SYSTEMATIC LITERATURE REVIEW: PROGRAMMING OF MICRO-ROBOTS ON THE BASIS OF ARDUINO

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Abstract: Modern technology is developing at a high speed and is being practically implemented in all areas of our lives. At the same time, the requirements of employers are growing, in order to keep pace with the time; students need to study diligently, to develop themselves, especially in the field of computer science and engineering. Over the past few years, in training in engineering areas most universities in the world are actively using Arduino platform to motivate students to learn, develop skills of teamwork and the application of knowledge in practice. In this paper, the state of research in this subject has been analyzed, and a literature review has been conducted. This work is a theoretical and methodological basis for further research.

Keywords: programming, Arduino, micro-robots, robotics, board, software products.

1 Introduction

Currently, there are many microcontrollers and platforms for the management of physical processes in relation to microprocessor systems. Most of these devices combine disparate programming information into an easy-to-use assembly. The Arduino Company (Italy), in turn, also simplifies the process of working with microcontrollers, but provides a number of advantages over other devices because of the simple and understandable programming environment, low price and a variety of expansion boards. For teachers, students, and amateurs, the Arduino platform can be a key element for research and problem solving in the fields of mechatronics and robotics.

Arduino is a tool for designing electronic devices that interact more tightly with the physical environment than ordinary personal computers, which do not actually go beyond virtuality. It is a platform designed to manage physical processes using an ECM with opensource code, built on a simple PCB with a modern environment for writing software. Arduino boards are built on the basis of Atmel microcontrollers, as well as binding elements for programming and integration with other circuits (Table 1). Linear voltage regulator +5V or +3.3 V is located on the board. Timing is carried out at frequencies of 8, 16 or 87 MHz by crystal oscillator. The microcontroller is pre-flashed with boot loader, so that an external programmer is not needed.

At the conceptual level, the weight of a board is programmed through A5-232. The Arduino integrated development environment is a cross-platform Java application that includes a code editor, a compiler, and a firmware transfer module to the board. The development environment is based on the programming language Processing and is designed for programming by beginners who are not familiar with software development. Strictly speaking, it is a C++ language, supplemented by some libraries. The programs are processed using a pre-processor and then copied using AVR-GCC. The advantages of Arduino family boards:

1. A large number of available options in the line of Arduino with the ability to select the most suitable ready-made controller from a large list of devices that have a wide range of variable parameters.
2. The presence of expansion boards designed to increase the functionality and perform specific technical tasks without the need for self-design of additional peripherals (motor control board s, sensor board s, wireless interfaces, displays, input devices) - several dozen types, more than 300 versions.
3. The programming environment that is fully adapted for the end user and is suitable for the entire line of Arduino board s and their clones, including software for programming controllers for Android.
4. The free license for devices and software.
5. There is a full Russian translation of the Arduino language, designed to overcome the language barrier in the distribution of the platform in Russia.

Arduino Uno is a controller built on ATmega328. The platform has 14 digital in/out (6 of which can be used as PWM outputs), 6 analog inputs, 16 MHz crystal oscillator, a USB connector, a power connector, an ICSP connector and a reset button. For the work it is necessary to connect the platform to a computer via a USB cable or power it with adapter AC/DC or batteries.

Because of the technical equipment, the Arduino platform is ideally suited for the educational process of designing various mechatronic systems and robots (1) due to the clear programming environment and the ability to observe physical processes in real time. More powerful Arduino boards (Due) are applicable for solving complex technical problems related to the development of large projects and their complex automation (2).

When power is supplied to the Arduino controller, execution of the program that was downloaded into it automatically begins, and if the program is missing or written incorrectly, a failure occurs, which either stops the execution of commands or causes the program hang-up. The number of the on-going program is stored in a special memory cell, which is called the command counter.

The programming language used in Arduino projects is based on C++. It is one of the most widely used programming languages, which supports both low-level commands and the construction of complex objects (3).

Electronic components, their operation, connection and programming are studied on the Arduino platform. Programming is carried out in the Arduino IDE in C++ (with some modifications). Having received basic knowledge of electronic components management, trainees implement creative projects, the complexity and functionality of which are limited only by the imagination of the author.

Arduino allows students to get acquainted with the world of electronics, to understand the principles of electronic components, to see many different sensors and devices unusual for them. Projects created on this platform can be used at home for the purpose intended (for example, automation of household appliances), which is an additional motivation to study. Classes in robotics based on Arduino contribute to the development of polytechnic competencies that are necessary in modern professional activities in the area of automation and IT (4).

