Model of an Education Robotics Course for Natural Sciences Teachers

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Abstract. STEM is a priority area of education in Ukraine. One of the innovative approaches in STEM education is the integration of academic disciplines through project-based learning using robotics. Therefore, the urgent problem is the development of training courses on educational robotics for teachers of natural sciences. The article presents the model of teaching the Education Robotics course for teachers of natural sciences, which includes the goal, objectives, principles, content, forms, methods, teaching aids. The educational robotics course is designed to introduce future teachers to the principles of creating robotic systems, programming systems, and learn how to create robotic devices based on educational designers, as well as control programs. The course has a modular structure, designed for 150 hours and provides for the study of robotics based on Lego EV3, MBot, Arduino designers and demonstrates scientific and technical solutions to global problems, such as environmental ecology, help with the elements, conservation of flora and fauna, creating favorable conditions for humanity in extraterrestrial conditions, eco-energy and etc. The article contains the rationale for the choice of programming platforms, the methodological basis for the selection of projects for conducting in the lessons at school in accordance with the curriculum. Particular attention is paid to the features of using the project methodology and the formation of soft skills. The importance of introducing the Education Robotics course in the professional training of teachers of natural sciences is due to the support of society for innovation in educational activities and is associated with the level of scientific and technological achievements

Keywords: Robotics, Educational robotics, STEM, ICT, robotics school programs.

1. Introduction

Any system of education must satisfy the requirements of the society and the labour market. Major tendencies influence the development and cause the changes of the

society. These tendencies are: humanization, globalization, automatization, robotization. The New Technologies arise: SMART, Internet of Things, Big Data and etc.

One the one hand there is an increasing demand for engineering professionals in the labour market. On the other hand technical knowledge of other specialists is also required. However, other skills are also required.

So, in the World Economic Forum the top 10 skills, which are necessary for success in the Fourth Industrial Revolution were announced. There are:

1. Complex problem solving.
2. Critical thinking.
3. Creativity.
4. People management.
5. Coordinating with others.
6. Emotional intelligence.
7. Judgment and decision-making.
8. Service orientation.
9. Negotiation.
10. Cognitive Flexibility.

5 out of 10 skills are related to communication, negotiation and managing skills, as well as understanding and serving skills.

Another 4 fields are related to brain abilities: to think fast, to see the core of things, to solve problems, to generate new projects and ideas.

A high level of education is a prerequisite for the country's economic development. Education system is in the search of new ways of educating pupils and students for successful professional work. So they need good knowledge in engineering, mathematics and physics. Educators are looking new ways of educating, for example Cloud technologies, Flipped Classroom, Gamification, BYOD (Bring Your Own Device), Do It Yourself in Education, Mentoring, STEM-education (including robotics) etc. But number of children who are interested in maths and physics is decreasing. So, we are searching for new ways how to motivate them. The key to the successful implementation of any innovation in education is the teacher.

Therefore, the preparation of a teacher who knows how to master new technologies on his own, critically evaluates various methods, sees the pedagogical value of various technologies, is technically competent and able to apply STEM education methods, becomes an especially important task.

The aim of the article is to develop a model and determine ways of teaching future teachers the basics of educational robotics and presenting the developed program for studying educational robotics for students of teacher specialties.

2. STEM-education

STEM-education is one of such ways. STEM means science, technology, engineering, math. We use project work, interdisciplinary methods and maker as the background of this system of education. STEM education contributes to formation skills need for labour market.

The main technologies and radical products of the future are geoengineering, intellectual energy systems, radical materials, synthetic biology, individual geonomics, biointerfaces, solar energy, nootropic drugs, new energy-intensive batteries, stem cells, biobiotic cells, biobaths communications, atmospheric rechargeable batteries, smart navigation systems, artificial intelligence and others [1, 2]. All of these areas are multidisciplinary in nature and require STEM professions.

According to international studies, East and Southeast Asian countries have emerged with post-Confucian heritage and are extremely dynamic in STEM: China, South Korea, Japan, Taiwan and Singapore [3]. Australia is also among the leaders.

