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SHORT PAPER

ECO-Environment of the Information—Analytical System of Scientific Personnel Training as a Means of Open Science

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ABSTRACT

The changes in the system of higher engineering education (HEE), the development of the scientific vector of STEM and the demands of Industrial Revolution 4.0 determine the revision of the concept of Scientific Personnel Training (SPT) of engineering direction. It is important to modernize the content of such education and to focus on meeting stakeholders in the context of open science. Methodologically substantiated principles of the construction information-analytical system (IAS) in integration software engineering with scientific approaches to teaching in physics will adequately affect the level of quality organization of the research in open science using the proposed ECO-environment of IAS for SPT. The purpose of SPT, based on the fundamentalization of the practical logic and of the provisions of transdisciplinary, systematic, competency and synergetic approaches is to provide subjects of scientific education with methodological tools for solving research problems in specific knowledge areas. At the transdisciplinary level, taking into account the concepts of STEM and open science justify adapting the methodology of constructing the transdisciplinary IAS; the terminology is systematized; the adaptive processes in an ECO-environment are revealed; the trajectory of development of transdisciplinary competence of applicants of scientific education is substantiated.

KEYWORDS

ECO-environment, Information-Analytical System, engineering software, physics, Scientific Personnel Training

1 PROBLEM STATEMENT

Given the current trends in HEE based on open science, the main direction of improving the scientific and educational process in technical institutions of higher education (HEI) and research institutions (RI), there is an urgent problem of innovating training by STEM technology and meeting the demands of stakeholders in

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extremely dangerous circumstances (quarantine restrictions from the COVID-19 pandemic, martial law, etc.). Note that transdisciplinarity is one of the properties of open science, where theoretical knowledge is supported by the results of scientific activities in the ECO-environment of IAS, which allows reflection of the objective world in its unity and dynamic development. Taking into account the transdisciplinarity of scientific knowledge and the integration relationships provoked by it in the system of scientific training, the introduction of the STEM approach in the scientific-educational process of cognition of physics as an important basic science is reflected in software engineering research. Within the reforms in the HEE and topical aspects of the development of the ECO-environment of IAS, in particular with the involvement of STEM technologies, certain trends are identified to substantiate the conceptual framework of adaptive management of SPT in the HEI/RI under the conditions of open science:

1. Profiling of physics and software engineering as components of HEE based on the development of STEM skills for the independent acquisition of knowledge by applicants of scientific education and application of appropriate methods. Thus, the structure of the scientific and educational process of HEI/RI will include the adaptive process of acquiring the competencies of research, design and inventive activities.
2. An innovative approach to the semantics of the concept of "ability" based on the achievements of basic, engineering and psychological-pedagogical sciences and having a decisive influence for substantiating the methodology for building IAS. This is based on the ECO-environment of IAS and the concept of STEM (the construction of an open scientific and educational space, which is mandatory for the SPT in engineering specifics that meet the requirements of modern societal demands).
3. The growing emphasis of the scientific and educational process in the engineering sciences on the knowledge of physics and software engineering, and the actualization of the creative component in this sense, as a factor for the organization of research and development activities based on STEM in the ECO-environment of IAS in the HEI/RI. It should be noted that the traditional trajectory of focus on professional-specific specialization in the SPT largely loses its significance. This is because technological structures are evolving so rapidly that potentially useful professional and educational-scientific information accumulated by applicants of scientific education during their development as scientists rapidly becomes obsolete. For example, the "half-life" of experience gained by scientists in the field of engineering training is now from 2 to 5 years. Continuing education, individual self-education and retraining do not compensate for this gap nor significantly change the scientific and educational paradigm towards universalizing the experience of future scientists in their basic training, including in general theory and the humanities.
4. Strengthening the differentiation and individualization of the scientific and educational process in the knowledge and teaching of physics and software engineering through the development of varied scientific and educational programs aimed at different categories of applicants of scientific education, as well as the development of individualized programs and pace, including STEM-training, taking into account the personal characteristics and competencies of each of the subjects of training of scientific personnel.

5. Improving the methodology of construction of IAS for SPT, including STEM-technologies in conditions focused not only on the intellectual potential of the applicant of science education but also on the applicant's emotional and subconscious sphere, aimed at emphasizing the future transformation of scientific subjects, via the educational process, in an active scientific community. This should be facilitated by the open scientific component of STEM education in the ECO-environment of IAS.
6. Research on the possible implementation of the principles of continuing STEM education for new types of non-formal education institutions, where scientific experience will be gained (e.g., self-education, self-development of researchers).
7. Strengthening of pure mathematical and engineering components using STEM education in HEI and RI (strengthening of the professionally oriented component in the structure and content of transdisciplinary competence of researchers).