Using this platform for educational institutions allows developing the programming skills in practice, as well as learns the basics of circuitry engineering (5).

A systematic review of the literature on this topic revealed the strengths of the use of Arduino as an auxiliary tool in the training of students of engineering profile of special disciplines in the design of micro-robots.

The effectiveness of teaching the basics of robotics depends on the organization of classes conducted using the following methods: Explanatory and illustrative presentation of information in various ways (explanation, narration, conversation, instruction, demonstration, work with technological maps, etc.); Heuristic method of creative activity (formation of creative models, etc.) Problem method is the formulation of the problem and the independent search for its solution by students; Programmed method is a set of operations

that need to be performed in the course of practical work (computer workshop, project activities); Reproductive method is a reproduction of knowledge and methods of activity (collection of models and designs on the model, conversation, exercises on the analog), Partly-search method is a solution of problem tasks with the help of a teacher; search method – individual problem solving; method of problem presentation - statement of the problem to teachers, the solution of the problem by teacher, the participation of students in solving process (6).

The subject of robotics is the creation and use of robots and other robotics tools for various purposes. Having emerged on the basis of cybernetics and mechanics, robotics, in turn, gave rise to new directions of development of these sciences. For cybernetics it is primarily due to intelligent control, which is required for the robots, and for the mechanics it is due to multi-chain-type mechanisms and manipulators.

A robot can be defined as a universal machine for performing mechanical actions, such as those produced by a person performing physical work (7). From the creation the first robots and up to now the model for them are the physical capacities of man. It is the desire to replace a man in hard work that gave rise to the first idea of the robot, then the first attempts to implement it (in the middle ages) and finally led to the emergence and development of modern robotics and robotics industry.

The versatility of robots implies the possibility of performing targeted actions that require certain intellectual abilities. This opens up wide opportunities for the use of robots as the main technological equipment (in such types of work as assembly, welding operations, paint coating, etc.), as well as the auxiliary equipment – to replace workers that are engaged in the maintenance of such equipment.

As already noted, the objective reason for the emergence and development of robotics was the historical need for modern production of flexible automation with the elimination of man from direct participation in machine production and the lack of traditional means of automation for this purpose. Therefore, the task of robotics, along with the creation of the actual means of robotics is the development of systems and complexes based on them for various purposes. Systems and complexes automated with robots are called robotic (7).

When developing models of the implementation of robotics in the educational process, it is necessary to take into account the main factors:

1) The need for practical training of teachers;
2) Choice of textbooks for students and guidelines for teachers;
3) Compliance with the continuity of curricula at different levels of education;
4) Taking into account interdisciplinary connections and coordination of subject programs of education in physics, computer science, mathematics, technology;
5) The need for a differentiated approach to learning, identification of gifted students, their support in the framework of individual development programs;
6) The connection of the content of subject training with the competition and competition activities dedicated to robotics. Robotics, as an applied science, is based on such disciplines as electronics, mechanics, and programming (20).

Accordingly, the school robotics can be integrated with such subjects as mathematics, physics, computer science (8).

In the national education system, robotics (RT) has become one of the most popular areas of additional polytechnic training of students. This is due to the need to focus of the most capable part of the student youth on choice in the future engineering professions, as well as the importance of early education of children in the field of robotic design. In this regard, the school robotics support system is actively developing. The special popularity of Tajikistan is provided by the high level of interest of young people in this sphere of technical activity. Educational opportunities of robotics as a direction of technical innovation are extremely high. However, at the present time competitive robotics and project robotics creativity in the system of additional education are mainly developing. Methods and technologies of robotics application in subject teaching have not yet become the subject of targeted pedagogical research. Directions and methods of application of robotics in the subject educational block are not quite obvious. Its introduction into the educational process is a new direction of the theory and methodology of Polytechnic education, integrating the knowledge and experience of teaching a number of school subjects. Its development should take into account the specifics of robotic systems as a new and significant in terms of its scope of the object of technological environment, the possibility of different areas of subject knowledge in its study, as well as the features of school education of different levels and profiles.

