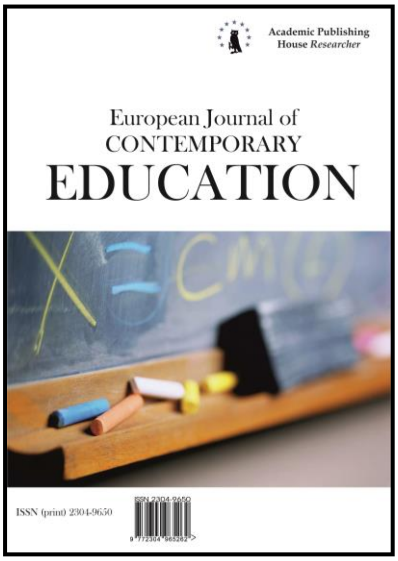
European Journal of Contemporary Education
E-ISSN 2305-6746
2018, 7(4): 845-857
DOI: 10.13187/ejced.2018.4.845
www.ejournal1.com



Improvement of the Robotics Cross-Cutting Course for Training of Specialists in Professions of the Future

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Abstract

The research is devoted to the actual problem of upgrading the existing model of robotics training in connection with the urgent need for implementing a strategy for training highly qualified specialists in the most demanded and promising sectors of the future, taking into account the requirements of business, society, and the State.

The aim of the study is to theoretically justify and experimentally test the effectiveness of the task approach in teaching robotics to form the required cross-professional competencies of the future.

The methodology of the study is based on the analysis of psychological, pedagogical, methodological scientific literature, Rapid Foresight methodology, system analysis, generalization of teaching experience, pedagogical experiment.

Results. First, the didactic and interdisciplinary potential of the robotics course is studied. Secondly, specific content for key cross-professional competences in the field of robotics and engineering is proposed. Thirdly, the basic ideas of the methodology for improving the existing system with a focus on the formation of key cross-professional competencies, the core of which is the system of tasks, are formulated. Fourthly, the effectiveness of the changed methodology of the training course to improve the quality of the educational process is confirmed.

In conclusion, findings that confirm that the improvement of the course of robotics will provide to obtain a useful skill – to be able to learn, to be prepared for the professions of the future are drawn.

Keywords: cross-professional competences, robotics and engineering, teaching methods, system of tasks, challenges of the future.

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1. Introduction

1.1. The relevance of the issue

The providing technological development in the field of information technology and supporting for the usage of new digital services in various activities are actual trends of upgrading the modern science of education. In addition, this direction is a priority in the program of the "Strategy for the Development of the Information Technology Industry in Russia for 2014–2020 and up to 2025" (Strategiya razvitiya..., 2013). This research is significant due to the fact that robotics is one of the most demanded and promising industries over the next 15-20 years as it has a significant potential of training of specialists to achieve the intended goals of the social and economic development of Russia. However, there are some objective problems in the developing of educational and scientific robotics, due to the contradiction between the models of robotics learning in educational institutions on one hand and the requirements of business, society and the State to specialists in professions of the future, on the other.

1.2. The aims and objectives of the study

Thus, the purpose of the study is determined from the need to change the cross-cutting course of robotics and is the theoretical justification and experimental verification of the effectiveness of the task approach in training for the formation of demanded cross-professional competencies of the future.

The objectives of the study are:

- to explore the didactic potential of the robotics course within the model of education implemented by educational institutions, based on the traditional trajectory “preschool education – school – university – additional education” in the context of the requirements of business, society and the State;
- to offer the specific content for key cross-professional competencies in the field of robotics and engineering;
- to formulate the basic ideas of the methodology for improving the existing robotics courses with a focus on the formation of popular cross-professional competencies of the future;
- experimentally confirm the effectiveness of the proposed model of training, the core of which is a system of tasks.

2. Relevance

2.1. Russian scientific literature review

The conditions for the development of digital technologies and robotics were formed due to the State support of nano-technologies, electronics and programming. According to this fact a great number of researches are conducted to define or to specify basic concepts: “robot”, “automaton”, “robotics”, “mechatronics”, “cyberphysical system”, “artificial intelligence”. The most significant of them are the works of G.N. Alekseev (Alekseev, 1986), V.M. Glushkov (Glushkov, 1986), I.P. Kuznetsov (Kuznecov, 1976). These studies are devoted to the phenomenon of constructing models of management activity, social cognition and philosophical interpretation of automation processes of people’s intellectual activity under scientific and technological revolution.

