[1] Kymbatsha Mukhamediyeva
[2] Nurgazinova Gulbarshyn
[3] Dariya Abykenova
[4] Yeltinova Raushan

Design and Implementation of Educational Technologies in Robotics in the Context of Digitalization

Abstract: - The formation of digital transformation is a objective for Kazakhstani universities at the highest strategic level. The digital transformation of higher education is a part of the process of change that affects society. In this respect, widespread training of educators to conduct general and supplementary courses in robotics in schools, colleges and universities constitutes a major challenge. There is a clear need in the education system for educators who have a sound grasp of the relevant methods of teaching.
We see the solution to these problems in the need to develop a functional model for the design of educational technology in robotics, which will allow us to change our approach to the process of design and implementation of educational technology from a holistic to a detailed view. The process of interaction between the educational process subjects involved in the formation of activity-oriented professionalism in robotics has led to the organization a digital environment, which is a prerequisite for the effective design of educational technologies in robotics utilizing digital technologies

Keywords: Design of educational technologies, digitalization of education, robotics, functional model, digital environment.

I. INTRODUCTION

Today educational institutions, including teacher training institutions in the Republic of Kazakhstan, are faced with the issue of systematic training of specialists in the field of digitalization of education, the issue which we regard as a preparation of future teachers for the implementation of their professional activities using digital technologies [1].

The formation of digital transformation is a key task for Kazakhstani universities at the highest strategic level. The digital transformation of higher education is part of the process of change that affects society as a whole. While the fourth industrial revolution has already begun in the world, the widespread digitalization of the economy is leading to the need for the elements of revolution such as automation, robotization, robotics and mechatronics, artificial intelligence, 3D object modeling technology, and big data exchange.

Therefore, the issue of advanced digital technologies suitable for the training curricula of students can be resolved based on the aforementioned elements of the fourth industrial revolution. Being an important area of the industrial revolution and modern economic development, the field of robotics requires training of specialists which includes teachers of robotics. In this respect, widespread training of educators to conduct general and supplementary courses in robotics in schools, colleges, and universities constitutes a major challenge. There is a clear need in the education system for educators who have a sound grasp of the relevant methods of teaching [1].

II. THE DIRECTION OF STEM-EDUCATION IN THE EDUCATIONAL PROCESS

The development of high-technology industries in Kazakhstan has influenced the strategy on education, which guides the school system on integration of knowledge and expansion of the role of STEM education. The direction of the latter involves comprehensive systematic training combining natural sciences with engineering, technology, and mathematics through an applied interdisciplinary approach. Educational robotics, denoting the study of robotics itself and its use in the multidisciplinary educational process in preschool preparation (Sung, J., Lee, J.Y. & Chun, H.Y.) [2]; in primary school (Ferrarelli, P., & Iocchi, L.) [3]; in higher education as a special training section (Bidaibekov E.Y., Abishev N.K., Dalinger V.A., Nurbekova Zh.K., Assainova A.Zh., Tewolde G., Kwon J. et al.) [4, 5, 6]; as a means of increasing the motivation of schoolchildren and students (Alfieri L., Higashi R., Shoop R., Schunn C. et al.) [7]; as a unique tool of deepening interdisciplinary knowledge (Alimisis D., Sophokleous, A. et al.) [8, 9], became widespread in the framework of STEM education.

[1] PhD, Associate Professor, Pavlodar pedagogical university named after Alkey Margulan, Olzhabay batyr Str., 58, 140000 Pavlodar, Republic of Kazakhstan. kymbatsha@gmail.com
[2] Master of Informatics, Pavlodar pedagogical university named after Alkey Margulan, Olzhabay batyr Str., 58, 140000 Pavlodar, Republic of Kazakhstan. nurgasinova@gmail.com
[3] PhD, Associate Professor, Pavlodar pedagogical university named after Alkey Margulan, Olzhabay batyr Str., 58, 140000 Pavlodar, Republic of Kazakhstan. abykenovad@ppu.edu.kz
[4] Master of Informatics, Pavlodar pedagogical university named after Alkey Margulan, Olzhabay batyr Str., 58, 140000 Pavlodar, Republic of Kazakhstan. yeltinova_raushan@ppu.edu.kz
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Educational robotics in education is recognized as an innovative learning tool that can change the learning environment, transform learning processes and create a new educational ecology (Atman Uslu et al.; Evripidou et al.) [10, 11].