1.1 The robot as an object of study

The robot in the educational process is, first of all, an interdisciplinary technical object, the device and the principle of operation of which is the area of application of knowledge of a whole complex of Sciences. The study of specific robotic systems as objects of modern technological environment should be accompanied by a consistent presentation of special educational information to students. They should get information on the history of robotics and modern prospects of robotics. It is necessary to demonstrate to the students the place and role of robotic systems in the modern technological environment. It is necessary to present it in an accessible form of the elements of the methodology of robotics (general, special): to explain the essence of the concept of "robot, to demonstrate its distinctive features; to acquaint with the types of robots and justify the need to create robots of different types, to give an idea of the basic laws of robotics and the basic approaches to the design of robotic systems (9).

Robotics in school is a great way to prepare children for a modern life full of high technology. It is necessary, because our life is abundant of various high-tech equipment. Knowledge of it opens up a lot of opportunities for the younger generation and will make further development of technologies faster.

Back in 1980, Seymour Papert, who is the founder of the programming language, in his book suggested using the computers to teach children. In his suggestion, Papert grounded in the child's natural curiosity and the tools to meet it. After all, every child is an architect, building the structure of his own intelligence, and as you may have guessed, any architect needs a material with which everything is built. And it is the environment that is the material for this purpose. And the more the child has these materials, the more he will be able to achieve (10, 19).

Training in applied programming is one of the basic courses in the process of training students from various educational institutions, entering into the disciplines of the variable part, mathematical and natural-scientific cycle. The purpose of the study is to create necessary ideas about modern software products, development environments and programming languages, as well as the application of knowledge, skills acquired in the learning process, in practice.

The best result of the practical application of knowledge, skills and abilities is achieved by solving problems that carry a payload. This requirement can perform the use of Arduino in education

The programming part of Arduino consists of an open program shell (IDE) for writing programs, compiling them, and programming the hardware. The hardware part is a set of printed circuit boards, sold as an official manufacturer, and third-party manufacturers. Fully open system architecture allows freely copying or addingto the line of products Arduino (11).

Having a basic knowledge of the basics of programming in the environment of Turbo Pascal can provide an optimal transition to the study of high-level languages. The benefits of using Arduino in teaching applied programming are expressed by the following factors: Economic availability is represented by several models:

Arduino Uno, Arduino Mega, Arduino Leonardo, Arduino Nano, Arduino Mini.

Easy to learn development environment is an intuitive interface that allows you to quickly master the development environment. The Arduino platform supports a very large range of peripheral devices. Use in software development programming language based on C++, a high-level language. The technological essence of the device development process consists in the presence of sequential execution of instructions. This issue is devoted sufficient quantity of professional literature and electronic resources. The Department of information systems and technologies has the following development, namely laboratory course “development of interactive devices on the hardware-software platform Arduino” and “Electronic devices on the hardware-software platform Arduino”.

Based on the above factors, it can be concluded that the use of Arduino in training on applied programming will provide students the opportunity to apply the knowledge, skills acquired in the learning process, on the hardware, which will motivate them to further training and consolidate the theoretical part of the training by doing (12).

Any program written for a robot is an algorithm, i. e. a sequence of its actions. The robot itself is nothing more than an algorithm executor. Making the algorithm of robot's actions, students check its work experimentally, seeing the action of mathematical laws not in textbooks or notebooks, but in the surrounding real world. Checking the algorithm in practice allows the revealing of the correctness of its compilation. The compiled program is downloaded into the robot's memory, and its verification is carried out – the robot performs the actions of a given algorithm, which are evaluated, and then the defects in the program are eliminated if they are detected. The robot's actions will be clearly visible at what step of the algorithm the error was made. Thus, students have the opportunity to link theoretical knowledge with the real world, based on the experience of their activities (13).

The content component of training primary school teachers to implementation of educational robotics, are: the teacher’s acquisition of basic theoretical knowledge and practical skills in the field of models design from educational sets, the acquisition of the basics of programming in graphic environments, acquisition of methodology of teaching the basics of educational robotics to younger students in curricular and extracurricular activities (14). Specifics of teaching programming in universities, training centers require sufficient and strong acquisition of basic knowledge. At present, training in programming is faced with a lack of training time, poor training and high demands in the labor market. The way to solve the problem is the formation of sufficient motivation among students (15).

The students metatechnical knowledge forming is one of the most important goals of the implementation of the principle of polytechnical education in its modern interpretation. Metatechnical knowledge (MTK) means a system of knowledge about the technosphere: its elements and their interrelation, peculiarities of functioning, factors and regularities of development, methodology of scientific and technical research.MTK is the basis for the formation of students 'ideas about the modern technical picture of the world - the picture of the "second nature", determines the development of their technical thinking of a new type and serves as a regulator of their life in the techno sphere (16, 18).