These studies are the result of the rising of the practical, educational and social necessity in training specialists for interacting with robots, inventing them and introducing modern robotic technologies into industry, agriculture, medicine, etc. The functions of robots are also determined in the papers of the following authors: T.V. Nikitina (Nikitina, 2014), I.A. Kalyaev, V.M. Lokhin, I.M. Makarov (Kalyaev et al., 2007), etc. The works of S.A. Vorotnikov (Vorotnikov, 2005), N.N. Bondareva (Bondareva, 2016), etc. are devoted to study the questions and branches of the robot usage. After the new requirements to specialists in the professions of the future have been worked out, the most important priorities for the development of the personality are determined. They are the initiative, the ability to think creatively and to make non-standard decisions, the motivation to learn throughout life. Under these circumstances the new researches are emerging in which the significance of engineering and construction for training people of the future is determined (N.T. Vishnevskaya and A.A. Zudina (Vishnevskaya, Zudina, 2017), O.B. Mizyakina and A.V. Mendel (Mizyakina, Mendel, 2018), etc.).

Among the main works on theoretical robotics we note the research of V.A. Glazunov, R.Yu. Sukhorukov and T.V. Silova (Glazunov et al., 2011). In this study the authors substantiated all the principles of robotics, basic concepts and cross-curriculum connections, the influence of robotics on the development of science and systems thinking from the position of synergetics.

The didactic potential of robotics is described in detail in the studies of M.G. Ershov (Ershov, 2011), N.A. Ionkina (Ionkina, 2018), V.I. Filippov (Filippov, 2016), S.A. Filippov (Filippov, 2013), etc. In (Ionkina, 2018) the author formulated the problems of training teachers in fields of robotics at schools. The problems of the organization of research and technical activity covering students from the 1st to the 11th grades (including the choice of the robot-kits) are partially solved in the work of V.V. Chetina (Chetina, 2017).

Although the fact that robotics is considered as an interdisciplinary activity based on mathematics, computer science, technology, and it offers new advantages for education in general at all the levels, there is no single methodological understanding of how to organize an effective response to the requirements of society, business and the State to specialists in the professions of the future within the interdisciplinary cross-cutting course.

2.2. Analysis of foreign researches

The importance of teaching and cognitive activity in the robotics training, the impact on the development of the child's thinking are justified both in classical and modern scientific works on robotics. Thus, the key ideas of modern methods of teaching robotics can be found in the works of S. Papert, developer of the Logo. Papert introduced and substantiated the thesis that, the Logo environment allows to teach children by studying artificial intelligence (Papert, 1993). A.R. Carberry and A.F. McKenna note the importance of project activity in modelling for high-quality engineering training of sought-after experts (Carberry, McKenna, 2014).

In studies (Crawford, 2014; Tocháček et al., 2016) it is noted that the robotics course has a powerful tool for motivating and encouraging students due to the development and management of robots by means of specific programming languages. Foreign authors also introduce such a term as "computational thinking", which is most effectively formed in solving a series of problematic tasks (Atmatzidou, Demetriadis, 2016; Ioannou, Makridou, 2018).

The researches (Gaudiello, Zibetti, 2016; Gabriele et al., 2017) show that the study of robotics has a positive impact on the development of students' critical thinking, problem solving skills and metacognitive skills. In (Kim, Kim, 2018) the authors propose an integrally whole methodical approach that is based on the unified educational program, which assumes theoretical cross-industry knowledge (engineering, mathematics, etc.) in the process of robotic engineering.

The attention of researchers is also paid to the resources of robotics in relation to social-economic development, the introduction of innovations for the implementation of automation trends, globalization and competitiveness (Keisner et al., 2016). Various training programs and curricula are offered to achieve theoretical, applied and educational goals of robotics, for example, the curriculum ROBOESL (Alimisis, 2018).

