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iJEP International Journal of Engineering Pedagogy

iJEP | eISSN: 2192-4880 | Vol. 13 No. 2 (2023) | OPEN ACCESS

https://doi.org/10.3991/ijep.v13i2.36245

SHORT PAPER

Onto-oriented Information Systems for Teaching Physics and Technical Disciplines by STEM-environment

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ABSTRACT

A significant problem of our time is the substantiation of the scientific approach to the construction of an innovative educational environment with the use of STEM technologies in the teaching of physics and technical disciplines. *Research hypothesis*: introduction of a scientifically based onto-oriented information system of teaching physics and technical disciplines using the requirements of STEM will help ensure the quality of the educational process of higher education institutions of technical orientation and stimulate the development of STEM skills in applicants. *The purpose of the research* is to substantiate the principles of an onto-oriented information system for teaching physics and technical disciplines using the STEM environment and its approbation in the process of training specialists in the technical specialties. *The object of research* is the process of modelling the onto-oriented information system of teaching physics and technical disciplines using the requirements of STEM education. *The subject of the research* is to improve the process of professional training of specialists in technical specialties based on interdisciplinarity.

KEYWORDS

STEM environment, physics, information system, modelling programs

1 INTRODUCTION

The current state of development of innovation is a consequence of the lack of strategic vision of the state policy of Ukraine on the formation of Ukraine's innovative ECO-system, which reveals the trends of STEM education. Peculiarities of innovative aspects of scientific and educational development in Ukraine are currently a topical issue in the war and are important for training the new generation youth, taking into account the requirements of international and state institutions, business structures, investors, stakeholders and various resources to be

Kuzmenko, O., Dembitska, S., Miastkovska, M., Savchenko, I., Demianenko, V. (2023). Onto-oriented Information Systems for Teaching Physics and Technical Disciplines by STEM-environment. *International Journal of Engineering Pedagogy (iJEP)*, 13(2), pp. 139–146. https://doi.org/10.3991/ijep.v13i2.36245

Article submitted 2022-10-19. Resubmitted 2023-01-24. Final acceptance 2023-01-25. Final version published as submitted by the authors.

used and the application of scientific knowledge, technologies, and modernized methods for onto-oriented information systems (OOIS) in the process of teaching physics and technical disciplines in higher education institutions (HEI). These factors will ensure the development of innovation and training and empowerment of competitive professionals, through the large-scale implementation of research results and scientific and technical (experimental) developments based on STEM education.

Currently, there are many innovative structures, but there is no holistic OOIS teaching of physics and technical disciplines of technical HEI, the purpose of which is to train highly qualified personnel in the field of STEM education and create innovative products for the STEM environment [1, 2].

Analyzing the identified problems [3, 4] through the prism of the requirements of interdisciplinary, integrated, competent and systematic approaches to the research of educational phenomena and processes, generalization of pedagogical experience of teachers of physics and related disciplines in technical HEI, the authors outlined the contradictions that have arisen between:

- Society's need for highly qualified specialists who can quickly adapt to the requirements of the modern labour market and incomplete compliance of the domestic education system on the content of professional training in OOIS in the context of requirements for the development of STEM education;
- Traditional methods of teaching physics in technical HEI and potential opportunities of the latest direction in the methods of teaching physics and technical disciplines in OOIS, based on the means of STEM education technology;
- Introduction of innovative STEM approaches to teaching physics in the conditions of OOIS and their fragmentation in the process of forming hard and soft skills in students.

Thus, the innovative activity and fundamentalization of physics education in HEI education by means of STEM education is an integral and important component of professional competence of students in the conditions of OOIS. On these grounds, the teaching of physics and technical disciplines (TD) involves the formation of students' system of fundamental end-to-end generating physics knowledge (laws, processes, concepts) and skills in the study of disciplines and in their lives. Taking into account these trends is the basis for the development of methods of teaching physics in the development of STEM education, which should improve the quality of physics and technical education in the HEI.

Therefore, based on modern realities, OOIS should be enriched with theoretical achievements of interdisciplinary, integrated, competency and systematic approaches to the research of educational phenomena and processes in the teaching of physics and TD in HEI.

In the process of scientific research, the authors focused on the integration and interdisciplinary levels to carry out theoretical and practical justification of the process of innovation in the development of OOIS training of physics and TD in the STEM environment, namely: (1) the essential characteristics of the readiness of the HEI of the technical direction of education as an important educational resource for the perception and implementation of innovations are outlined; and (2) the theoretical aspects of digitalization of the process of innovations from the point of view of ontologies are substantiated.