Future bachelors need to have the skills of work with modern software. The study of new information environments gives the future specialist the opportunity to identify the advantages and disadvantages of these programs and thus determine the degree of effectiveness of their use in practice, which will allow maximization of the use of these programs in professional activities. In today's competitive environment, professionals often have to change the job, i.e. change the scope of their knowledge, skills. Each professional regularly receives new tasks, new projects for their development and implementation, he knows that to solve the problem, a comprehensive view of the problem is necessary (17).

2 Materials and Methods

During the study, we conducted a systematic review of literature (18) from available articles published over the past five years. Systematic review is a search methodology that limits systematic error in the collection, critical evaluation, and synthesis of a study on a particular topic It plays an important role in choice of the most effective treatment and preventive and diagnostic means (19, 20).

The meta-analysis technique, which appeared in the late of 80s, today belongs to one of the most popular and rapidly developing methods of system integration of the results of individual scientific research. For example, up to 50% of all treatment methods of diseases of the internal organs currently used in the UK are based on the results of randomized and controlled trials (RCT) as well as on related meta-analyses (21) characterizes meta-analysis as a method of "the results combination of various studies that formed from the qualitative component (for example, the use of pre-defined criteria for inclusion in the analysis, such as data completeness, the lack of obvious deficiency in the organization of the study, etc.) and the quantitative component (statistical processing of the available data)." In the famous monograph of I. Chalmers and D. G. Antman "Systematic reviews" meta-analysis is defined as "a quantitative systematic review of the literature or quantitative synthesis of primary data in order to obtain summary statistical measures " (22).

2.1 What is meta-analysis for?

About 2 000 000 scientific medical articles are published annually currently in the world, not excluding the materials from numerous national and international conferences, books, etc. In this situation, the obvious need to synthesize the information presented in the form of a literature review on a particular issue. The present descriptive approach to the synthesis of such information has the main disadvantage — the lacks of systematicity, in descriptive (non-systematic or qualitative) reviews strictly scientific methods are not used, whereas in the presentation of research data they are usually used. As a result, such literature reviews are difficult to reproduce and often reflect only the subjective opinion of their authors. The distinct advantages of meta-analysis include the possibility of increasing the statistical power of the study, and therefore, the accuracy of assessment of the effect from the analyzed intervention (this allows more accurately than in the analysis of each single small clinical study, to determine the categories of patients for whom the results are applicable), as well as the relatively low cost and efficiency of its conducting. Correctly conducted meta-analysis involves the use of strictly scientific principles (including testing of any scientific hypothesis, a detailed and clear statement of the methods used in meta-analysis, including statistical methods, a fairly detailed presentation and discussion of the results of the analysis, as well as its conclusions) to reduce the likelihood of random and systematic errors. This approach ensures the reproducibility and objectivity of the obtained results.

The results of constantly updated meta-analyses can be widely used in both practical and scientific terms. First, they allow the doctor to obtain the most objective information about the results of research in areas of interest, including a generalized assessment of the effectiveness of a method of exposure (therapeutic, diagnostic or preventive). Secondly, meta-analyses help scientists to:

a) To formulate and justify a research hypothesis (there are many examples of using the results of meta-analysis to establish not only the effectiveness of a therapeutic effect, but also cause-effect relationships between disease and risk factors, as well as to determine the generalized indicators of morbidity and mortality, the effectiveness of diagnosis);
b) To justify the scale of the planned clinical study (meta-analysis allows obtaining reliable data to assess the expected effect of a particular treatment method for its subsequent verification in the planned research Institute);
c) To determine the important side effects of the studied therapeutic drug, as well as to establish predictive valuable factors of the development of a particular disease outcome;
d) To avoid mistakes made in previous studies (for example, in the organization of the planned study).

Third, the results of the meta-analysis help health professionals and experts in the development of recommendations and legislation about the use of certain diagnostic and treatment methods. In this regard, regularly updated recommendations are a good example of the American Association of board biologists for the management of patients with cerebra-vascular and board bio-vascular diseases (23).

