

Information and Mathematical Modeling as the Basis for the Professional Activity of Future Engineers in the Digitization Era

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ABSTRACT

The development of new Information and Communication Technologies (ICT) and end-to-end digital technologies has led to the advent of the Digitization Era at the present stage of development of society. Thereupon “digitization” is the basis for transformation of engineering education. It is analyzed the significance of interdisciplinary approach to the training of a modern specialist of engineering-technical type with a justification for the need for mutual integration of knowledge at the level of ICT and fundamental technical sciences by the example of the disciplines “Computer Science – Mathematics”, that is informational and mathematical modeling. The aim is to identify impact of Digitization on the theoretical and methodological foundations of an interdisciplinary approach in engineering education. Methods: it is used general scientific dialectic method, theoretical and methodological analysis and generalization of the content of informational, mathematical, pedagogical, methodological, scientific and technical literature in the field of engineering education. This allows to define the concept of integrated training task in Computer Science and Mathematics, complementing both the conceptual apparatus of the theory of learning tasks and interdisciplinary approach to the training of engineers. Results: it is formulated the concept of integrated training task in Computer Science and Mathematics. The concept is based on meaningful and activity approach to information and mathematical modeling. It is defined the typology of integrated training tasks in Computer Science and Mathematics characterized by the corresponding types of professional activity of technical engineers. It is substantiated the role of information and mathematical modeling as the main method for solving integrated training tasks. Conclusions: it is revealed the need for expanding interdisciplinary approach to the training of the “digital generation” of technical engineers in the conditions for the modern innovative economy of Russia.

Keywords: digitization, information and communication technology, engineering education, integrated training task, information and mathematical modeling

1. INTRODUCTION

The modern stage of the development of the information society is characterized by Digitization, which is understood as a socio-economic transformation that facilitates the mass introduction and assimilation of end-to-end digital technologies for the creation, processing, and transmission of information (robotics, artificial intelligence, quantum technologies, wireless technologies, new manufacturing technologies, and others) [1, 2]. In this regard, the transformation of higher engineering education is directly related to the growing role of Digitization in all

areas of human life. In addition, according to federal state educational standards of higher education (FSES HE) 3+ and 3 ++, the implementation of basic educational programs involves the use of e-learning technologies, including interactive and innovative teaching technologies, which contribute to the development of self-education skills. All this leads to the search for modern teaching methods for a new generation of technical engineers who are able to successfully carry out their professional activities in the Digitization era.

As the analysis of scientific and methodological literature shows, a special role in solving this issue is given to the creation of integrated training courses that allow for the integration of knowledge, skills acquired in the study of a

specialized discipline with an appropriate set of knowledge, skills in information disciplines. In particular, if we are talking about specialists in engineering and technology, the integration of knowledge at the level of "Computer Science-Mathematics" is of increasing importance. And this is not accidental since Mathematics is a kind of foundation on the basis of which a huge layer of engineering problems of a technical profile is solved, related to the construction of a mathematical model, its study, as well as interpretation within the framework of the problem being studied. At the same time, continuously developing information and communication technologies (ICTs) allow us to optimize a number of stages in the study of this mathematical model in terms of considering the multiplicity of approaches to its solution; data analysis, changes in these data and their impact on the result; conducting an experiment (including on a virtual level), visualizing and analyzing its results.

2. METHODOLOGY OF THE STUDY

The theoretical conclusions obtained in this study are based on the study and analysis of scientific and educational literature, scientific works of domestic and foreign scientists in the field of teaching Mathematics (M. Kline, A.N. Kolmogorov, L.D. Kudryavtsev, V. A. Gusev, S. M. Nikolsky, V. F. Butuzov, V. A. Dalinger, S. N. Dvoryatkina, etc.) and Computer Science (K. K. Kolin, A. A. Kuznetsov, M. P. Lapchik, N. I. Pak, E. S. Polat, I. V. Robert, E. K. Henner and others), context competency (V. I. Baidenko, I. A. Zimnyaya, A. V. Khutorskoy, V. D. Shadrikov, A. A. Verbitsky et al.) and systematic-activity (L. G. Peterson, Vygotsky, L. Zankov, Luria, Elkonin, V.V. Davydov) approaches to learning.