2 ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

Under the conditions of innovative tendencies of development of a scientific and educational direction of training of physics and TD in HEI, the definition of *ontologies* and *ontological models* acquires importance.

The term *ontology* first appeared in the scientific work of T. Gruber [5], which considered various aspects of the interaction of intelligent systems directly with each other and with man.

The definition of *ontology* outlines the use of a set of three components: taxonomy of terms (concepts), definitions of terms and rules for their processing. Therefore, the formal "ontology model" is understood as an ordered set of species:

$$O = < C, R, F > \quad (1)$$

where C is a finite set of concepts (concepts, terms) of the subject area, which is represented by the ontology O; R is a finite set of relations between the concepts of a given subject area; F is a finite set of interpretation functions (axiomatization) given on the concepts and/or relations of ontology O.

The natural constraint imposed on set C is its finiteness and that it is a nonempty set. Logically, components R and F must also be finite.

If the conditions $R = \emptyset$ and $F = \emptyset$ are satisfied, the ontology O is transformed into a simple dictionary: for $R = \emptyset$ and $F \neq \emptyset$, the ontology O is transformed into a passive dictionary, and for $R \neq \emptyset$ and $F = \emptyset$, into a taxonomy (here the taxonomic structure is understood to mean the hierarchical system of related concepts) [6].

Scientists Strizhak et al. [7] developed a method of creating an ontological interface in the information system.

Lupenko et al. [8] outlined the development of onto-oriented information systems for folk (nontraditional) medical areas studied in their research.

Intelligent systems are programs that simulate some aspects of the intellectual activity of the learner. Recker et al. substantiated theoretical and methodological recommendations for the use of intelligent systems [9].

Thus, it is necessary to take into account the transformation of innovation processes and patterns of development of scientific and educational areas of education for the creation of OOIS in the STEM environment which should be taken into account in the methodology of teaching physics and TD in HEI, namely:

1. The trend of spreading innovations is introduced in STEM education, which absorbs innovations, and the method of teaching physics and TD in OOIS based on STEM technologies is changing, taking into account the structure, functionality and content of education.
2. The introduction of STEM technologies in the methodology of teaching physics and TD in the conditions of OOIS depends on social, economic, psychological and pedagogical, personal, ergonomic and other factors.
3. The emergence of innovative processes taking into account the STEM direction of training in technical HEI for technical specialties and their development is associated with transformations in society, reforms, progressive movements, etc.

3 STATEMENT OF BASIC MATERIAL AND THE SUBSTANTIATION OF THE OBTAINED RESULTS

Given the laws of integration of knowledge and their consequences, we present a logical-structural model of integrative physics and TD (LSMI FTD) in the STEM environment, which is related to the ontological basis of individual disciplines of the cycle of technical HEI Figure 1). The proposed integration approach will promote the formation of integrated personal quality – soft skills based on STEM-technologies.

Currently, the integration approach to optimizing the educational process is an obvious fact. Integration as the embodiment of an integrated approach to the teaching of physics and TD in the OOIS in a STEM-environment – one of the tools that can unify, integrate and concentrate knowledge based on the interpenetration of its elements, strengthening and complicating the links between them.