In countries such as Denmark, Israel, Korea, China, the USA, Japan and many others, educational institutions are developing educational programs individually or jointly with industry companies to engage students and students in the technical field [4].

In Ukraine, the development of STEM education is in the making. There is good experience and interesting developments in STEM implementation as a non-formal education or special subject at school. However, there are no systematic well-scalable developments for the school.

Robotics is one of the areas of modern STEM education. The main purpose of the introduction of educational robotics related to the social order of society: to form a person who is able to set educational goals independently, to design ways of their realization, to control and evaluate their achievements, to work with different sources of information, to evaluate them and to formulate their own opinions and judgments on this basis, evaluate, initiate and create your own designs, embark on the path of researcher and maker. That is, the main goal is the formation of key competences and soft skills [5].

However, the biggest problem with STEM implementation is the lack of teachers with the necessary skills. The problem of preparing future teachers for STEM implementation, in particular educational robotics, involves two aspects.

The first aspect is pedagogical, it refers to the teacher's understanding of STEM principles, ability to implement projects and apply research methods in teaching.In this aspect, it is important for the teacher to be able to organize the work of students on the project in groups, to help the children to plan the work on the project and to share the roles and tasks in the team. All this should contribute to the development of awareness of the holistic picture of the world and the practical value of knowledge in

mathematics, physics, engineering and other subjects, as well as the formation of students' soft skills.

The second aspect can be called technological. It is more concerned with the ability of the teacher himself to master new technologies, in particular robotic constructors and their programming environment; ability to predict what difficulties students may encounter in the process of mastering new technologies, to select the technical means that will best meet the educational objectives of students of a certain age.

Another complexity that arises when teaching teachers the use of STEM at school is interdisciplinarity. This is knowledge from other areas required for project implementation. Today in Ukraine there are such specialties as the teacher of physics, the teacher of mathematics, the teacher of informatics, etc. But STEM projects require knowledge from different fields. For example, the project of creating a smart greenhouse requires knowledge of *botany* (for the selected plant, you need to know its size, planting density, air temperature, frequency of irrigation, soil composition, etc.); *engineering* (to design the size and shape of the greenhouse, the opening parts of the structure for ventilation and care of plants, ways of fastening motors, technical openings for irrigation tubes, fastening sensors, etc.); *physics* (principles of operation and features of humidity sensors, temperature, light, electrical engineering basics, such as connecting an electric motor, its power, hydrodynamics, laws of rotational motion, etc.); *mathematics* (calculation of necessary materials for the greenhouse, engine speed to open the greenhouse for ventilation, etc.); *programming* (data reading from sensors, data analysis, system response (switching on / off irrigation, opening / closing windows, switching on/off additional lighting, etc. when reaching the threshold values of indicators obtained from sensors)). Special interest is the economic calculation of the cost of creating a greenhouse, maintenance costs, scale and payback period of the real smart greenhouse system.

STEM training courses are currently being developed for students, students, and future teachers [5, 6]. Therefore, introducing the Educational Robotics course for future teachers is an important part of their professional training.

3. The purpose and objectives of the course

In school curricula there is no separate discipline "Robotics". In Ukraine, there are several training programs in robotics approved by the Ministry of Education and Science. These programs are used in formal education institutions, in particular schools. Robotics programs are also created and implemented by institutions of extracurricular (non-formal) education. It should be noted that classes in robotics are held in schools in fragments: in the study of individual topics in physics, computer science, technology or optionally. The reason for this, as mentioned above, is the

insufficient number of teachers who are ready to use robotics in the educational process.

To rectify the situation at Kherson State University, the course "Educational Robotics" was developed to prepare future teachers of natural sciences.

The purpose of the course: effective application of innovative methods of teaching future teachers of natural and mathematical disciplines by means of robotics and their preparation for the introduction of STEM technologies.