3. RESEARCH RESULTS

According to some methodologists, the key role in the practical implementation of integration processes at the interdisciplinary level in general, and at the level of the disciplines "Mathematics" and "Computer Science", in particular, is assigned to the inclusion in the learning process of integrated training tasks (ITT), which combine Mathematics with others subjects (V. A. Dalinger, F. A. Rassamagina, S. A. Novoselov, E. A. Demina, A. G. Mayburov, O. N. Efremova, V. M. Fedoseev and others). ITT are "tasks during the implementation Computer Science of which disciplinary knowledge is mastered, as well as personal, interpersonal competencies and the ability to design and create new products and systems" [3]. In the structure of the integrative approach, A. G. Mayburov and E. A. Demina play an important role in accounting for interdisciplinary, intrasubjective, interpersonal and intrapersonal integration. According to the authors, the ITT should be oriented towards organizing the activities of students in the formation of general and professional competencies of future technical

specialists [4]. In building training based on an integrated approach, researchers S. A. Novoselov and F. A. Rassamagina see the main condition for the formation of creative and professional-creative competencies of future university graduates. The authors put, among others, the set of ITT [5] as the basis of the methodology for the formation of such competencies. O. N. Efremova considers as an educational institution integrative educational projects in Mathematics and Computer Science as active teaching methods in organizing students' independent work [6]. The author conducts the classification of integrated educational projects depending on the section of Mathematics being studied and the functions of the teacher and student. The main requirements for integrated educational projects are presented in [6, 7]. It is noted that as a means of integrating natural-scientific and mathematical disciplines and, as a result, solving ITT, mathematical modeling is used [8].

The participants of the international conference "Interdisciplinarity in Engineering Education: Global Trends and Management Concepts - SYNERGY", held in 2016, proposed "interdisciplinary projects" as the basis for designing the main educational programs, while emphasizing the important role of the interdisciplinary approach in graduate readiness "to integrated engineering, taking into account its social and environmental consequences" [9]. Y. V. Krasavina, O.F. Shikhova as a result of an experiment on introducing electronic interdisciplinary training projects into the learning process showed that "the phased and systematic use of technology throughout the entire period of study at a university provides positive dynamics in the quality of students' professional training" [10, p. 161].

As a form of integration of engineering and mathematical training in the educational process of a university, V. M. Fedoseev singles out research work with students [11]. In [12], the authors presented a non-traditional interdisciplinary approach developed by them, applied to the concept of a task, which allows developing a basis for a holistic objective interdisciplinary presentation of knowledge in any scientific field when solving interdisciplinary tasks.

The concept of "interdisciplinary approach" to training is very relevant in foreign studies, while the concepts of "interdisciplinary training", "interdisciplinary cooperation" and "interdisciplinary task" are used. In the scientific article J. S. Gouvea et al. [13] draw attention to the need to strengthen interdisciplinarity in the teaching of natural sciences. The team of authors presents the structure of an interdisciplinary scientific course on the example of the discipline "Physics", for which they created a series of interdisciplinary tasks that combine Physics and Biology [13]. A study by Marqués-Sánchez et al. [14] proposed a methodology for the cooperation of students in different specialized courses (nurses and students in the field of computer technology), based on joint interdisciplinary training. A study conducted by the authors showed that a similar approach to learning can

increase the number of social connections between students.

An analysis of the scientific and methodological literature on the topic of this study made it possible to distinguish the following types of ITTs used in the training of future technical engineers in the disciplines of "Computer Science" and "Mathematics" in the context of their mutual integration: 1) integrated training tasks; 2) integrative educational projects; 3) research work of an interdisciplinary nature. It should be noted that in modern scientific and methodological literature there are a number of issues that are not well developed. In particular, we are talking about the impact of ITT on the formation and development of competencies that correspond to the types of training activities of the corresponding future engineers of technical profiles in the context of Digitization of education at the present stage.

4. DISCUSSION OF RESULTS

In this work, by an integrated training task in Computer Science and Mathematics, we mean a task associated with the field of technical research, the solution of which requires the combined use of the methodology of mathematical modeling and modern ICT, leading to the construction of an information-mathematical model and subsequent work with it. Thus, the decision of the ITT on Computer Science and Mathematics for technical engineers should be based on information and mathematical modeling (IMM).

Babich V. N. by information and mathematical modeling means the process of constructing a formalized image of the object of cognition, perceived by certain properties as an analog of this object, with groups of research functions, based on processing and analysis of a system-based information array that displays all aspects of the organization and functioning of the object by the integration of mathematical formalization, geometrization, and information technology support procedures in order to obtain new knowledge about the object, for example, aimed to resolve relevant problems [15].

Taking into account the specifics of the use of IMM, ICT methods and tools in the professional activities of a technical engineer, we distinguish two groups of ITT in Computer Science and Mathematics for students of engineering specialties. We assign tasks to the first group of ITT, the fulfillment of which is associated with activities that correlate with the professional activities of the engineer, and the second group includes tasks oriented to general activities. Moreover, the types of activities that underlie typology of the tasks of the second group can be either involved at some stage of the tasks of the first group of ITTs or independently be included in the ITTs of the first group. For example, production and technological activity, being the fundamental activity of an engineer, is

at the same time associated with other types of his or her professional activity.

The first group of ITT.

1.1. ITT for engineering forecasting (prediction of technical processes based on data from observations of actually developing engineering processes; they are used if necessary to take into account trends in the development of equipment, technology and the organization of production, operation and repair of a technical object).

