Innovative and Scientific ECO Environment: Integration of Teaching Information and Communication Technologies and Physics

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Abstract. Given the trends of digitalization, the main directions of improving the educational process in institutions of higher education and the requirements for the next generation, it is important to develop a model of the innovative scientific ECO environment, where the modernized methodology will properly implemented in teaching physics in integration with ICT based on STEM education. Physical and technical training of future specialists (in particular, aviation) is a component of their professional training, which forms personally and professionally important qualities, readiness for training in the specialty "Aviation Transport". Each of the disciplines (Avionics, Flight Dynamics, Aerodynamics, Radio Equipment, Flight Simulator etc.) of professionally oriented training has a positive effect on the level of professional competence of future professionals. Therefore, the method of teaching physics and professionally-oriented disciplines using ICT based on STEM-approach should promote the development of student's critical thinking, creativity, skills of quick orientation and response in difficult situations. The effectiveness of the developed methodology based on STEM technologies is con-firmed by the conducted pedagogical experiment in technical institutions of higher education in Ukraine. The authors substantiate a model of innovative-scientific ECO environment; develop a methodological system for the formation of student's knowledge of physics-based on fundamental end-to-end generating concepts, taking into account, transdisciplinary and professionally oriented approaches to technical disciplines based on STEM technologies.

Keywords: Innovative-scientific ECO-environment · STEM-technologies · Physics · ICT · Pedagogical experiment

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1 Problem Statement

At the stage of modern transformational changes in society in general, and in the field of education in particular, the formation of an innovative-scientific ECO environment (hereinafter – ISD-ECO) of an educational institution becomes an urgent problem. This allows talented young people to develop their research skills and acquire relevant life and special professional competencies based on STEM education.

Today, the introduction of innovations that are part of the ISD-ECO, taking into account the principles of STEM education is a challenge to the rapid postpandemic space. In addition, in the Ukrainian educational space, these implementations have some state support and are regulated by current regulations. After all, Ukraine is gradually joining the international educational standards of quality of natural sciences and mathematics; at the same time forming a civil society that requires an appropriate level of professional training, including in the technical field of education. Thus, Ukrainian scientists study in detail the experience of different countries (UK, Italy, China, Poland, Singapore, USA, etc.) on the development of STEM education.

Based on certain trends in education, in particular, in STEM education, own retrospective experience and results of scientific activity, taking into account analytical data on the study of primary sources for the rational construction of the model of innovation-scientific ECO environment (hereinafter – M-ISD-ECO), it is necessary to strengthen the identified contradictions between: the needs of society in highly qualified, competitive professionals (not taking into account the demands of employers), able to quickly adapt to new requirements of today and in complete compliance of the Ukrainian education system, its quality in terms of training of technical training; the latest scientific achievements of subjects in physics education based on the integration of information and communication technologies (hereinafter – ICT) based on STEM education in higher education institutions (hereinafter – HEI) and traditional methodological approaches to the formation of professional training teaching; introduction of innovative approaches (transdisciplinary, competence, professionally-oriented, systemic) teaching of physics and ICT and their fragmentation in the process of formation of professional competence, which is formed in the development of ISD-ECO based on STEM education.

Thus, the lack of systematic methodological basis for the introduction of methods of integrated teaching of ICT-oriented physics in the context of STEM education, insufficient level of theoretical study of this problem and practical implementation, its importance for training highly qualified specialists, allows to develop a methodical system of teaching physics and ICT, by studying natural sciences and professionally-oriented disciplines in the free economic zone of technical direction based on creating an innovative scientific model of ECO environment.

2 Analysis of Recent Research and Publications

Achieving pedagogical goals and effectiveness in teaching will contribute to the functioning of our proposed innovative scientific ECO environment based on STEM education in terms of integration of teaching physics and ICT.