The objectives of the course: to provide students with sufficient knowledge, skills and competencies necessary for the effective use of robotic devices and programming technologies in the work of the teacher.

Methodical tasks of the course:

- Familiarize yourself with the digital competency framework and its importance for key competency formation.
- Reveal the value of technology and their conversion in today's society.
- Make cross-curricular connections when teaching discipline.
- To show the integration of concepts in modern science and the possibility of applying the acquired knowledge in different fields of activity.
- Orient future teachers to use technology to support project-based teaching methods.

Cognitive tasks of the course:

Generate understanding:

- basic principles for creating robotic devices;
- principles of operation and interaction of various electronic components;
- structures and algorithms for creating robotic devices.

Create conditions for:

- further improving the scientific search for problem solving,
- improving their work by technology;
- activation of cognitive activity;
- implementation of design and research activities in accordance with the current level of technology.

Practical tasks of the course:

to form skills:

- work with sensors and devices of robotic systems;
- be able to create and test basic designs of educational robotic kits;
- to develop program code for constructions of robots EV3, Mbot, Arduino;
- modify and extend the capabilities of robotic devices.

to provide the formation of algorithmic thinking style and the ability to implement robotic systems.

The development of the device involves the design, study of components, circuits, writing programs, diagnostics. Each of the stages forms the skills of modeling and designing not only physical objects (robotic systems), but also logical

constructions, abstract thinking. Robotics helps build core competencies. This affects the formation of a scientific worldview and the corresponding system of thinking.

4. Learning Principles in Educational Robotics

When it comes to robotics in the context of its use in the educational process, we are talking about a new direction in education - "educational robotics" ("educational robotics").

Educational robotics is an interdisciplinary direction of student learning, during which knowledge on STEM-subjects (physics, technology, mathematics), cybernetics, mechatronics and computer science is integrated [7]. In this direction, a modern approach is being taken to introduce elements of technical creativity into the educational process through the combination of design and programming in one course. Integration of informatics, mathematics, physics, drawing, natural sciences with the development of engineering thinking is a powerful synthesis tool, lays a solid foundation for system thinking.

The study of educational robotics can only be effective if it maintains its integrity and the unity of its components. This integrity is ensured primarily by the general principles of the educational process.

The principles of instruction are determined by the objectives of instruction, which, in turn, depend on the needs of people, society and the state. Consider the content of the didactic principles of modern pedagogy in the application to the educational robotics course:

The principle of objectivity and scientificness provides that the content of education is based on the state of modern sciences. Trainees are attached to the elements of scientific research, research methods, master the ability to distinguish between true and false positions. Students gain access to modern equipment and innovative programs. Educational robotics is an effective tool for the formation of a scientific worldview among students as an integral component of the general human culture, a necessary condition for a full-fledged life in modern society. Educational robotics contributes to the intellectual development of the personality, in particular, the development of logical, algorithmic and creative thinking among students in solving applied problems, information culture, memory, attention, scientific intuition.

The principle of the connection between theory and practice aims at the need for constant doubt and verification of theoretical principles using reliable practice criteria. Learning with the help of robotics allows students to solve real life problems that require knowledge of STEM-subjects.

The principle of consistency, systematicity assumes that the teaching of educational robotics is conducted in a specific order, the system is built in strict logical sequence, the material studied is clearly planned, divided into completed sections, the main concepts are established in each topic. At the same time, logic is combined with emotions and feelings, which together increases the motivation of students.

The principle of accessibility assumes that the training is consistent with the accumulated knowledge and individual characteristics of the trainees. Training is conducted at an optimal level of complexity, taking into account the interests and life experience of the trainees. An effective teacher teaches his students themselves to find the truth, introducing them to the search process. In the formation of the basic competencies of the student, a gradual transition from simple models to complex design decisions is carried out. The project method, which is used using the LEGO MINDSTORMS EV3 Education and Arduino robotic designers, allows students to engage in cognitive activities. Educational robotics teaching corresponds to the ideas of advanced education (teaching technologies that will be required in the future) and allows you to attract students to the process of innovative and scientific and technical creativity.