Thus, a fundamental core of knowledge and ideas is formed in the context of transdisciplinary links between knowledge and teaching of physics and software engineering disciplines, taking into account the conceptual basis for the introduction of STEM education technologies in the ECO-environment of IAS for SPT in HEI/RI. The solution to this problem is based on the methods of cognition and teaching physics and software engineering disciplines based on the transdisciplinary approach and to the implementation of STEM technologies, interdependence and complementarity of theoretical and empirical methods of cognition in the ECO-environment of IAS. Accordingly, this allows the formation of integrated methodological ideas about the importance of fundamental and engineering knowledge, and the importance of increasing the level of transdisciplinary competence, for example, in the speciality "Air Transport", "Software Engineering" and others.

2 ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

We studied innovative processes in the ECO-environment of IAS for SPT, which is aimed at adaptive development of scientific and educational space of HEI/RI in the context of open science [1]. Such processes are adaptive and universal, and function following the laws, principles and conditions that determine the direction and content of innovations (robotics, STEM kits, elements of augmented reality, artificial intelligence, etc.).

They also provide a systemic level of implementation of digitization vectors [2] (transdisciplinarity, systematicity, interdisciplinarity and synergetic integration in substantiation and development of methods of scientific component for teaching professional disciplines, such as physics and software engineering) in the ECO-environment of IAS for SPT in HEI/RI. Realities of modernization of the system of HEE determine new features and circumstances of the development of educational innovative STEM processes [3, 4, 5, 6] and necessitate a thorough understanding of their laws on development and functional support of the ECO-environment of IAS. In this sense, the effectiveness of innovation in the system of SPT is determined following the specifics of the methodology of knowledge and teaching of physics and disciplines of software engineering in HEI. This is happening in the trend of open science. Thus, in the context of the obtained analytical results, a vision of the concept of "open science" was formed, which becomes the main driver for creating a modern paradigm of transparent evidence-based science and intensification of innovation. In Europe, this trend is being implemented under the European Open Science Cloud

(EOSC) program, which aims to develop an infrastructure that provides services to its users and facilitates open scientific practices.

Leading scientists interpret the concept of "open science" as a process of improving the effectiveness of control and reproducibility of research results and creating conditions for transparency of research [7], which, in our opinion, will have quality support in the ECO-environment of IAS for SPT. According to the definitions of researchers such as S. Albagli, M. Maciel and A. Abdo [8], "open science" is a movement that provides free access to research and promotes the dissemination of their results to any subject of scientific education. This allows the reuse, redistribution and reproduction of basic data and research methods in their field of research. Also important is the fundamentalization of scientific education, aimed at improving the quality of training and ensuring the optimal level of awareness of applicants for scientific education. This is achieved by modifying the content of specific disciplines and methods of the scientific and educational process (for example, the specifics of physics, software engineering, etc.), including the means of STEM-approach. This orients researchers to acquire scientific education in the vector of innovative research activities in the ECO-environment of IAS. In this environment, an important aspect is the adaptation process of applicants for scientific engineering education and awareness by each of them of the important context of innovation in research (approaches transdisciplinary, systemic, interdisciplinary, competency based and professionally oriented – in other words, the direction of research driven by invention, resulting in a novelty). D. Scott [9] in his research substantiated the predominance of transdisciplinarity, emphasizing in this sense also fundamentalism and instrumentalism. Researchers S. Biswas, R. Benabentos and E. Brewe [10] developed and tested programs for the adaptation of scientific training based on STEM innovations and substantiated certain principles in this vector by implementing the actual results of scientific research in the educational practice of HEI.

Thus, HEE should be fundamental, based on modern advances in science and the experience of past generations, carried out by applying the methodology of a transdisciplinary approach, provided with innovative tools of STEM technologies and more. The result is that scientific and educational activities in the ECO-environment of the IAS for SPT in HEI, as well as in RI, should be based on the following basic postulates: compliance of scientific education with the needs of socio-economic development and advanced development of education; ensuring the intellectual development of the researcher's personality, including the applicant's mastery of scientific education, effective methods of self-education, self-development, self-management, self-organization, self-monitoring – which necessarily bring the applicant closer to the highest level of research.

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

We developed a theoretical and methodological model of ECO-environment of IAS based on STEM technologies for the implementation of the methodology of transdisciplinary approach in the scientific and educational process of HEI and relevant RI. The model reflects the goal of transformational trends in education and STEM education; in particular, a sequence of stages of conceptualization, adaptation, direct implementation, active productive use and development of innovations. It also details the content of transformational changes in the system of HEE using open science (see Figure 1).