In this context, research into the implementation of the idea of STEM education (abbreviation first proposed by American scientist R. Colwell) showed interest S. Galata,

H. Gonzalez, N. Honcharova, D. Kuenzi, O. Kuzmenko, O. Korshunova, D. Lenhdon, N. Morze, K. Nikols and etc. The solution of the main task of the modern education system is determined by the trajectory of innovations, which are aimed at preparing a new generation of people who have certain abilities for self-improvement, self-development, self-education and finally – for self-realization in the profession. That is, the educational system, in our opinion, should contribute to the creation of adequate conditions for the formation and development of human capital of the state (scientific, intellectual, labour potential of the country) as an important component of the knowledge economy. At the same time, the legitimate transience of the emergence of information resources – technical means, production technologies and management affects the development of innovative educational systems of developed countries. This suggests that the leading factor in the modernization of education in most countries is the STEM component. For example, the national program for the training of STEM educators is already functioning in the USA [1].

For example, the factors that stimulate ECO innovation and the formation of the above-mentioned environment are outlined in the works of Chinese scientists (Jun Chena, Jinhua Cheng, Sheng Dai, 2017), who point to the importance of innovations, modernized technologies and their sale in the economic market. Examining the corporate ECO environment (Fang Hea, Xin Miaoa, Christina W.Y. Wong, Stacy Lee, 2018), scientists focused on factors such as stakeholder requests, ECO innovation drivers, ECO innovation systems, ECO design, science interactions, business and government, which are important factors for the implementation of innovative trends in the educational space for the development of the technical industry [2, 3].

Thus, the system should become an innovative and educational ECO environment, for the formation of which it is important to understand the essence of the concepts of "information and educational environment", "interactive learning environment" and "virtual environment". In this vector, the term field of the semantic-logical construct "information-educational environment" is understood as a single space where the integration of necessary information through various media in the educational process, including the teaching of physics and ICT. The semantics of the term "interactive learning environment" mainly reveals and supports the structured interaction between learners (outlining the demands of the younger generation on the quality of education). The ontology of the concept of "virtual environment" includes in its content various types of interactions, and is also considered as software for the provision of educational services in the teaching of physics in integration with ICT based on STEM education.

According to V. Bykov and M. Shyshkina [4], the structure of the learning environment determines the internal organization, relationship and interdependence between it's elements. Scientists V. Vovkotrub and N. Manoilenko [5] consider the learning environment like an office or laboratory in the context of a system with an "experimental setup" (demonstration, laboratory) and an experimenter (teacher, pupil or teacher, student) to increase its efficiency, which is one of the goals of ergonomics of educational physics experiment. The concept of "cloud-based learning environment", which is an important component of innovation-scientific ECO environment, V. Bykov [6] defines as an ICT environment HEI, in which certain didactic functions, as well as some fundamentally

important functions of research, include expedient coordinated and integrated use of cloud computing services and technologies.

Focusing on the scientific work of V. Bykov, A. Gurzhii and M. Shyshkina [7], we note that to increase the efficiency of the process of forming an ISD-ECO it is necessary to comply with such basic requirements as strengthening the material and technical base of HEI; creation of a reliable system of delivery of STEM-teaching aids and necessary equipment in the process of integration of physics and ICT teaching; development of pedagogical methods of effective use of STEM-learning tools; application of specific organizational and pedagogical conditions for the effective use of teaching aids, including modern ICT and digital equipment; creation of an information base of knowledge on the development and implementation of STEM-teaching tools in the educational process of free economic education; funding for the STEM development program.

3 Statement of Basic Material and the Substantiation of the Obtained Results

Summarizing the results of analytical research, it can be argued that in science at present there is no clear concretization of the semantic and logical justification of the essence of the concept of "innovation-scientific ECO environment". However, we consider it expedient to introduce it into scientific circulation, at this stage of the formation of modern education. In accordance with the above, we offer the model developed in the course of our study of the ISD-ECO (Fig. 1).

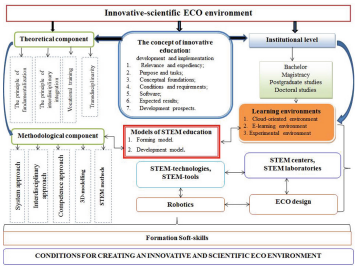


Fig. 1. Model of innovation-scientific ECO environment.