The most important methodical idea, from the position of the conducted research, is presented in the study (Ospennikova et al., 2015). Robotics training should implement a three-component educational technology: a) robot as a subject of study, b) robot as a mean of cognition, c) robot as a mean of learning, development and upbringing. This trinity reflects one of the essential principles implemented in foreign programs for training highly qualified experts in the trend of robotics and engineering.

3. Materials and methods

3.1. Theoretical and empirical methods

Theoretical methods: analysis of psychological, pedagogical, scientific and technical literature, studying methodological works on the teaching of robotics at all levels of learning; analysis of construction kits and software to support the students' technical activity; studying of robotic systems in the creative projects made by participants of the educational process.

Praximetric methods: studying the practice of teaching robotics in the model "preschool education – school – university – supplementary education" for the description, identifying the characteristics, analysis of methods, means, forms of organization and control; systematization and generalization of ideas, patterns and the principles of didactics in the teaching of robotics.

The Rapid Foresight methodology: for developing a core set of tasks and recommendations for changing the used model of training robotics for the challenges of future professions and for proposing mechanisms for coordinating of the goals of employers, the students themselves and the education system.

Empirical methods: observation, questioning, testing, analysis of cognitive activity of students to obtain up-to-date information about the developing key cross-professional competences in the field of robotics and engineering.

3.2. The base of research

The experiment involved 204 students of different classes of schools (Kirov and Kirov region), including 30 preschoolers, 100 middle school students, the remaining 74 respondents – high school students.

At the sampling stage, the pairwise selection strategy was used. The experimental and control groups were made up of individuals equivalent in significant for the experiment side parameters (age, class, method, software, teacher, the type of construction kit). The selection of homogeneous subgroups was carried out according to this principle. Experimental (100 people) and control (104 people) groups were determined. The experiment was conducted in the 2016-2018 academic year.

3.3. Stages of research

The research was conducted in three steps.

In the first stage, an ascertaining experiment was conducted. We examined the current state of issues and problems of robotics training within the model implemented by educational institutions based on the traditional system "preschool education – school – university – supplementary education". For this purpose we analyzed the psychological, pedagogical, mathematical and scientific-methodological literature on the research problem. Also we made the comparative analysis of the experience of teaching robotics in Russia and in other countries to identify directions for improving the course of robotics.

The second stage was devoted to the development of a methodical approach to the design of a cross-cutting course of robotics training as a basis for the developing of fundamental knowledge in computer science, information technologies, object and process management. In addition, we carried out analysis of the requirements of business, society and the State for specialists of the future. The content of key cross-professional skills for demanded professions in the field of robotics was clarified, and a corresponding system of tasks was developed for the selected set of competences.

The third stage of the study covers the experienced teaching and improving the course of robotics, an experimental evaluation of the effectiveness of the proposed approach in developing key cross-professional competences in the field of robotics and engineering, cyber-systems and artificial intelligence. Teaching the course is accompanied by permanent monitoring of the results of students' cognitive activity, which allows one to improve the proposed methodology consistently.

4. Results

4.1. Clarification of the essence of key cross-professional competences

Cross-professional skills or soft skills play an important role in the modern world. We define these abilities as a complex of non-specialized meta-subject skills, responsible for successful participation in the work process and high productivity. According to the Atlas of new professions, they include environmental thinking, project management, systems thinking, collaboration with people, work in conditions of uncertainty, computer programming, robotic skills, knowledge in the field of artificial intelligence and lean production, skills of artistic creativity, multilinguality and multiculturalism, cross-industry communication, customer-oriented approach (Nadprofessional'nye navyki). It is necessary to note that these skills are only listed in the Atlas, and they are not particularized for definite industries and professions. All these competences are represented in professions in the branches of robotics and engineering (a home/medical robots designer, an engineer-composer, a designer of industrial robotics, etc.). Therefore, one of the problems in improving the robotics cross-cutting course is to clarify what each competence exactly includes for the training of engineering and management stuff.

The content of a set of key competences for such a profession of the future as "Medical robot designer" includes systems thinking, cross-industry communication, project management and programming (artificial intelligence).