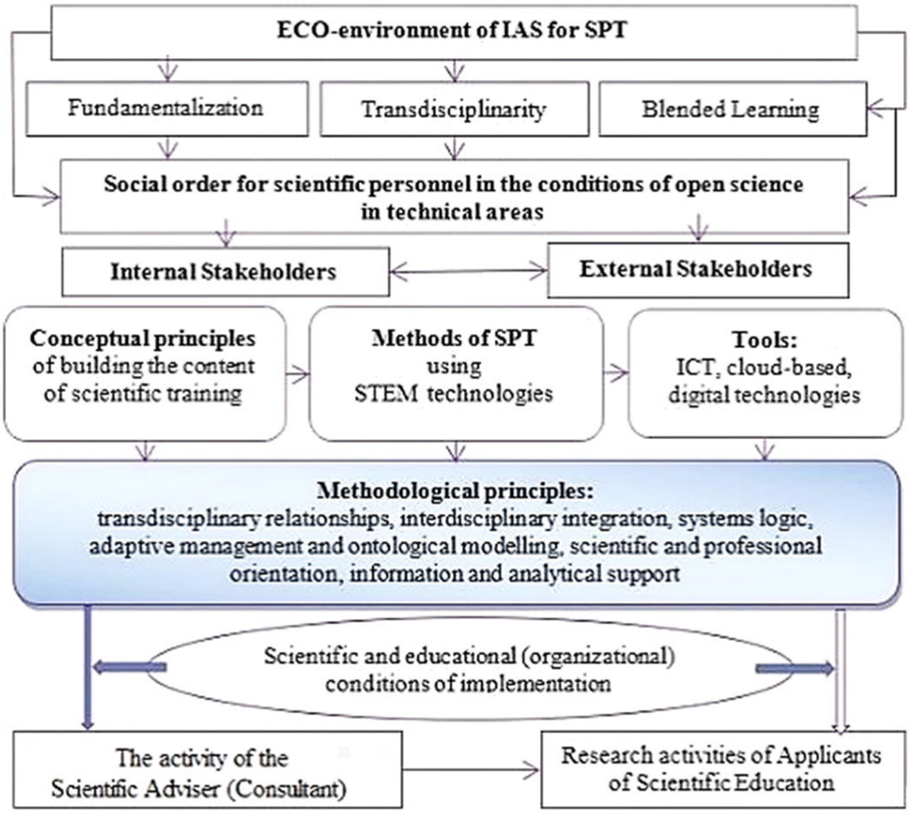

Fig. 1. Theoretical and methodological model of the ECO-Environment of IAS for SPT [1, 11, 12]

The main functional purpose of STEM technology in the ECO environment of IAS for SPT is to monitor the reproduction of innovations, adaptive development and implementation of new methods of e-learning and teaching physics and disciplines in software engineering, as well as ensuring their widespread use in educational and scientific practice RI. The proposed authors' methodology, taking into account STEM technologies, has been expertly assessed as an educational innovation.

It involves the implementation of several successive methodological stages, the result of which is the formulation of an expert opinion on the possibility of implementing innovations in the scientific and educational process of technical HEI and RI. Expert assessment is used to analyze, evaluate, classify, and predict the features of implementation and projected results of the implementation of STEM technologies following the conceptual framework. In the process of scientific research, it was established that at the transdisciplinary level of scientific training, taking into account the concept of STEM education and open scientific education requires:

- substantiation of the adaptive principles of transdisciplinarity of knowledge and teaching of physics and disciplines in software engineering;
- systematization of the terminological base of STEM in pedagogical and engineering innovation and to create the corresponding thesaurus;
- determination of the theoretical and methodological aspects of the technologization of adaptive processes based on a transdisciplinary approach, in particular for innovations in the ECO-environment of IAS for SPT;
- correlation of the interdependence of the development of transdisciplinary and STEM competencies of scientific personnel with the means of ECO-environment of IAS.

Open expert evaluation of research activities in the context of SPT, for example, in the system of work of the National Aviation University, allows selection and implementation of those innovative open science projects that would best meet "the Strategy of the National Aviation University" and "the Strategy of the Flight Academy of the National Aviation University". Preliminary evaluation and forecasting of results allow avoidance of possible risks and increase the effectiveness of proven methods of scientific training in knowledge and teaching of physics and software engineering disciplines in the transdisciplinary paradigm of the ECO-environment of IAS, including STEM innovations. For the experiment, engineering HEI laborartories were selected, as these are best equipped with equipment for scientific and educational physics experiments and optimally correspond to the ECO-environment of the IAS of SPT. For example, the research laboratory STEM-Education and Innovative Education was opened at the Flight Academy of the National Aviation University.