The principle of visualization means that the learner should present everything that is visible - for perception by sight, audible - by hearing, subject to taste - by taste, accessible to touch - by touch. Robotics is a new visual aid stimulating the active perception of the course material. Robotic demonstrations are of high quality production, adjustable data presentation speed, allow the necessary number of repetitions, can be accompanied by visual, mechanical and sound effects that focus students on the most significant elements of educational material and increase interest in its development [5, 8, 9].

The principle of activity of students follows from the nature of the structure of educational activity, which includes: a teacher, a student and the environment. The most important component of the educational robotics program is the organization of students' educational activities in the field of technical creativity at the design and research levels, in particular, modeling, design and programming of robotic systems. The activity of students is manifested in the assimilation of the content and goals of training, planning and organizing their work, in checking its results. The teacher provides stimulation of this activity by forming motives for learning, using cognitive interests, professional inclinations, using such teaching methods as business games, discussions, elements of competition, etc.

The principle of the strength of assimilation of knowledge suggests that as a result of developed motivation, as well as a high cognitive activity of the student, the content of instruction is fixed for a long time in his mind, becoming the basis of his behavior.

A holistic system of interconnected didactic principles allows us to ensure the high-quality organization of the educational process as part of the educational robotics course.

5. Course Content Educational Robotics

The course "Educational Robotics" is taught as a discipline of free choice for students of all specialties, as well as part of the course "Selected Programming Issues" for students of the specialty "Mathematics" and "Computer Science" of the educational

level "Bachelor". The course "Robotic systems" for the "master" level partially uses the materials of this course. It was formed on the basis of materials for seminars with teachers in continuing education courses. The curriculum program consists of two modules:

Module 1. Organization of research activities in the context of STEM education.

- DigComp digital competence framework.
- STEM in teacher's work.
- Review of training robotic designers.
- Preparing students for competitions and competitions.

Module 2. Methodology for designing and programming robotic devices.

- Lego MINDSTORMS EV3.
- Makeblock designers and techniques for working with them.
- Arduino designers and techniques for working with them.

The Educational Robotics course is published in the distance learning system KSUONLINE, which is based on LCMS MOODLE [10].

In addition, the course acquaints future teachers with the following data:

- Legislative framework for implementation of the STEM-education.
- Methodological recommendations on implementation of STEM-education.
- Curriculum for learning the basics of robotics.
- Software for learning the basics of robotics.
- Useful links of STEM groups and experts on Fb.

This content was selected taking into account the demand from practicing teachers during the seminars for continuing education.

The first module contains theoretical material. It examines the framework of digital competencies, which has become the basis for the creation of many standards for the use of digital technologies, including professional standards. Thanks to the formulated criteria, DigComp [11] made it possible to establish the criteria and levels of their achievement in digital skills. Digital skills are some of the 21st century skills that are needed to adapt to the technology world.

Digital competency is part of the competencies that are formed in the STEM learning process. The emphasis in STEM education on natural-mathematical disciplines allows you to build training based on the integration of disciplines in the form of scientific research. The basis of STEM education is project activities. The introduction of integrative courses in the study of biology, physics, and chemistry requires the training of teachers of natural-mathematical disciplines to form their respective competencies. A survey conducted among university representatives showed that the study of innovative teaching methods and the knowledge economy, which is a component of the latest achievements in the professional field, are relevant.

Recent advances in the natural sciences are closely related to the development of digital technologies, in particular robotics. An example would be biorobots, neural networks, artificial intelligence. Therefore, educational robotics, in our opinion, combined with the study of basic disciplines, is an innovative tool for understanding the integrativity of objects. In a broader sense, robotics is the basis for the perception and support of the social potential of technology, and consequently, the raising of the prestige of the scientific and technological direction of development in society.