Systems thinking. Systems thinking combines two closely related aspects. The first is to consider the object (study, design, etc.) as a system and take into account all the characteristics of its system being. This includes the following principles: a) the principle of mutual determination, b) the principle of structure's hierarchy, c) the principle of the object's integrity, d) the principle of purposefulness of the object and e) the principle of the object's historicity. The second aspect is the organization of the activity process as a systemic one in its logical structure and in used tools and methods. Here we can distinguish the following principles: a) system-challenge problem, b) system analysis of the object under study (including morphological, structural and functional analysis of the object) and c) synthesis of the results of system analysis. In other words, an expert in the sphere of robotics and engineering should understand the "language of systems", be quickly enough to solve complex problems and see a complete view of a particular problem (Mizyakina, Mendel, 2018).

Cross-industry communication. Cross-industry communication skills development implies understanding of technologies, processes and events in various related and non-related areas of activity. Indeed, in today's world, advanced products are manufactured by the cross-sectoral industries: IT and medicine, construction and nanotechnology, science and art. This competence allows students to learn faster, to take the best from different areas, to support development within the area of activity due to such "cross-transmission". Therefore, experts in professions of the future should understand the technologies, processes, development of scenarios in different industries and they also should have a wide range of knowledge to compete in the future job markets.

Project management. In the future this competence will no longer be the prerogative of special trained managers. The enterprises will move away from a strict hierarchical structure in the organization and management, so the leadership ability, skills of setting priorities in solving problems, ability to choose the right team are becoming decisive in these circumstances.

Programming / Artificial intelligence. It goes without saying that competition with machines in the future will simply be useless in some areas. However, a person can become indispensable for the employer, if he/she learn how to design and program robots, machines, cyber-physical systems, artificial intelligence for the tasks set by a human. The minimum requirement for specialists in professions of the future is to master programming at the basic level, because of computer literacy as it understood traditionally will not be enough.

Thus, we have clarified the content of cross-professional competences for the profession of the future "Medical robot designer". The next important issue of the robotics cross-cutting course for training specialists in demand is to change the methodical system of training.

4.2. The system of tasks as a core component of teaching methods in robotics

Any methodical system in didactics is characterized by learning objectives, the place of the topic in the course, content, means, methods, organizational forms and control. However, the specialist in profession of the future should be able to navigate in changing conditions quickly, to anticipate scenarios, to assess the occurrence of the so called "wild cards" (they considered to be potential storylines for future development). Under these circumstances the "strict" teaching technology with the logic between the content lines, specific software, clearly defined goals and traditional methods of learning becomes ineffective. In the future we need specialists with both fundamental theoretical knowledge and ability to develop and improve their skills. So in the new method of teaching, in robotics in particular, the cognitive component comes to the fore – the development of skills to constantly expand the range of knowledge, to find points of growth in one's professional activity, to anticipate and predict.

The requirements of society, business, and the State to educational results allow one to assume that for professions of the future such component of the methodological system of teaching as "learning objectives" should be replaced by "cross-professional competences" for more effectiveness. Also the components "place in the course" and "tools" should be qualified by students themselves. Indeed, in new conditions, it should not matter by which mean to implement the algorithm – the specialist of the future should be able to change one construction kit or programming language to any other. A similar situation is with the "place in the course" component, as the moment of studying the topic depends on the problem situation and the practical task. The particular attention should be given to the "control" component. Despite the emergence and increasing usage of interactive assessment methods and game tools of control in training, the leading form of verification in the course of teaching robotics should be monitoring the results of students' cognitive activity (in the form of project, model, system, the solution of the problem, etc.). It is impossible during the training of robotics to reduce control to evaluation through tests, quests, crosswords, since the learner gets the necessary fundamental theoretical knowledge precisely through experimentation and object manipulation.

All of the above is relevant for the "Medical robot designer" profession of the future. They are professionals in the designing of biocompatible robotic complexes and cyberdevices for medicine and the biotechnology industry (for example, robotic surgeons, diagnostic robots, cyberprotezes, etc.). The employees of this profession should be specialists of high qualification, should have the ability to conduct large-scale scientific research, to manage the projects, to generate and implement innovations, using knowledge from such industries as IT, molecular biology, chemistry, histology, physics, ecology, etc.