The components of M-ISD-ECO have certain integration relationships, which are established in the system of teaching physics and information and communication technologies, taking into account the basic provisions of transdisciplinary, systemic, competent, professionally-oriented approaches. Note that the change in the qualities of these components causes a change in the quality of the educational environment. Indeed, the component components of the ISD-ECO are interdependent, systematically integrated and determined by the general goals of the educational process of free economic education, in particular technical. Consider M-ISD-ECO on the example of its implementation in HEI – Flight Academy of the National Aviation University (hereinafter – FA NAU); Vinnytsia National Technical University; Kamianets-Podilskyi Ivan Ohiienko National University.

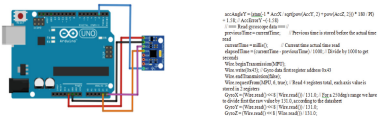
For example, we give a certain factual analysis of the environment of FA NAU. We state that the professional training of highly qualified specialists in the field of 272 "Air Transport" is an integral part of this environment, as the next generation needs to acquire the following competencies: be able to quickly find non-standard, effective solutions to scientific, industrial, social and other problems, based on basic theoretical knowledge and practical skills of personal research in the integration of physics and ICT; feel the need for constant, systematic replenishment and updating of acquired knowledge and soft-skills, without stopping the process of self-improvement, self-education and self-learning throughout life; rethink and apply in practice the necessary information of the research direction based on STEM approach.

In the educational ECO environment, it is possible to perform both real and virtual experiments. For example, a real physics experiment makes it possible to observe the results of the impact on the system under certain initial conditions, considering the ontological visualization of structures [8]. In addition, the results are analyzed and conclusions are drawn about the physics nature of the phenomenon. But the real experiment does not always give a complete picture of the process under study. Therefore, the formulation of a real experiment should be carried out whenever possible to achieve the goals.

In the context of the introduction of information and cloud technologies in the educational process of teaching physics, a virtual experiment becomes important [9]. A deeper study of a physical phenomenon can be done through its modelling. Phenomena models more fully reflect the essential properties of the object or process under study.

The authors of the study developed a method of teaching physics based on STEM technologies [9]. Thus, in the process of studying the topic of solid mechanics for aviation students, it is very important to understand the concept of the gyroscope and its principle of structure, as it underlies the control of the aircraft.

Therefore, we offer an example of the use of the ARDUINO program with inertial measuring sensor MPU 6050 by students of FA NAU, with the help of which students get acquainted with the basic concepts and laws of rotational motion. The experiment is entitled: "Study of the gyroscope with ARDUINO inertial measuring sensor MPU 6050". Requires certain equipment: Arduino board or Arduino clone (Freeduino); MPU 6050 sensor; wires for connection, software: Arduino IDE; Processing IDE. Note that the use of inertial sensors ARDUINO (Fig. 2a) are used in smartphones, unmanned aerial vehicles, balancing robots, electronic gadgets. This program has a built-in motion processor. It processes the values of the accelerometer and gyroscope to provide accurate 3D values. This sensor measures linear acceleration but does not respond to turns. Both sensors can fully describe all types of movement. The main advantage of a gyroscope over an accelerometer is that it responds to movement in any direction. The Arduino coding fragment is shown in Fig. 2b by which students can observe the reading of data from the accelerometer and gyroscope to determine the characteristics of rotational motion.



a) b)

Fig. 2. Program Arduino MPU 6050 tutorial

The effectiveness of the proposed method in the integration of teaching physics and information and communication technologies based on STEM education in terms of M-ISD-ESO was confirmed by the results of a pedagogical experiment. 153 students of the control group and 161 students of the experimental group took part in the experiment. The experiment was conducted based on FA NAU. The dynamics of the formation of the cognitive level of quality of student achievement in the physical workshop is reproduced graphically (Fig. 3), which confirms an increase of 22% provided the integration of physics education with ICT (using 3D modelling, cloud-based learning tools, robotic kits, etc.) than the traditional teaching method.

