommendations, expanding access to digital learning platforms, as well as supporting teachers through training and mentoring programs. In the long term, these steps can become the key to creating a sustainable model of technical education that can function even in crisis situations.

III. DIGITAL STEM EDUCATION TOOLS: OPPORTUNITIES FOR DISTANCE ENGINEERING TRAINING

In conditions of limited access to physical laboratories, one of the most effective solutions for ensuring full-fledged STEM education is the use of digital tools that allow modeling of real technical processes in a virtual environment. Such platforms not only provide students with the opportunity to perform practical tasks, but also allow them to visualize complex concepts that are usually difficult to understand without visualization. Digital simulators allow you to create electronic circuits, program microcontrollers, and explore the algorithms and logic of control systems. This is especially important in the context of training future engineers, where a fundamental understanding of the principles of electronics and automation cannot be formed exclusively theoretically. Many such environments are designed taking into account educational needs and provide integration with typical platforms such as Arduino [6] or ESP [7], which makes them accessible and close to the real engineering environment. Online simulators allow teachers to organize feedback, track student progress, and use interactive tasks that stimulate critical thinking. In turn, students can experiment without fear of making a mistake, because everything happens in a safe virtual space that supports independent and creative work.

Virtual laboratories allow you to implement mini-projects that meet the real tasks of modern engineering, and also form research skills in students that are important for professional orientation. It is important to note that the chosen platform should be intuitive, multifunctional and correspond to the level of user training. Among the numerous solutions on the market, some of them are better suited for the initial level, while others are for in-depth technical training at the university level. That is why it is advisable to conduct a comparative analysis of such environments according to a number of criteria, which allows you to choose the optimal tool for the educational process. A comparative analysis of modeling environments for STEM education is presented in Table 1 [8].

TABLE I. COMPARATIVE ANALYSIS OF MODELING ENVIRONMENTS FOR STEM LEARNING

Platform	Arduino / ESP Support	Circuit modeling	Educational potential
Tinkercad	Yes	Yes	High (STEM grades 5–11)
Fritzing	No (no code simulation)	Yes	Medium (circuit visualization, PCB)
Proteus	Yes (various MCUs, including ESP)	Yes (with models)	High (university level)
CircuitVerse	No	Yes (digital circuits)	Intermediate (logic, digital engineering)
Tina-TI	No	Yes	Medium (analog/digital circuits)

A general analysis of the presented modeling environments for STEM education shows that each of them has its strengths and limitations depending on the level of training of students and the specific goals of the educational process. Tinkercad is distinguished by its simple interface, integration with Arduino and high potential for initial STEM education in school lyceums. Fritzing is useful for circuit visualization and prototyping, however, the lack of simulation limits its use as a full-fledged educational environment. Proteus provides a professional level of modeling with wide capabilities, which makes it optimal for the university level, but the paid model limits access in the school sector. CircuitVerse is focused on logical digital circuits, therefore it is valuable mainly for studying digital electronics, but does not cover the full range of microcontroller systems. In general, the choice of environment should be based on a combination of pedagogical goals, technical capabilities of the educational institution and the level of training of students, while a phased implementation is advisable - from simple online platforms to professional emulators.

IV. PROSPECTS FOR INTEGRATION OF THE STEM APPROACH INTO THE EDUCATIONAL PROCESS

The integration of the STEM approach into the educational process opens up wide opportunities for improving the quality of training future engineers, especially in distance learning. Thanks to the use of digital platforms, students gain access to practical work with electronic circuits, programming and modeling without the need for physical laboratory equipment.

This allows not only to maintain the continuity of engineering education during crises, but also to increase motivation for learning through interesting, interactive tasks. This format contributes to the development of independence, critical thinking and the ability to work on interdisciplinary projects. Students have the opportunity to implement their own ideas by participating in competitions, hackathons or creating prototypes of devices, which develops engineering creativity. Teachers, in turn, can effectively control the learning process by providing individual tasks and monitoring the dynamics of material mastery. Platforms with microcontroller simulation allow the implementation of full-fledged educational modules, integrating physics, computer science, mathematics and technology. It is important that such an education model is accessible even in difficult conditions, when learning takes place outside traditional classrooms. This ensures flexibility and inclusiveness of the educational process, which is especially important for students from temporarily occupied or remote regions. Further development of STEM education requires methodological support, advanced training of teachers and updating of curricula. In the future, this will allow to form a sustainable educational ecosystem that can effectively respond to the challenges of the time. The STEM approach is already an important element of the modernization of education today, and in the future it will become the foundation for training highly qualified personnel who will be able to actively participate in the technological development of the country.

CONCLUSION

STEM-education during distance learning is not only a challenge, but also a powerful opportunity to transform traditional engineering training. Thanks to digital platforms, educational institutions are able to ensure the continuity of the development of practical skills in schoolchildren and students, preparing specialists who will be able to respond to the technological challenges of rebuilding Ukraine. In the near future, it is advisable to expand state and regional programs for the implementation of STEM in lyceums, provide technical support to teachers, and adapt curricula to new tools.

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