Such components as "methods" and "organizational form" expand significantly in new environment. Different innovative technologies such as project activity, E-mentoring, virtual assistant, "flipped" learning, etc. are implemented and propagated. However, despite of the digital resources diversity, the "content" component determines the formation of fundamental theoretical knowledge. The most important idea of the proposed approach is to get new knowledge through the "task". This idea is fully consistent to the requirements for experts of the future, which should be able to solve or to predict solutions for a variety of tasks. At the same time, "task" is defined broadly. The process of robotics training can be considered as a process of resolving the contradictions between the cognitive and practical tasks on one hand and the existing level of competences and student' intellectual development on the other.

The main point of the task approach is that the acquisition of new knowledge occurs through the process of cognitive activity in solving the problem, which is set by a system of specially selected tasks. For the development of systems thinking, the characteristics of the system that are formulated in clarifying the content of this competence are taken as a basis (Table 1).

Table 1. Cross-professional competence "Systems thinking"

Preschool education	School education	University and supplementary education
Consider each of the following objects as a system that interacts with the environment. Describe the inputs and outputs of this system: a thermometer, scales, an inhaler. Select subsystems in the following systems: hospital, wheelchair, robot-surgeon. Determine the part of what these are: a figure, a bandage, an arrow.	Consider each of the following objects as a system that interacts with the environment. Describe the inputs and outputs of this system: a robot surgeon, a diagnostic robot. For each system, select subsystems. Implement an automatic device that diagnoses the air temperature in the room and signals to change the room temperature to comfort mode. Provide the possibility of manual configuration of the device. Identify the possible subsystems of the developed device. List the possible versions of the modification.	Consider each of the following objects as a system that interacts with the environment. Describe the inputs and outputs of this system: a robot surgeon, a diagnostic robot. Make an expert system that diagnoses a respiratory disease or indicates the disease (e.g. diabetes mellitus). Describe the inputs and outputs of this system. Consider its parts, determine the part of which external system this system can be.

The specific practical problems that will be relevant in the future are taken as a basis to form skills in programming and automation of robotic systems (Table 2).

Table 2. Cross-professional competence "Programming/Artificial Intelligence"

Preschool education	School education	University and supplementary education
Make up a possible dialogue between the patient and the doctor at the initial (return) visit. Make up an algorithm for taking blood tests, for the procedure of vaccination.	Develop an automatic device called "The mechanical hand". Calculate the dose of the medicine in dependence on the patient's weight. Write a program that determines the fastest route for an ambulance from point A to point B on the basis of a city map (including traffic data).	Write a program for recognizing the variant of flat foot (or lack thereof) using the footprint. Choose the most appropriate methods for implementing a program for diagnosing a respiratory disease. Develop "a mobile companion" for diabetes patients, which would allow to take into account the products eaten during the day (encourage or blame for them) and recommend some kinds of products. Write a library file (module) for the wristlet (that could count the steps and measure the heart rate) for the heart-disease patients to keep the statistics of every day.

For the development of skills in project management, the projects of our own experience in teaching robotics are taken as the basis. These examples take into account the requirements for a specialist in the profession of the future (Table 3).

Table 3. Cross-professional competence "Project management"

Preschool education	School education	University and supplementary education
Organize the learning process for students to manipulate with the following subjects: a thermometer, a chameleon mug, a mood ring, a doll whose hair color depends on the water temperature. Implement the project "Thermosensitive items". The aim of the project is to get acquainted with the temperature, as a characteristic of the objects of the surrounding world and living beings, to learn how to measure temperature, to study the temperature characteristics of different objects.	Implement the project "Application of thermochromic objects in medicine". The purpose of the project: Investigation of the thermosensitive properties of materials and the development of objects used to diagnose the temperature characteristics of different objects.	Implement the project – "Cardiologist's assistant" (pressure and pulse are measured at home), "endocrinologist's assistant" (the sugar level is measured at home). Develop a mobile application that allows you to send to the email or to the database the results of patient tests that they can independently determine at home. Thus, doctors can observe their patients in more detailed dynamics.

Various demand and promising for the next 15-20 years spheres are used as a basis to form and develop skills in cross-industry communication (Table 4).