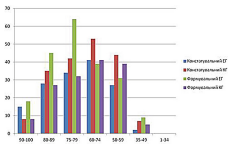


Fig. 3. Dynamics of indicators of quality of educational achievements of students in the process of performing a physics workshop based on STEM-technologies.

The study, adjustment and generalization of the results of approbation of the proposed method of practical and experimental tasks by physics students were conducted through selective attendance, discussion with teachers of opportunities to improve the learning process in physics in experimental groups, analysis of efficiency and effectiveness in the context of STEM education. To identify statistically significant differences in the levels of knowledge of students of control and experimental samples, the authors used the method of testing null and alternative hypotheses by Pearson's criterion (χ^2), because all the necessary conditions are met, ie: both samples are random; the samples are independent and the members of each of the samples are independent of each other; the scale of measurements is a scale of names from 7 categories. The results of the third stage of the pedagogical experiment indicate the effectiveness of strengthening the role and importance of methods of teaching physics in the development of STEM education, namely the organization of student's practical tasks, skills and abilities in performing physics workshops using STEM technologies.

Thus, our proposed M-ISD-ECO has a certain dependence on the psychological and pedagogical support of its use in the educational process in the integration of physics and ICT. The factors of its effectiveness include:

1. Compliance with the didactic principles of clarity on the methods and forms of experimental presentation of educational material in classes that take place in the integration format of physics and ICT based on STEM education.
2. Ensuring openness in the selection of means of conducting a physics experiment.
3. Motivation of purposefulness to study physics according to professionally oriented and integrated approaches under the condition of full-fledged formation of the student concerning the purpose of the experiment, stimulation of cognitive activity which is directed on achievement of the set purpose.
4. Implementation of personal performance of a physical experiment based on the individualization of the learning process. It is necessary to take into account a differentiated approach to the formation of student competencies.
5. Acquisition of new STEM competencies involves the use of teaching aids that should be aimed at the development of logical and systematic thinking.
6. Motivation to perform a physics experiment by students increases interest in learning and the emotional component of the process promotes interactive learning.
7. Creating constant feedback between the subjects of study, which makes it impossible to make mistakes when experimenting.
8. The formation of methods of flexible learning, which contributes to the organization of independent decision-making by students in terms of organizational aspects of the experiment. Then students have the opportunity to feel like a subject of this process, which has the right to make suggestions.
9. Providing timely assistance to students in planning and implementing a system of experiments to study integral physical systems.

4 Conclusions

Industry 4.0. and implementation of innovative approaches translates the innovation process in physics in combination with integration with ICT on the basis of STEM education in HEI to a specific technological task, which is solved due to the use in ISD-ECO: design technology for innovation in physics and ICT in technical free economic zone; clear forecasting of the purposes of innovation and guaranteed achievement of results of innovative activity of students in the course of training of physics on the basis of STEM-education; the formation of the optimal volume and sequence of actions and operations required to obtain the predicted results of students in teaching physics with a combination of ICT; reduction of terms of performance of certain stages and operations of educational process on physics on the basis of STEM education; creation of opportunities for change of algorithm of actions, simplification or complication of operations at change of conditions of realization of innovations, growth of innovative potential of HEI.

The ISD-ECO and methods of teaching physics in integration with ICT and professionally-oriented disciplines proposed by the authors, allows us to highlight the following relevant aspects: modelling methods (physical, mathematical), which are components of STEM-technologies; in the conditions of educational physical experiment STEM-technologies are means for interpretation of the observed physical processes and phenomena that allows establishing transdisciplinary interrelations between STEM-elements (science, technology, engineering, mathematics). Based on this, we believe that

the method of teaching physics should be consistent with the use of new equipment, technical means of teaching, reflect the current level of scientific achievements in physics, take into account the individual characteristics of students to improve knowledge, skills and abilities HEI technical profile of education and properly solve the problem of formation and development of the personality of each student in the context of the development of STEM education. The results of the experiment and their processing using this technique confirmed its effectiveness and relevance of the proposed topic.

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