

Digitization of the educational and scientific space based on STEAM education

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Abstract. Society's social demand for highly qualified specialists capable of innovative engineering and technical activities actualizes the need to ensure the quality of engineering and technical training. Such changes require modernization of higher technical education at the legislative and administrative levels. Therefore, the introduction of innovative STEAM (virtual and augmented reality, IT technologies, robotics) into the educational process of higher education institutions is a relevant element of the formation of STEAM skills in students. *The purpose of the research* is the scientific substantiation, conceptualization and development of a digitalization system of the educational and scientific space of a higher education institution based on STEAM technologies, which will contribute to the adaptation of education seekers to educational activities, ensure procedurally and increase the quality of education. *The object of research* is the educational process in institutions of higher education. *The subject of the research* is the theoretical and methodological justification of the possibility and expediency of creating a model of digitalization of the educational and scientific space based on the principles of STEAM education. To achieve the outlined goal, the authors used the following research methods: theoretical-comparative and retrospective analysis of pedagogical, psychological, and sociological sources on the research problem; determined the theoretical foundations of the formation of the digitalization system of the educational and scientific space of the higher education institution based on STEAM; empirical (diagnostics (questionnaires, surveys) to find out the level of interest and activity of students in learning engineering and technical disciplines based on STEAM; pedagogical experiment.

Keywords: educational process, STEM technologies, professionally oriented learning.

1 The relevance of creating a model of digitization of the educational and scientific space

Digitization of society is recognized as a global trend of modern times, which contributes to the rapid development of innovations and technologies, significantly accelerates the development of each industry and the economy as a whole, and depends on human capital. The main issue for discussion at the World Economic Forum in Davos in 2019 was the key change in the functioning of the labor market due to the influence of Industry 4.0 [1]. The participants emphasized the existing transformation of the quality of life, activities and interaction of society members precisely based on STEAM technologies. To take into account these innovative challenges, a development strategy was adopted, which is based on the following principles:

- promoting the development of knowledge and the formation of soft skills among students of education, innovations, education and digital society (SMART development);
- production of resource-saving and competitive products (sustainable development);
- increasing participation in the labour market of representatives of various categories and fighting poverty (inclusive development, overcoming the gender gap in the context of STEAM education) [1].

Taking into account what has been said, it is expedient to speed up the conditions of digitization of the educational and scientific space (hereinafter – DESS) based on STEAM education, in particular in the context of the further prospective development of the educational environment of the higher education institution (hereinafter – HEI).

The purpose of the research is scientific substantiation, conceptualization and creation of a model of DESS based on the principles of STEAM education. The object of the research is the educational process in HEI. The subject of the research is the theoretical and methodological substantiation of the completeness of the construction of the DESS based on STEAM education.

To achieve the outlined goal, the authors used the following *research methods*: theoretical-comparative and retrospective analysis of pedagogical, psychological, and sociological sources on the research problem; distinguishing the foundations of the formation of the system of DESS of HEI based on STEAM technologies; empirical (diagnostics (questionnaires, surveys) to find out the level of interest and activity of students in learning engineering and technical disciplines based on STEAM technologies; pedagogical experiment (declarative, formative); experimental verification of the methodology of teaching engineering and technical disciplines in the context of STEAM education.

2 Analysis of the development of the educational and scientific space in the conditions of digitalization

In the field of education and science, digital development will make it possible to integrate the educational environment of the state into the Digital Single Market of Europe, subject to compliance with the society members' quality of life, activity and

interaction nness to the world» [2]. The basis of this provision is the European cloud of open science and European data infrastructures, implemented, in particular, through the development of interoperable digital infrastructures for the needs of educational and scientific institutions. It is thanks to the development of the digital environment that the transition to Open Science will take place, the concept of which is that the entire research process, from the search for the necessary information to the publication of research results, is carried out using open means and tools.

The importance of the initiated research is confirmed by some publications. In particular, the crucial importance of digital technologies in the development of education is revealed in scientific studies by Cabero-Almenara, Gutiérrez-Castillo, Palácios-Rodríguez, Barroso-Osuna [3] and others. Ettore, Michel and Faron [4] emphasized the need for innovative solutions regarding the structural restructuring of the educational system, taking into account the development of digital technologies. The research of Albreiki, Habuza and Zaki [5] is interesting, in which it is substantiated that digital technologies are technological educational tools with the help of which a new educational concept is created and a significant potential is formed for monitoring the educational progress of students and predicting their success.