Table 4. Cross-professional competence "Cross-industry communication"

Preschool education	School education	University and supplementary education
Biology: Study the structure of the human body, build a puppet-doll (an automated model on gypsum form/foil). Determine which parts of the human body are represented as unique one (that is, one cannot live without them), and which of bodily organs have a pair. Perform a study to identify flat feet from a footprint on paper. Ecology: Implement the project "The air which we breathe". The purpose of the project is to study the human respiratory organs, determine lung volume, detect air properties and investigate human dependence on air quality. Physics (optics): Project for the use of lenses in everyday life. The purpose of the project: to get acquainted with the concept of lenses, to study the types of lenses and how to use them to improve human life.	Biology: Study the structure of the internal organs of a human body. Build an automated model of the human heart. Ecology: Investigate the air characteristics, determine what parameters of the air environment can threaten human health and life. Develop an automated device "Fire Safety System". A device based on a gas sensor should determine the level of smoke and flammable gases, such as liquefied natural gas, butane, propane, methane, alcohol vapors and hydrogen/ It also should make a signal in the case of danger for persons' life or health. Physics: Study the properties of sound waves and implement a project for the application of ultrasonic in medicine. Develop an automated device for diagnosing acuity.	Physics / Biology: Calculate the power for closed-chest heart massage, depending on the weight and age of the patient. Develop an automated device for closed-chest heart massage. Calculate the pressure and volume of oxygen for anapnotherapy. Develop an automated device for anapnotherapy. Ecology Implement the project "Automated system of forecasting air quality in your city": develop mathematical models and a complex automated system, oriented to the forecast of air quality in different regions for calculation of background characteristics of air pollution.

The proposed set of tasks possesses the following characteristics, valuable from the point of view of the training the most sought after experts:

– continuity between levels of learning and the possibility of getting knowledge at time determined by student;

– orientation of the cognition subject's activity to the possible development of scenarios;

– formation of fundamental theoretical knowledge through experimental work;

– taking into account the requirements of the State, society and business for the skills and competences of future professionals.

The presented set of tasks does not pretend to be universal and ultimate. The purpose of the research is to demonstrate the possibility of composing the system of core tasks for forming the required cross-professional competences and to show its didactic potential for improving the quality of the existing path of robotics training.

4.3. Experimental evaluation

4.3.1. The ascertaining stage of the experiment

To assess the effectiveness of the proposed approach, a statistical analysis of the results of cognitive activity of students in the work with construction kits and software was carried out and the formation of a key set of cross-professional competencies was assessed.

At the first stage of the experiment, the students were given a control test on robotics, concerning the simulation of an automated system in accordance with the presented professional skills. Thus, it was possible to collect experimental data on 204 students of various educational institutions (94 students in the 2016-2017 academic year, 110 students in the 2017-2018 academic year). Since as a result of the preliminary control measures was revealed almost the same initial level of preparedness of students participating in the pedagogical experiment of three years, we can consider them as a general sample of 204 people. On the basis of the pairwise selection strategy, groups of individuals equivalent in significant experimental side parameters (age, class, method, software, teacher, the type of constructor kit) were distinguished. Thus, experimental (100 people) and control (104 people) groups were formed. Characterizing the sample, we note that the experimental group consist of 75.3 % of girls and 24.7 % of boys.

4.3.2. Forming stage of the experiment

Theoretical classes for students were conducted in the same way, and practical work in the computer class was organized in different ways. Students in the experimental group were trained according to the proposed method, and students of the control group studied the material in the traditional way in accordance with the teaching materials, performing tasks on specific topics of the course.

In order to assess the effectiveness of the proposed methodology at the end of the educational process, students were offered a test, which contained one task from each type of formed cross-professional competence (system thinking, management of projects, cross-industry communication).

Excellent evaluation was exhibited, if the student in the solution of all tasks of the control for a set of individual elements sees the system integrity, its structure, the relationship of the system and the environment; completely independent in choosing the scope of practical application of the device, the preparation of the algorithm and the method of solution; correctly interprets the messages of the software environment (error information); searches for ways to improve the mechanism.

Good evaluation corresponded to the cases when the student in solving one task finds it difficult to independently determine the inputs and outputs of the systems in question; does not always search for the optimal state of the system and the scope of its practical application; allows one or two errors in the design solution of the project and the software component.