The plan of implementation of the review consists of three important phases (Figure 1). At the planning stage, we define the main objectives of the research, sources of research, and develop a protocol of systematic review. The works selection, data extraction, process monitoring and data synthesis will be performed in the second stage. The last stage will be the arrangement of our work as a report, thesis or article in scientific journals.

2.2 Planning process

The protocol consists of several components (31):

1) Research questions;
2) Search strategy;
3) Criteria for exclusion of scientific papers;

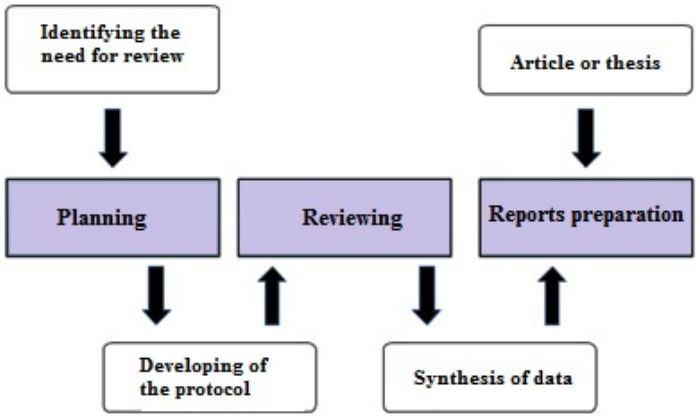

Figure 1. A systematic review of literature (24)

4) Data extraction strategy;
5) Synthesis strategy.

In this study, we should get answers to the following questions:

a) In which subject areas is the Arduino platform used?
b) What teaching methods are used alongside this platform?

Search for scientific articles will be carried out in international bibliographic databases (Table 1), by the following keywords: “Arduino OR Arduino in education OR microcontrollers OR microcontrollers in education OR education robotics OR raspberry Pi OR beagle bone black OR raspberry Pi in education”.

Table 1. Databases

No.	*Bibliographic database*	*Database URL*
1	Web of Science	https://apps.webofknowledge.com
2	Scopus	http://www.scopus.com
3	Springer Link	http://springer.com
4	IEEE Xplore	http://ieeexplore.ieee.org/Xplore
5	ACM Digital Library	http://dl.acm.org

2.3 Data extraction strategy

The 9 data units were identified and will be used for the analysis of selected scientific works:

1. Article’s title;
2. Number of publications;
3. Year of publications;
4. Number of participants;
5. Platform;
6. The subjects that are taught with the use of the platform;
7. Skills acquired through the use of platforms;
8. Applied teaching methods in research;
9. Justification for the application of this technique.

Synthesis strategy: the synthesis is based on the analysis of data from selected publications to obtain answers to our main questions.

3. Results and Discussion

In the course of the research we have considered more than 50 scientific works in this area from different sources (Figure 2).

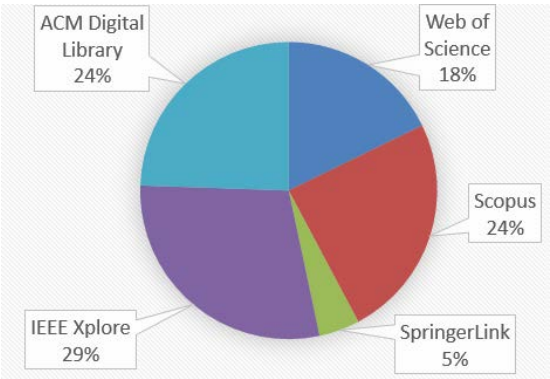

Figure 2. Search Sources

About 30% of these research papers were selected from the IEEE Xplore Digital Library of the Institute of Electrical and Electronics Engineers (IEEE). Next are the digital library of the professional Association in the field of computer science ACM Digital Library (24%) and bibliographic and abstract database Scopus (24%). Scientific works were selected on the basis of the keywords mentioned above. It should be noted that some works are placed in several scientific bases. Most of the works were presented in international conferences. Below we have listed the major scientific journals (Table 2) where the articles in our direction were published:

Table 2. List of main scientific journals

No.	*The name of the scientific journal*	*Terms of publication (average)*
1	Computers & Education	9 months
2	International Journal of Education and Information Technologies	10 months
3	Computer Applications in Engineering Education	5 months
4	International Journal of Engineering Pedagogy	4 months
5	European Journal of Engineering Education	3 months

The 15 publications were selected out of 50 scientific papers using exclusion criteria (Table 3). The basic information on these works is systematized by the name of the source, year of publication, the number of participants in the experiment and the platform used by researchers (Table 3).