The introduction of robotics into the school system has determined the need for quality training of teachers willing to teach educational robotics. At this stage, education universities are already providing training for future teachers of computer science and robotics [1].

Few researchers have examined the conditions of preparation of students for future pedagogical activities in the area of educational robotics. The basis for the development of a robotics teaching methodology was laid by a team of scientists led by Dr. Alimisis who conducted a study under the TERECoP project (D. Alimisis, A. Pina, J. Arlegui, E. Menegatti, M. Moro) [8]. The study outlines the active methods of teaching robotics and didactic tools structured around constructionism. Although many studies on teaching robotics represent empirical material, solutions to the issues on the development and improvement of their pedagogical impact on students might not be enough to cover the technology for developing a training toolkit on robotics. In most cases, it is difficult to use methods and forms of training based on constructionism, while project method is only being partially exploited. Moreover, materials are mainly supplied in a complete form with step-by-step instructions. These shortcomings can be overcome by using the so-called educational technology, which is an integral (procedural) part of the methodological (didactic) system. For instance, with methodological system being aimed at solving the following problems: 1) what to teach? 2) why teach? 3) how to teach?, learning technology answers primarily the third question with one significant addition: 4) how to learn effectively? Thus, the methodological training system underlies the development of educational technology, and the data from the system are used to select methods, means, forms of training under specific conditions of training for robotics.

III. Educational Technology As A Subject Of Pedagogical Design

Research of education theory methodologists such as Slastenin V.A. [12], Pidkasistyi P.I. [13] and many others has shown that using educational technology is one of the guaranteed ways to increase the effectiveness of the educational process.

It is common knowledge that educational technology (technology in the field of education) is a combination of scientifically and practically sound methods and tools to achieve the desired result in any field of education. Educational technology as a field where there is a connection with the design, development, use, management, and evaluation of processes and resources for training.

The work of Babanskyi Y.K. [14], Bespalko V.P. [15] et al. addresses the issues of designing the teacher's work system. According to these studies, educational technology constitutes a system of complex elements, and it is important to accurately design the sequence of algorithmic steps to develop the educational process that guarantees the effective delivery of results in the teaching process.

The structure of educational technology within the methodological system of education is determined by many factors depending on the educational goal and includes the following:

– Competency-targeted stage: conducting a baseline analysis of students' competencies, alongside with selecting a set of competencies that will be formed in the process of studying the discipline and determining the learning objectives;
– Informative stage: selecting the content of education, considering model study plans, model curricula for vocational training, capabilities of students, modern trends in the development of science and technology, as well as its layout in the curriculum in line with the logic of educational material;
– Methodological stage: developing methodological support in accordance with the goals and substance of the educational material, selecting or creating educational tools with instrumental and didactic tools and forming the content of each thematic unit in the system;
– Assessment and diagnostics stage: assessing the achievement of stated objectives in addition to developing a diagnostic system and measuring materials for each thematic unit.

Our analysis and research concerning the teaching robotics in the country and the world have shown that authors cannot develop a methodology for teaching robotics without using educational technology. However, educational robotics has not been fully utilized as a subject of instructional design in research.

Therefore, it is clear that for the full scope of the technology for developing educational material on robotics, it is necessary to use educational technology as a subject of instructional design for the effectiveness of training in robotics, which is the focus of our study.

IV. Digital Transformation Of Education

The design of educational technology in robotics requires a strict logical sequence incorporating expert knowledge and solutions in the field of robotics, which is achievable through digital technology.

The studies of Bidaibekova E.Y. [4], Grinshkun V.V. [14], Balykbaev T.O. [1], Nurbekova Zh.K. [5] and other scientists address the problem of digital of education. Their studies underline that digital transformation is becoming a key objective for universities at the highest strategic level. As a solution to existing problems at a fundamental

level, digitalization is integrated into the general planning of overall development of universities. Furthermore, digitalization creates new opportunities and areas of action to enhance the profile of universities, increasing and strengthening their international presence and role in society.

There have been a number of studies on the use of digital technology for instructional design. For example, a group of academics headed by Dr. Dmitry Matros [17] developed a program to design a computer science lesson system for school education. Also, scientists led by Professor Nurbekova Zh. K. [5] designed software for planning the content of training courses. The technology assists in structuring the content and information model of lessons using digital technologies. Notwithstanding its limited coverage that only included structuring content of training, the study reflects the need for the use of digital technologies in the formation of an educational process.