A satisfactory assessment was made in a situation where a student in solving problem projects focuses only on one of the features of the elements, highlights the essential features of the system object, identifies the relationship between the elements, but does not know how to actively use this ability in specific practical situations. This category included decisions when a student tries to propose his/her model, but does not understand the meaning of the executed algorithms. The successful implementation of the project was accompanied by the constant support of the teacher.

In all other cases, the rating was "unsatisfactory".

The results of the control work are shown in Table 5 and displayed in the diagram (percentage of correctly solved problems of different types) in Figure 1.

Table 5. Distribution of students based on the assessment

Groups	Rating				
	Excellent	Good	Satisfactory.	Unsatisfactory	
Experimental group	32	40	18	10	100
Control group	18	28	40	18	104
	50	68	58	28	

Criteria for assessing the formation of competence: the ability to form the problem in such a way as to use a computer and other means to solve it; logical systematization and analysis of data; the ability to provide information on abstractions, models; the ability to automate solutions based on a series of ordered steps; identification, analysis and implementation of possible solutions in order to achieve the most optimal combination of steps and resources for maximum effect; the ability to generalize and transfer the algorithm for solving a specific problem on a wide range of similar problems.

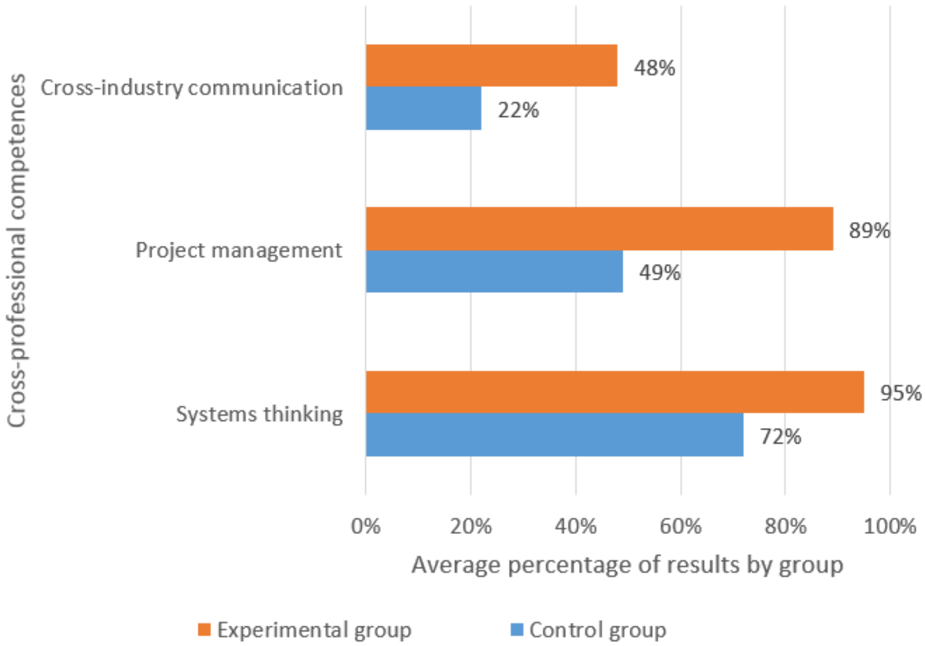

Fig. 1. Results of control works

4.3.3. Control stage of the experiment

Statistical differences in the levels of formation of cross-professional competences in the control and experimental groups before and after changes in the system of robotics teaching were evaluated using the Pearsen criterion χ^2 (chi-square). Let us assume the following hypotheses: 1) H_0: the level of cross-professional skills of students of the experimental group is statistically equal to the level of cross-professional skills of students of the control group; 2) H_1: the level of cross-professional skills of students of the experimental group is higher than the level of cross-professional skills of students of the control group.