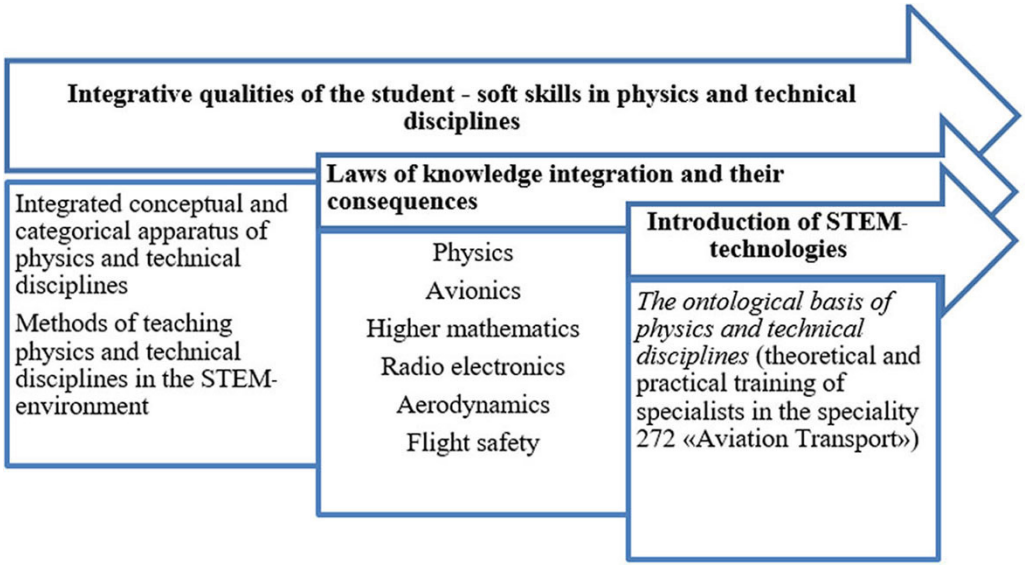

Fig. 1. Logical-structural model of integrative physics and technical disciplines in the STEM-environment

From this point of view, the problem of formation and development of LSMI FTD in the STEM environment is solved at the interdisciplinary level, which helps to overcome the contradiction between the need to ensure a high level of integration of scientific knowledge of physics and TD in educational and cognitive activities in physics-based disciplines on STEM education; a methodical approach in the analysis of a physics phenomenon or process in terms of various theoretical schemes, promoting the development of thinking, creative and intellectual abilities of students; and practical skills during the adaptation of scientific knowledge to the educational conditions of the technical HEI.

In addition to the invariant knowledge from the general cycle of disciplines, which is acquired by all students of technical HEI, the fundamental and technical component of training in OOIS in the STEM environment is important for future engineering specialists. This is manifested in the need for the formation of specialists in this area of training specific qualities that are unique to them. The scheme shown in Figure 2 illustrates the OOIS of teaching physics and TD in the STEM environment, as well as the nonlinearity of interdisciplinary links at the level of professional training of future specialists in the technical specialties.

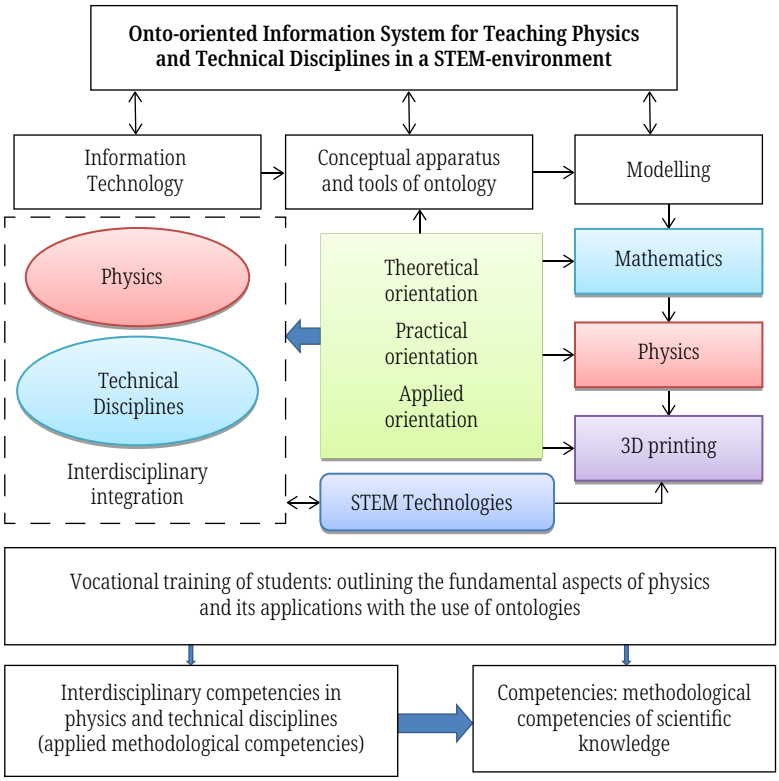

Fig. 2. Onto-oriented information system for teaching physics and technical TD in a STEM environment

The rapid development and spread of information and communication technologies lead to the understanding and solution of new educational problems, including informatization and computerization of the educational process, computer literacy and information culture. Information technologies penetrate the depths of physics and mathematical and engineering education; affect the style, content and methods of knowledge of nature and didactics of physics; and enrich it and expand the scope. Given this, the clarification of the form of presentation of the component composition of the methodological training of future technical specialists requires strengthening the activity aspects of such training – theoretical and practical based on STEM technologies. Physics and technical training of future specialists in engineering belongs to the basic variable component. Its structure is due to the presence of a specific methodological component, which reflects the peculiarities of the methods of scientific knowledge of nature, and is not only complex and nonlinear but also interdependent. The combination of theoretical and empirical methodological components is due to the dualism of the methodology of scientific knowledge, and for the field of physics and mathematical sciences, it is important and a mathematical component as an integrative effect of their interaction.