Table 3. Scientific papers

No.	*Article title / Year of publication*	*Number of students*	*Platform*
1	Increasing Students' Interest by Encouraging them to Create Original Lab Projects, 2017	26	Arduino
2	Closing the Gender Gap in an Introductory Programming Course, 2015	76	Arduino
3	Project-Based Learning in Basic Course of Technical Physics: Computer-Controlled Experiments and Agros 2D Modeling, 2017	-	Arduino
4	Influence of Arduino on the Development of Advanced Microcontrollers Courses, 2017	-	Arduino
5	The Arduino Platform Connected to Education Process, 2017	124	Arduino
6	Using Arduino to Enhance Computer Programming Courses in Science and Engineering, 2013	-	Arduino
7	"From Making to Learning": Introducing Dev Camps as an Educational Paradigm for Re-inventing Problem-Based Learning, 2017	25	Arduino & hardware devices
8	Teaching Undergraduate Introductory Course to Mechatronics in the Mechanical Engineering Curriculum Using Arduino, 2013	26	Arduino
9	15-Year Educational Experience on Autonomous Electronic Information Devices by Flipped Classroom and Try-By-Yourself Methods, 2017	125	Arduino, Raspberry Pi, Black
10	Reprint of 'First Exposure to Arduino Through Peer-Coaching: Impact on Students' Attitudes Towards Programming, 2018	44	Arduino
11	Design of a Low Cost Remote Electronic Laboratory Suitable for Low Bandwidth Connection, 2017	36	Arduino
12	Using Assembler for Microcontroller Study on Arduino-Based Platform, 2017	49	Arduino
13	More Missing the Boat - Arduino, Raspberry Pi, and Small Prototyping Boards and Engineering Education Needs Them, 2015	-	Arduino, Raspberry Pi, Bblack
14	A Competition-Based Approach for Undergraduate Mechatronics Education Using the Arduino Platform, 2014	30	Arduino
15	Implementation of Embedded System Design in Student's Final Year Project Using Problem Based Learning Approach, 2017	-	Arduino

3.1 In what subject areas is the Arduino platform used?

Analyzing the extracted data, it should be noted that the use of robotic platforms in training are focused on two main points: the study of the subject and the development of certain skills.

As we can see in figure 3, in many cases (40%) the Arduino platform is applied as an auxiliary tool in programming courses. For example, the use of Arduino Board has helped to increase students' interest in programming and largely students worked with great enthusiasm (25). Demonstration of various physical examples enhances understanding of students. They used melodies to represent the theme "arrays". This approach helped students to understand in detail the process of concatenation of arrays, the difference between the position and the value of the array element (26). Moreover, the simplicity of programming and the variety of Arduino-compatible devices make them useful for all levels of ICT students, and for those who are trained in other engineering areas (27).

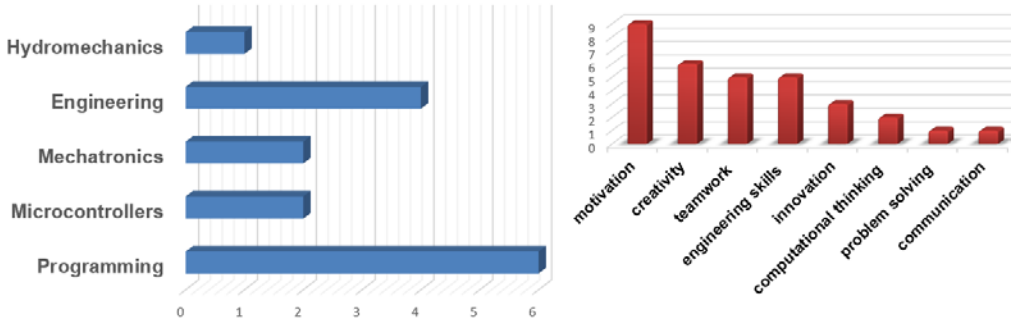

Figure 3. Subject area and objectives of the platform

The analysis of the works shows that this tool was used mainly to increase the motivation of students, development of creative skills and ability to work in a team (28, 29).

3.2 What teaching methods are used alongside this platform?

Due to the specificity of the tools under consideration, the use of project-oriented methods of training prevails (73%). This allowed approving the relevance of the study of project-oriented methods of teaching to programming the micro-robots.