The introduction of robotics in the educational process of the school is carried out through the work of extracurricular circles. The teacher conducts additional classes with individual students who have shown interest in the course. There is no robotics course in school subject programs. But the curriculum of such disciplines as chemistry, physics, biology provides hours for project activities. Some programs describe the topics of such projects; in others, the topic is left to the teacher's choice. Examples of topics that can be implemented as part of the design work of the curricula of various disciplines are described in [12].

6. Forms and methods of teaching

Among the methods that we use in the study of educational robotics, we highlight: projects, cases, discussions of problematic issues, experiments, group practical tasks, and the like.

The gamification method actively instills in students the basics of engineering skills from the trial and error method, gradually moves on to pondering and planning their actions, and interest and curiosity are formed.

Design work combines research and technology. Such activities differ from laboratory workshops in the absence of instructions on the sequence of actions, taking measurements, processing data, and drawing conclusions. Educational projects provide students with independent preparation of an action plan, the choice of a method for solving and processing results.

The issues of preparing students for participation in contests, festivals and olympiads (hereinafter referred to as the competition) require special attention. In recent years, the number of such contests has increased. The teacher has the opportunity to choose a convenient format of the competition, venue, time. Both local level competitions (city, regional) and all-Ukrainian competitions are held. Distinctive features of competitions can be the following:

- by age of participants (primary school students, elementary school or senior);
- by types of robotic designers used (Lego, Arduino, any);
- by the number of participants (team or individual);
- by the number of stages;
- requiring preliminary preparation of projects or not.

The second part consists of practical work in the form of small projects. Future teachers get acquainted with various robotic designers, studying their characteristics.

Since future teachers have different levels of training in physics, programming, and design, the course contains tasks of different difficulty levels. Entry-level projects are technological literacy projects. They are fundamental and realize the formation of a knowledge base for future activities. During the work, future teachers get acquainted with the individual components of robotic designers, assemble a robotic system according to the model and program it. For those who are already familiar with robotics, the second is the level of deepening knowledge, which takes the form of independent work on a task without reference materials. There is also a third level of robotics projects. Its important characteristic is the use of project activities aimed at independence and based on the solution of vital tasks. At this level, the use of long-term projects has several advantages:

- Allows you to carry out work in real conditions or close to real ones.
- It makes it possible to organize cooperation with institutions or production, career guidance.
- There is time to work out many hypotheses.
- There is a more detailed discussion of the topic and a deeper analysis of the results.

A set of mini projects that are implemented at the first level has several functions: it forms the basic skills for conducting theoretical or experimental research in separate special sections, teaches you to plan studies, choose the best methods and means to achieve the research goal, find ways to solve scientific problems and improve the methods used.

The design, modeling, programming of robots in combination with the use of information and communication technologies, as a rule, is characterized by a high degree of creativity, independence, rivalry, communication in the group. During the implementation of students' projects, the competencies necessary for the modern teacher are formed. Among them:

- disciplinary;
- interdisciplinary;
- communicative;
- technological;
- informational;
- research.

For the second module, remote course support was created in the Moodle system (Fig. 1).

Fig. 1. An example of the Educational Robotics course in Distance Learning System KSUONLINE

7. Conclusions

The introduction of STEM education is a powerful step for the development of soft skills of students of the school, training on real socially significant projects, the formation of practical value of theoretical knowledge and a holistic picture of the world.

Robotics is developing, combining with various educational fields, such as physics, mathematics, computer science, biology, chemistry, medicine, technology. Promising trends related to robotics are Internet of Things (IoT), big data, artificial intelligence. Industries directly related to robotics are developing rapidly, in which scholls students will be able to realize themselves in the STEM professions, such as aerospace engineering, astrophysics, biochemistry, biomechanics, civil engineering, nanotechnology, neurotechnology.

Therefore, the training of teachers of natural and mathematical disciplines for introducing STEM into the realities of a modern school is of particular importance. Of course, the full preparation of future teachers for teaching STEM at school cannot occur within the framework of one subject. Therefore, further directions of the study will be the revision of existing educational programs for the training of future teachers in terms of including elements of preparation for using STEM in school [13].

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