According to the Regulations on the Research Laboratory of STEM education and Innovative Education of the academy, this laboratory is part of the STEM-Center of the academy, which is a structural unit of the Flight Academy of the National Aviation University and provides research in STEM for pedagogical and scientific-pedagogical workers, students, graduate researchers, doctoral researchers, etc. [13].

In order to statistically process the results of the formative stage of the experiment, methods of testing statistical hypotheses based on the comparison of measurements of property in independent samples (Kolmogorov-Smirnov test) were used.

The effectiveness of scientific and experimental work in physics in experimental (EG) and control (CG) groups were tested in the HEI engineering profile: Flight Academy of the National Aviation University (Department of Physics and Mathematics Disciplines), Vinnytsia National Technical University (Department of Pedagogy of Safety and Life Safety), National Aviation University (Department of General Physics), and Bohdan Khmelnytsky National University of Cherkasy (Department of Automation and Computer Integration technologies). The effectiveness of the proposed methods of cognition in physics and software engineering disciplines based on STEM technologies in the ECO-environment of the IAS for SPT of the selected HEI is confirmed by the results of the experiment. The experiment involved 125 CG respondents and 137 EG respondents (see Figure 2).

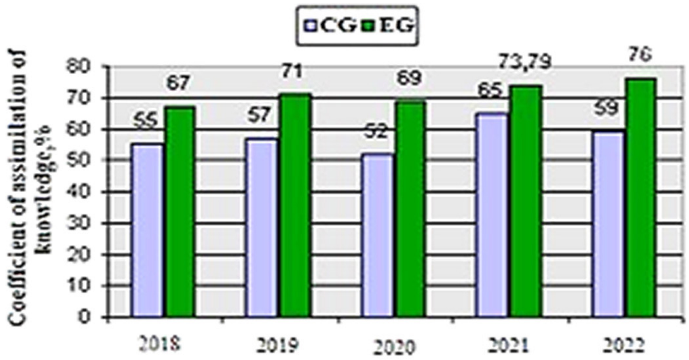

Fig. 2. Dynamics of indicators of quality of educational and research achievements of applicants for scientific education in ECO-environment of IAS for SPT

Analyzing the results presented in the Figure 2, we concluded that the knowledge of applicants of scientific education in physics and software engineering disciplines, obtained in the ECO-environment of IAS, was strong and deep, and met a high level of specific scientific and professional training. In particular, there was a deep understanding of the essence and quality of experimental reflection of reality with the use of STEM tools in open science: scientific and educational physics workshops (where the knowledge acquisition rate 69%). At a sufficient level (coefficient of mastering the proposed material 67%) were purely professional, professional and industry-specific scientific competencies (skills and abilities) of applicants of scientific education, acquired during the solution of research physics problems. For use of application software, namely a set of "L-micro", the absorption rate of 76%.

This makes it possible to assert the effectiveness of the proposed methodology and relevant recommendations for the knowledge and teaching of physics and software engineering disciplines, taking into account the basics of STEM education.

4 CONCLUSIONS

We found that the well-founded adaptive principles of the transdisciplinary approach to scientific knowledge and practical SPT of physics and software engineering in open science, in particular using the ECO-environment of IAS, have a positive impact in the context of modernization and reform of HEE and its close relationship with STEM education. It is noted that in this sense, the system of higher education and science in Ukraine and many other countries has the modern dimension of the general trend ahead of the challenges of globalization and European integration processes: a transdisciplinary-competence paradigm, scientific orientation, adherence to the principles of open science education, availability of research training, the relevance of advanced technologies of self-education, self-development, self-management, self-monitoring of applicants of scientific education, etc. Important factors in the functioning of the ECO-environment of IAS identified trends included:

– specialization aimed at the formation and development of applicants of scientific education transdisciplinary competence, including the acquisition of competencies for independent search for promising areas of research methodology and monitoring of relevant scientific developments in physics and software engineering, including those based on STEM technologies under the conditions of open science;
– restructuring of the scientific and educational process to ensure the training of scientific personnel in the context of knowledge management methodology, critical thinking, creative methods of solving research problems and intensification of innovative processes of design activities on an adaptive basis.

The results of the experiment and data analysis using the methods of scientific knowledge and teaching of physics and software engineering based on STEM technologies with the involvement of appropriate scientific-analytical and technical-technological tools confirmed the relevance and efficiency of quality Scientific Personnel Training in an innovative ECO-environment of IAS of the HEI/RI.

Full approval and applied aspects of the authors' research are at the stage of future development. Further experimental studies will be presented by the authors in the next article.

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