The development of software for the design of educational technologies in robotics requires structuring educational content for education universities considering the interdisciplinary content, systematization, and formalization of the methodological system for teaching robotics.

The question of what place educational robotics takes in the fundamental training of future computer science teachers is essential to justify the necessity of such training and to determine main conceptual lines in the content of robotics training.

A few researchers studied the topic of introducing educational robotics into training programs for future teachers. [2, 3, 4, 5, 8, 9]. Nurbekova Zh., Assainova A. and others [5] studied two aspects of it. Firstly, most relevant is the use of robotics as a learning tool for the integration of interdisciplinary knowledge, such as physics, mathematics, computer science and programming. Here we are talking about competence in the field of robotics, which is a part of the professional competence of students studying physics and mathematics. Many researchers and educators [5, 8, 9] agree that having science, technology, engineering and mathematics included in the education of future teachers provides strong motivation, a significant improvement in the speed of training, strengthening of subject knowledge and the expansion of professional competencies.

Thus, our proposed approach to the design of educational technology in robotics allows us to ensure the organization of educational activities in robotics using the project-based learning and is the target result of the cross-curricular data and research.

V. The Functional Model Of Educational Technology Design

Development of educational technology is a complex procedure that demands a systematic approach to designing an educational object. Requirements are applied to all elements of educational technology. To demonstrate the technological efficiency of the process of designing educational technologies from the concept design stage to implementation and dissemination of results, the procedure is presented schematically in the figure below [18].

Functional modeling tools were used to build the model. Functional modeling refers to the process of building functional models of an automation object or separate processes.

The functional model of the design of educational technology has been constructed using the features of designing educational technologies in robotics, the design sequence, the language of the methodological theory of activity, and charts [18] (Figure 1).

The presented functional model changes our approach to the process of design and implementation of educational technology from a holistic to a detailed view.

This model describes the logically consistent stages of designing educational technologies on competency-based, informative, and methodological units. Also, it demonstrates the organization of the implementation process and reflection for diagnosis and feedback.

The functional model of the educational technologies design includes the unit for determining competencies (setting goals / estimated learning outcomes), learning content generating unit, methodological unit (selecting methods, tools, forms, and techniques for teaching robotics), unit for implementing educational technology in a digital environment, and reflection unit (analysis, assessment of educational technology and adjustments if necessary).

The process of interaction between the subjects of the educational process stemming from the need for building professionalism in the field of robotics has led to the organization of a digital environment, which is a prerequisite for the effective design of educational technologies in robotics. The digital environmental medium is interpreted with an emphasis on the organization of communication between participants in the educational process.

Digital environment creates a space in which a teacher designs and implements educational technologies using IT tools. In accordance with the stages of design and implementation of educational technologies, the digital environment defines the units for development of competencies, content of training, specific training models, diagnostic and control units. Learning tools and resources based on digital technologies (digital educational resources with elements of AR objects, a computer program on design of educational technologies, an electronic workshop on educational robotics, animated presentations, STEM laboratories and parks, and robotic platforms) are also of significant importance for training.

The software for compilation of technological maps, which describe the step-by-step process of training in educational technology, is the central element of the digital environment development by a teacher using educational technologies in robotics. In contrast, the content is structured according to the stages of creating a robot

(planning, prototyping, design assessment, diagnostics, documentation). The flow chart includes goals (estimated results), the duration of technology, logistical base, target group and prerequisites, training activities, assessment of achievement of goals, and management mechanisms for educational technology.

The technological map is a description of the process in the form of a step-by-step and phased sequence of actions (Figure 2).

The *benchmarking unit* includes the main micro goals for a specific topic. Micro goals are set at the project map development stage. Subsequently, the only remaining step is to enter micro targets into the benchmarking unit of the technological map, where two to five diagnosed micro goals are determined for each topic.

When designing a diagnostic component, we proceed on the basis of the fact that diagnostics (independent work) includes four tasks at three difficulty levels:

– Level one (required). The level implies a student's ability to apply the acquired information to solve problems in basic robotics;

– Level two involves the ability to use the acquired information for solving more difficult tasks (with a large number of actions using integrated knowledge);

– Level three pertains to information retention and ability to solve any creative tasks by transforming knowledge and skills.