The interdependence of the digitization of the educational environment and the introduction of STEAM education was discussed in several scientific publications [6-8]. According to Lu, Yang, Shi and Wang [8], this is because the integration of many disciplines, which is provided by STEAM training, is impossible without the use of digital technologies and the formation of algorithmic thinking. And this type of thinking is leading for the next generation of the 21st century and should be formed in the future qualified specialist [7]. In this context, there is an increase in the number of educational institutions that are focused on the implementation of STEAM education based on IT technologies [9].

The analysis of the cited publications and my own practical experience proved that in the conditions of the digital transformation of education, urgent tasks arise, taking into account the need of scientific and methodological support of educational activities. Among the primary ones, the authors of the research outlined:

- theoretical justification and methodical support for the construction of various models of a digital educational environment based on STEAM to meet the educational needs of students;
- creation of high-quality digital content based on STEAM technologies (robot technical kits, virtual experiment elements, 3D technologies) from various fields of knowledge for various levels of education and ensuring open access to it for all participants of the educational process;
- pedagogical design and psychological support of adaptive information and digital didactic systems based on STEAM technologies, built taking into account the peculiarities of the mental development of students, their cognitive interests and intellectual abilities;
- formation of digital soft skills of pedagogical, scientific-pedagogical and scientific workers, etc.

3 Justification of the digitalization model of the educational and scientific space based on STEAM education

Considering the conditions of social development in the period of Industry 4.0, interdisciplinary knowledge and the ability to solve professional tasks comprehensively, going beyond the boundaries of a single field (for example, 272 Aviation Transport, 123 Computer engineering, etc.) are in demand among future specialists. Such an approach allows for the very concept of STEAM, which involves the combination of various sciences, technologies, engineering creativity and mathematical thinking into a single logical system of scientific knowledge. The main principle of the STEAM approach in education is interdisciplinarity. This approach is in demand when solving a real problem of the applied aspect (study of physics and professionally oriented disciplines). The STEAM concept of education allows you to implement various types of interdisciplinary approaches, which the authors identified in their research, such as:

- interdisciplinarity – related to the study of the object within many disciplines (physics, flight safety, aerodynamics, meteorology, etc.), as well as the adaptation of the methodology of one discipline to the needs of another based on STEAM technologies;
- multidisciplinary – comparison of several disciplines (physics, radio electronics, electrical engineering, resistance of materials, etc.), which focus on solving one problem without a final combination. This approach contributes to expanding knowledge, obtaining information and using STEAM technologies;
- cross-disciplinarity – conducting research at the intersection of many disciplines (for example, basic and elective courses in engineering and technical direction);
- transdisciplinarity – researching a problem with going beyond the boundaries of individual disciplines, focusing attention on the problem and obtaining relevant knowledge and results, taking into account the trends of STEAM education.

In the research, the authors determined that, despite the potential advantages and effectiveness of integrated STEAM education, the implementation of this educational strategy has several significant obstacles that must be taken into account in the process of developing the educational centre based on STEAM technologies. First of all, the educational process of HEI has an established structure based on a list of academic disciplines and requires a deep restructuring of the curriculum and the form of conducting classes, as well as material costs for equipment and laboratories. Therefore, the creation of the educational centre which implements the integrated STEAM approach to teaching and learning, is expensive and time-consuming. In addition, teachers who will work in the conditions of implementation of STEAM education must have not only interdisciplinary knowledge but also appropriate pedagogical skills for such work. This problem is outlined in the works of scientists El-Deghaidy, Mansour [6], Liao, Chiang, Chen [10] and others.

Digitization of the educational and scientific space based on STEAM education involves the cooperation of scientific institutions, educational institutions and scientists who will provide the educational process, as well as the infrastructure that will allow for the digital transformation of education. The authors of the research determined the components of the proposed model of the DESS based on STEAM technologies by the

approbation aspects: methodological support, which involves the development of educational programs and resources, and the selection of forms and methods for the implementation of STEAM education approaches. The survey of respondents conducted in the course of the research indicates the needs and readiness of teachers for the introduction of STEAM technologies, the level of which depends on the educational policy regarding the introduction of integrated education in HEI. The authors conducted a survey regarding the implementation of STEAM training in HEI (see Fig. 1). 112 respondents took part in the survey, of which 94 are teachers of higher education institutions (Vinnytsia National Technical University, Donetsk State University of Internal Affairs), as well as 18 employees of a scientific institution (National Center "Junior Academy of Sciences of Ukraine"). The greater part of the respondents (81 people, which is 72,33%) indicated that the creation of the DESS based on STEAM technologies is possible under the conditions of integration of formal and informal education, taking into account gender indicators.