Summarizing the results of the above scientific research in this direction, we identify groups of conditions for the implementation of innovative educational processes of teaching physics and TD in OOIS based on a STEM environment: institutional, organizational and managerial, psychological and pedagogical.

Institutional conditions include: the necessary regulatory and legal support for the regulation of innovative educational activities of OOIS in the STEM environment, developed innovation infrastructure and the formed innovation environment in the teaching of physics and TD based on STEM technologies.

Resource support and development of innovation based on STEM technologies in OOIS technical HEI includes the formation of motivational factors to intensify innovation processes is an integral part of innovation policy, which is formed through the regulatory framework for regulating innovation processes in education.

Innovation infrastructure is developed through the introduction of *institutional conditions* – namely a set of interconnected, complementary systems and their corresponding organizational and management subsystems necessary for the effective implementation of innovation activities of the OOIS and the implementation of innovations in HEI in the context of STEM education.

New knowledge, which arises as a direct experience in the work of research in OOIS in the STEM environment, is removed from the sphere of cognitive process and transformed into an innovation process in new systems of technological activities.

Implementation of organizational and managerial conditions for the implementation of innovation processes in the OOIS in technical HEI include actualization of the needs of students in the process of teaching physics and TD based on STEM technologies; availability of effective, scientifically based innovations (STEM technologies) necessary for solving modern problems of education and sufficient awareness of the pedagogical community about them; organization of innovative activities of the HEI based on modern OOIS based on STEM technologies; readiness of the structural and functional state of the pedagogical system of the HEI for the perception and implementation of STEM innovations; innovative management at all levels of the education system; and scientific-methodical and organizational support of innovation processes.

Psychological and pedagogical conditions for the implementation of STEM innovations are the formation of the readiness of teachers and teaching staff in general to actively creative, creative search and implement STEM innovations; development of innovative thinking of teachers; removing barriers to innovation; maintaining the health of teachers and preventing their professional burnout; and obtaining a positive emotional effect from the introduction of STEM technologies in the educational process of technical HEI.

At this stage of the research, the authors conducted a statement experiment: they analyzed the state of preparation of students for the use of OOIS in the teaching of physical and TD based on STEM technologies in technical HEI; diagnosed the state of development of the problem of teaching physics and TD using OOIS on the basis of a transdisciplinary approach; and clarified the current level of formation of students in the process of studying theoretical courses in physics. In particular, the normative documents regulating the organization of the educational process in the technical HEI in the conditions of OOIS were analyzed; possible ways of formation and development of students' motivation to study physics and TD with the use of OOIS were considered.

We found that the possibility of involving OOIS in motivating the study of physics and TD, according to respondents (43.2%), is more useful; 34% of students would like to solve practical problems with the possibility of further experimental verification of the effects of physical and mathematical modeling using physical equipment; and 37% of students want to solve problems of computational or graphical content using STEM technologies or application software.

To statistically substantiate the absence of differences between the distributions of students of the experimental and control groups on the level of academic achievement based on OOIS, the authors proposed using the Pearson test (χ^2); to assess the statistical significance of the growth of the levels of formation of certain components

of the OOIS model in students of experimental groups compared with the control, the authors used G-criterion of signs, which will be considered in future research.

4 CONCLUSIONS

The authors identified and substantiated the need for an integrated approach and the use of interdisciplinary links in the teaching of physics and TD using STEM technologies in HEI; it is established that the implementation of the proposed OOIS training of physics and TD using STEM technologies provides STEM-technologies practice for teaching methods in the scientific and educational space, which meets the requirements of stakeholders to prepare students for technical specialties.

The authors developed OOIS and LSMI FTD in the STEM environment; outlined the requirements for the components of the OOIS, which is the basis for ensuring HEI, and infrastructural levels to coordinate the activities of students in the direction of technical specialties; and determined that the implementation of the proposed OOIS based on STEM environment for training technical specialists is provided by integration and synergetic approaches based on theoretical and methodological practices, methods of teaching physics and TD. The reliability of scientific results and conclusions is ensured by the conformity of research methods to its purpose and objectives, representativeness of the sample, comprehensive testing of the main provisions in the pedagogical experiment and implementation of the developed OOIS training of physics and TD in a STEM environment.

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