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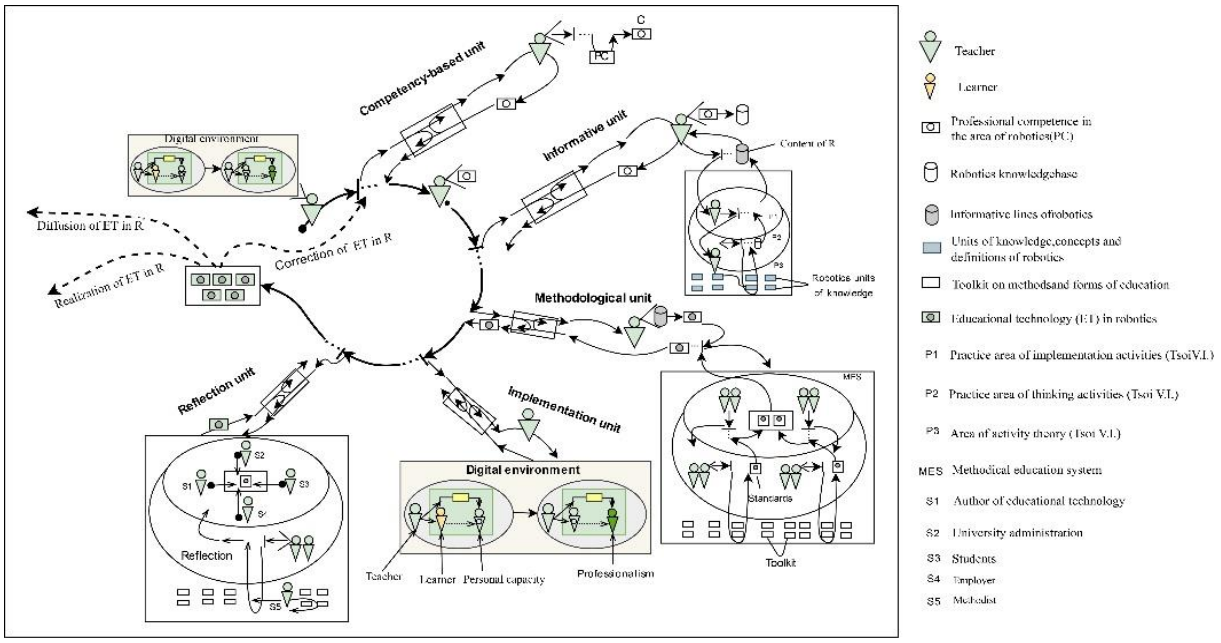