Among the reasons that slow down or make impossible the construction of the educational centre on the basis of STEAM technologies, the following are identified: the lack of equipped STEAM laboratories, specialists in the implementation of STEAM education, the training of teachers in the use of digital resources and tools for STEAM, the lack of appropriate digital tools for the implementation of STEAM education, the lack of methodological recommendations regarding inter-subject integration, lack of readiness of higher education seekers to change the type of activity, etc.

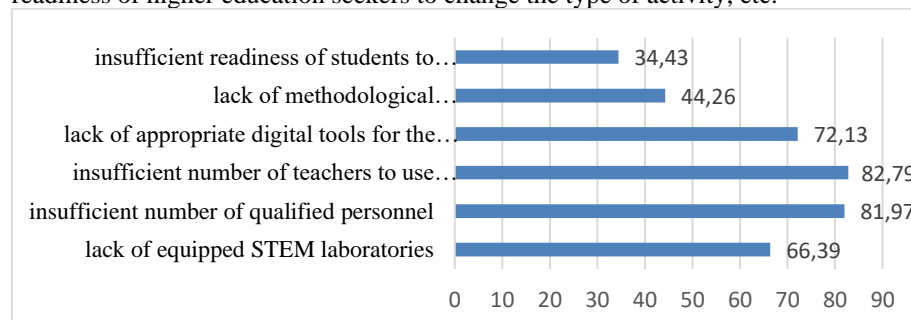


Fig. 1. The result of the survey on the reasons that inhibit the construction of the STEAM space

During 2020-2023, experimental work was carried out on the selection of digital instruments for the implementation of STEAM training. We believe that properly selected digital tools make the educational process as motivated and effective as possible. The results of the conducted survey proved that the students showed the greatest interest in STEAM classes (lectures, practical) in the use of virtual, mixed and augmented reality, virtual laboratories (<https://stemua.science>), 3D printers, robotics kits (Arduino, DIYrobot STEM, MakeX Starter Educational Competition Kit, etc.), tools for modeling objects and processes, as well as creating animations (see Fig. 2). The survey involved 386 secondary school graduates of 2-4 courses at Vinnytsia National Technical University and Donetsk State University of Internal Affairs.



Fig. 2. Implementation of Arduino kit and elements of States of Matter PhET simulation in the educational process of HEI

Thus, the effectiveness of the developed methodology for teaching physics and professionally oriented disciplines based on STEAM technologies was confirmed by the expert evaluation of the Central Technical Education Center based on STEAM, practical didactic tools, the system of educational and methodological support during the calculation of: 1) the indicator of generalized opinion by finding the arithmetic mean value, variance, mean square deviation, coefficient of variation; 2) the degree of agreement of the opinions of experts regarding the importance of the requirements for the teaching methodology of physics and professionally oriented disciplines based on STEAM was confirmed by the calculation of the concordance coefficient, namely: the evaluation of the DESS based on STEAM technologies ($W = 0.078$); practical didactic tools ($W = 0.085$).

Taking into account the results of the experimental work, the authors of the research have developed a structure of DESS based on STEAM education for higher education, which contains the following elements:

1. Digitization of management activities in the context of STEAM – is implemented by planning a digital strategy and a developed concept of STEAM education, assessing the feasibility of implementing digital initiatives, and ensuring a gradual transition to electronic document management. An important point is the creation of a system for monitoring educational trends and determining the conditions for the adaptation of students of higher education to the introduction of STEAM technologies.

2. Digitization of educational activities based on STEAM technologies – expansion of cooperation with institutions and enterprises of the digital industry is planned to involve scientists and practitioners in the educational process. Within this section, cooperation agreements were concluded, advanced training programs were developed for the formation of digital competence of scientific and pedagogical staff, best practices in this direction were analyzed, educational and methodological support for the educational process was developed taking into account modern trends in the development of digital technologies (STEAM). In particular, the use of cloud technologies, augmented, virtual and mixed reality, chatbots and virtual assistants, robotics tools, and electronic portfolios of scientific and pedagogical workers have been created in the educational process.