1.2. ITT for the construction of technical objects (creation of models of technical objects with the compilation of their projects (graphic images, accompanied by technical, economic and other calculations) using ICT).

1.3. ITT for experimentation (directly modeling, checking the adequacy of models of a technical object using ICT, interpreting the results, and their correction).

The second group of ITT.

2.1. ITT for computing (labor-intensive calculations when working with large data sets using ICT tools).

2.2. ITT for data analytics (collection, processing, study, and interpretation of data on a technical object using ICT).

The training of a competent competitive specialist implies that the educational process in a university should be based on professional activities. "The activity-oriented education paradigm has a clearly expressed functionalist orientation..." [16, p. 21]. Since the management of a technical object is a significant professional function of an engineer, this should be reflected in the ITT. Based on the analytical review of FSES HE 3+ and 3 ++ technical engineers, the following types of professional activities are identified: research, production and technology, design, organizational, and management.

Thus, the basis of the developed typology of the ITT for Computer Science and Mathematics is the functional feature of the problem [17, p. 50], which in this case reflects the function of managing a technical object in the selected types of the professional activity of future technical engineers (see Table 1).

As a practice and numerous studies in the field of vocational education show, the ability to solve problems in different spheres of human activity is one of the most important cognitive actions of any specialist, including an engineer. Modeling belongs to a special group of universal educational actions, which, in a broad sense, determine the invariant basis of the learner's ability to learn, self-development and self-improvement. In this regard, IMM is also a universal educational action of a future engineer at a technical university. Subsequently, a university graduate, having "plunged" into professional activity, will be able to see from personal experience the need for IMM in solving the tasks that will be set for him in his work in the digital era. Thus, we can assume that the actions to perform the IMM are one of the components of the professional competence of a technical engineer.

Table 1 Typology of integrated study assignments in Computer Science and Mathematics for technical engineers

| Type of professional activity | Type of ITT | ITT wording example for technical engineers |
|--------------------------------------|---------------------------------|---|
| <i>organizational management and</i> | ITT for engineering forecasting | Predict the period of maximum and minimum capacity at the intersection of the central streets of your city N (select the location of the intersection on your own) on such days of the week as Monday and Sunday. Take the data on the number of cars passing through the intersection of your choice from the database of the GLONASS / GPS tracker monitoring system or the Unified ElecTraCop technology platform (if this is not possible, collect data yourself). |
| <i>designing and constructional</i> | ITT for technical objects | In an Excel spreadsheet, simulate a simple robot-soccer player who juggles a ball with his foot. Some restrictions are given. The robot soccer player stands still and does not bend his knees while juggling. The ball rises up at the moment of the kick and under the force of gravity falls down until it touches the foot of the robot. The speed of the leg can be adjusted and set the speed of the ball at the time of the strike. The initial position of the ball is determined by the coordinates of the robot leg during the strike [18]. |
| <i>scientific research</i> | ITT for experimentation | Based on the experimental data, find out which of the factors (speed of ultrasonic waves, humidity, rebound of the peen hammer) has the greatest impact on the strength of concrete. |
| <i>production and technological</i> | ITT for computing | Using an arithmetic cycle with complex branching, create a flowchart for calculating function values and program code in Visual Basic for Applications. $y = \begin{cases} \frac{1+x^2}{2 \cdot \sqrt[3]{1+x^4}}, & x \leq 0; \\ 2x + \frac{\sin^2(x)}{2+x+x^2}, & x > 0 \end{cases}$ On the sheet of the Excel spreadsheet, in the form of a table, display the values for x , y , and the branch number. Based on the data obtained, make y -function graph. |
| | ITT for data analytics | Based on the results of measuring the strength of concrete, depending on such an indicator as the speed of ultrasonic waves, draw a conclusion about the optimal amount of data necessary to draw reliable conclusions about the effect of this indicator on strength. |

5. CONCLUSIONS

As a result of the study, the following conclusions were formulated.

1. The importance of integration processes in the era of Digitization of education in the formation of the students' understanding of the role of IMM in solving engineering problems is shown. Thus, it is justified that the basis for the training of engineering specialists should be an integrated approach that promotes the interaction of fundamental technical and information disciplines. As a means of implementing an integrated approach to teaching students, ITT in Mathematics and Computer Science are acting.
2. One of the main digital skills of a technical engineer is IMM. As a result, the basis of the ITT offered to students

studying in engineering specialties of technical universities should be set as IMM.

3. The typology of the ITT on Computer Science and Mathematics is highlighted in accordance with the types of professional activities of technical engineers. The first group of ITTs includes those for engineering forecasting, technical design, and experimentation; to the second - ITT for computing and data analytics.

ACKNOWLEDGMENT

The team of authors thanks the other authors of scientific works devoted to the topic of this study, which inspired us to continue studying the problems of Digitization of education; students actively participating in the practical implementation of our scientific developments,

as well as each other for their coordinated work in the preparation of this article.

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