Fig. 1. The functional model of the design of educational technology

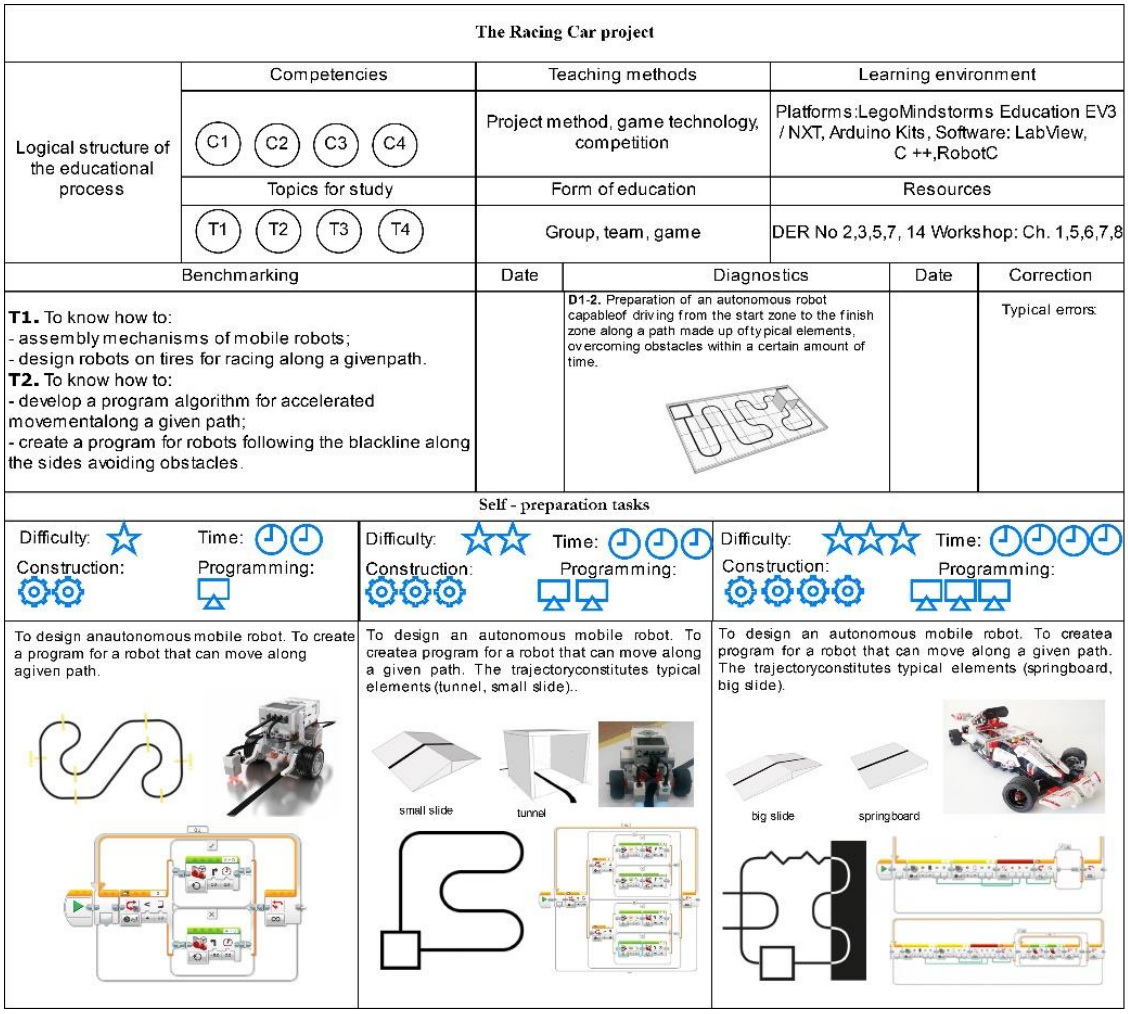

Fig. 2. Technological map

Self-preparation tasks. Tasks for self-training provide guaranteed preparation for diagnosis. Since the diagnostic system operates at multiple levels, tasks correspond to the three levels of complexity. The logical structure of the training topic is the description of each lesson's activity, definition of trajectory from one micro target to another, and movement toward the zone of proximal development. At the same time, it is a sequence of classes combined with the logical structure of the subject area content. Thus, the logical structure of the course is designed to ensure the consistency of study topics.

Correction. The final component of the technological map which completes the project cycle is designed for students who failed in diagnostics, i.e. not mastered the training material in the amount set by a specific micro goal. The instructor identifies and systematizes typical errors, along with providing ways and means to prevent and eliminate them. Typical errors written in this block will help students to improve self-control.

Figure 2 illustrates an example of a technological map for the Race Car project.

Therefore, an educational process based on the technological approach:

– Is individually oriented, turning the student into a subject who builds their own learning pathway consciously and independently;

– Becomes available and reduces the overload of students;

– Guarantees competent learning for each student, providing an objective and unambiguous assessment of material retention;

– Organizes independent cognitive activities of students;

– Forms the professional competence of students in correspondence with the goals of the educational program.

Based on the foregoing, the educational process on educational technology is implemented using the program of creating technological maps, which develops projects for teaching robotics.

VI. Conclusion

Since the key task for universities is forming digital transformation, the digital environment we created includes not only inanimate objects of the material world, ICT infrastructure, software, but also interaction of participants in the educational process that is implemented through educational technology. The system meets the needs of students and teachers, governing bodies, and provides interaction between them. Meanwhile, coordination of the opinions of all participants in the educational process leads to equitable management with no harm to the environment, to subjects of the learning process in particular. Digital environment is presented as an environment of interaction between the subjects of learning and teaching through digital tools and solutions.

The results of statistical analysis on data obtained in the course of experimental work have shown that using the functional model for the design of educational technologies as a methodological basis increases the proficiency of teachers in the robotics design process. In conclusion, the use of a digital environment in the implementation of educational technology improves material retention for robotics students.

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