3. Digitization of scientific activity – the integration of scientific activity of HEI into the European scientific space through participation in interdisciplinary projects is foreseen; connecting the university to the European cloud of open science; creation and development of scientific digital infrastructure; digitization of monitoring of the implementation of the results of scientific research; digitization of student science.

4. Involvement of stakeholders in cooperation in the development and implementation of educational programs based on STEAM education – the creation of programs for the development of digital soft skills for learners of any age and social status, using the possibilities and concepts of distance learning in partnership with academic institutions and employers (use of open online courses based on STEAM technologies).

The levels of the DESS on the basis of STEAM education, which are implemented in HEI in today's conditions, are shown in Fig. 3.

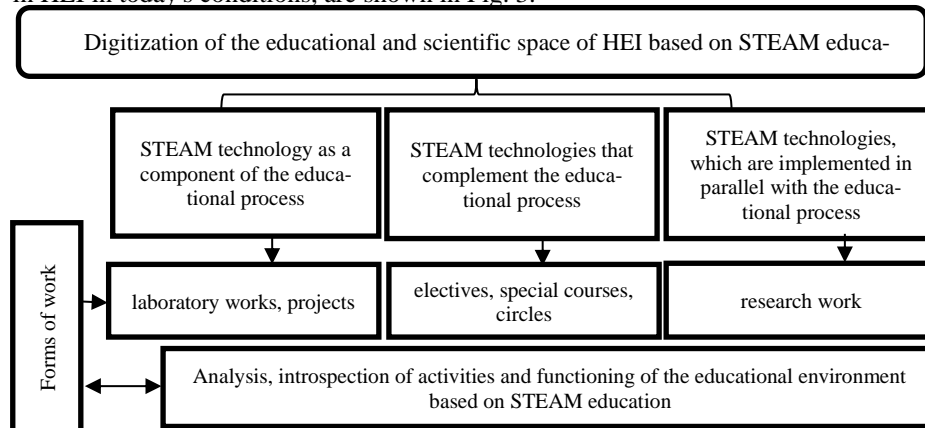


Fig. 3. A model of the levels of the DESS based on STEAM education.

The authors of the research carried out the approbation of this model of the levels of implementation of the DESS on STEAM education at the Vinnytsia National Technical University, the Donetsk State University of Internal Affairs, and the National Center of the «Junior Academy of Sciences of Ukraine». The implementation of levels of implementation of the DESS based on STEAM education made it possible to strengthen the research and scientific and technological potential of scientists and students of higher education, to develop critical, innovative and creative thinking skills, to solve the problems of communication and teamwork regarding project activities based on STEAM education. Digitization of the educational space of HEI based on STEAM education made it possible to ensure the interdisciplinary integration of disciplines and to promote the formation of motivation of the scientific and pedagogical staff and students of higher education for self-realization, partnership, initiative and entrepreneurship in the educational and scientific activities of HEI based on STEAM education.

The authors have substantiated the regularities of the formation of the DESS system on the basis of STEAM technologies; the concept of STEAM education for technical HEI was created, which reflects the sequence of stages of conceptualization, adaptation, direct implementation, active productive use and development of innovations; didactic requirements for solving problems in engineering and technical disciplines based on STEAM technologies have been established; the criteria for the technological feasibility of STEAM education are substantiated; the peculiarities of the teaching methodology of engineering and technical disciplines based on STEAM technologies are determined; methods for the autonomy of learning subjects have been *developed* and the function of the teacher has been changed from a source of knowledge to an organizer of their learning.

4 Conclusion

.Therefore, the authors created a model for the implementation of the DESS based on STEAM education, which will provide a methodological, theoretical and methodical basis for the introduction of STEAM technologies into the educational process of technical HEI, which will create the prerequisites for their implementation for the training of professionally oriented specialists; innovative digital tools and methods of organizing the educational process in engineering and technical disciplines based on STEAM are considered; the main features of the use of STEAM technologies in the educational process of engineering and technical disciplines are determined. The authors see prospects for further research in the development of engineering and technical disciplines teaching methods in the context of STREAM education

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