Calculating the value of the criterion statistics:

$$\chi^2_{observ.} = \frac{1}{100 * 104}\left(\frac{(32 \times 104 - 18 \times 100)^2}{32 + 18} + \frac{(40 \times 104 - 28 \times 100)^2}{40 + 28} + \frac{(18 \times 104 - 40 \times 100)^2}{18 + 40} + \frac{(10 \times 104 - 18 \times 100)^2}{10 + 18}\right) \approx 16{,}6$$

At the significance level α = 0,05 and the number c = 4, the number of degrees of freedom is equal:

$$n = c - 1 = 3$$

According to the tables of distribution χ^2 for n = 3 and α = 0.05 the critical value of statistics is equal:

$$\chi^2_{critic.} = 7.82$$

Therefore, the following inequality is satisfied,

$$\chi^2_{critic.} < \chi^2_{observ.}$$

According to the decision rule, the null hypothesis must be rejected and an alternative hypothesis accepted.

Thus, the experimental assessment confirms the qualitative difference in the level of formation of cross-professional competence in the control and experimental groups on the example of training specialists of the profession of the future "Medical robot designer".

5. Discussion

The most noticeable influence on the formation of cross-professional competencies (based on the results of the experiment) is provided by the following factors supported by the cross-cutting system of tasks: activity in cognition; self-reliance in creativity, design of robotic systems;

convergence of the learning process with the process of real knowledge, career guidance and socialization; continuity between the levels of training.

The influence of these factors affected the following types of cognitive activity of students when working with construction kits and software:

– the choice of optimal ways and means of implementation of activities (the ability to plan and carry out cognitive work with machines, cyber-physical systems, artificial intelligence, to structure information, to determine the option of its adequate representation);

– development of the ability to manage their activities, the work of the team to solve problems (the ability to assess the correctness of their actions and the team, the work of the technical means; obtaining skills of self-control and decision-making).

The significance of the research is in the fact that for the implementing of the program "Digital Economy of the Russian Federation" at national level (Strategiya razvitiya…, 2017) it is the improvement of the crosscutting robotics course that will provide the theoretical basis in the field of Informatics, Cybernetics and Artificial Intelligence, in time to orient in the profession, in time to give a useful skill – to be able to learn, to be prepared for the professions of the future. The most important thing is to remember that features and result of educational and cognitive activity should contribute both to the individualization of human development and to the development of IT competence corresponding to the level of information culture determined by the conditions of one's life in robotic society.

The proposed improvements fully comply with the directions of the strategy of scientific and technological development of the Russian Federation.

6. Conclusion

The results of the study prove that the course of robotics has a rich didactic potential for the formation of demanded by society, business and the State cross-professional competencies of the professions of the future, as it is interdisciplinary, enriches cognitive activity of students with new tools of knowledge, provides opportunities for obtaining skills of project and team work.

A significant result of the research is the clarification of the content of cross-professional competences in the industry through the example of a particular profession of the future – "Medical robot designer": systems thinking, cross-industry communication, project management.

The authors formulate the basic ideas of the methodology for improving the existing course of robotics with a focus on the formation of popular cross-professional competencies of the future, the central element of which is the system of tasks. The value of the technique is that it is the task that motivates the need for new knowledge, and only in the process of solving the problem new knowledge is born. The set of tasks is the core around which the cognitive (project) activity of students is built. In addition, the set of tasks determines the trajectory along which the student moves from ignorance to knowledge and further to understanding. All this takes place in the design, development of robotic systems, experimental activities that are based on the needs of students.

The effectiveness of the proposed approach is confirmed by the pedagogical experiment, during which the result of cognitive activity was evaluated by a set of criteria corresponding to the essence of competencies.

Thus, experimentally proved the effectiveness of the proposed model through the robotics course for the formation of popular cross-professional competencies of the future.

The results of the research can be used:

– to develop a methodical system for training teachers in robotics as a promising branch of the future;

– to ensure the individualization of the educational path due to specially organized areas of supporting for creative, cross-industrial, cognitive research activity of students at all levels of studying robotics;

– to continue working on the solution of scientific problems in the training of robotics in the framework of the used model implemented by educational institutions;

– to improve the methodology of educational robotics.

The perspective direction of improving the proposed methodology is seen in the addition of its aspects related to the construction of a nonlinear individual educational path of studying robotics and engineering.

7. Acknowledgements

The research is funding by the grant provided by the Russian Science Foundation (project № 18-78-10053 “Scientific substantiation of the algorithm for applying the technology of the opportunity map in robotics course for training of specialists in professions of the future”).

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