Figure 4 presents an analysis of the characteristics of the above-mentioned methods of teaching programming the micro-robots in accordance with the specifics of the platform.

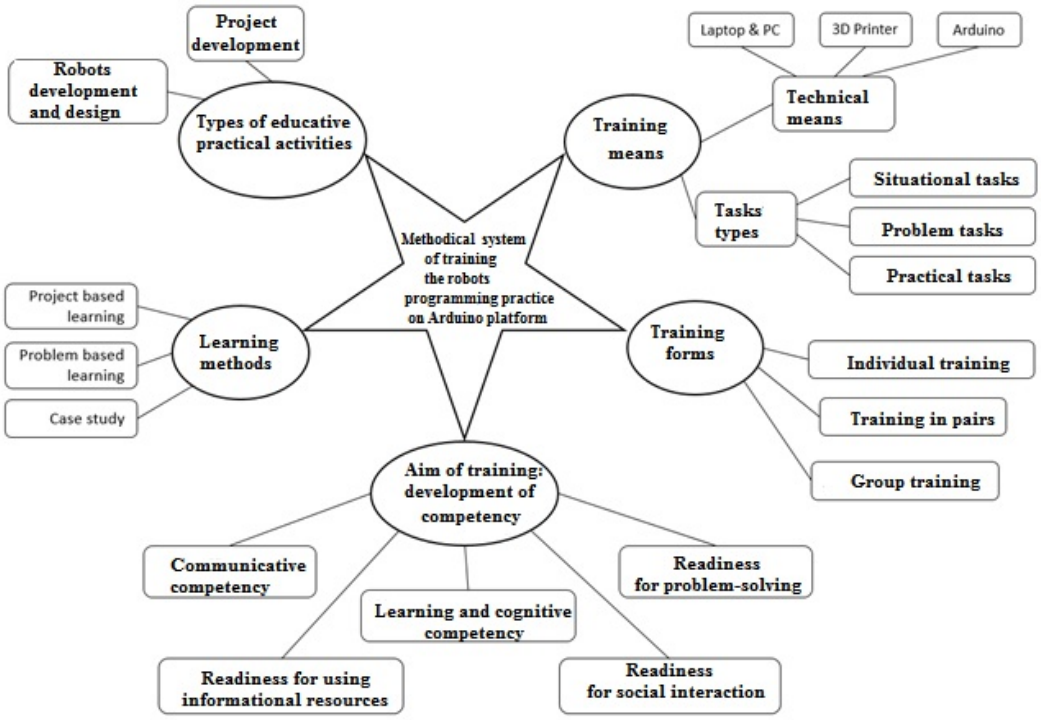

Figure 4. Characteristics of teaching methods for programming the micro-robots

The formation of the above-mentioned competencies of a student is very important and it is the level of formation of these competencies upon which depends how valuable will be a student's attitude to the subject and the process of education in

general. Every practicing teacher knows that it is the educational competence that motivates students and develops their creativity (30).

4 Conclusion

In this work, we have considered fifteen selected articles on this topic, in particular the use of robots as auxiliary tools in higher education. The potential benefits of these scientific papers were analyzed. It was noted that robots are an effective tool to support such subjects as programming, engineering, mechatronics, microcontrollers and other areas of natural science. This type of training significantly increases the students' motivation, develops creative and computational thinking skills and forms key competences.

It is revealed that project training is the best method when using the Arduino platform, as the work takes place in a team and each participant is responsible for the performance of its functions. In the process of such work, the study of a certain area is systematic; moreover, students receive as a result of their efforts – the finished product.

A promising research is the systematization of methodological and technical means of project-oriented training and the development of an educational environment for teaching programming the micro-robots.

Literature:

1. Radionov AA. 2011. Electrical equipment and automatics. Moscow: Magnitogorsk.
2. Omelchenko EYa, Tanich VO et al. 2013. Brief overview and prospects of the Arduino microprocessor platform application. Electrotehnicheskie sistemy i kompleksi [Electrotechnical systems and complexes], No 21. pp. 28-32.
3. Momot MV. 2017. Mobile robots on the basis of Arduino. St. Petersburg: BHV-Peterburg.
4. Klyachenko DN. 2018, 14-15 February. Educational robotics: from Lego to Arduino. Proceedings from: “Robotics and education: school, university and production”. Perm.
5. Sytnikov PL. Proceedings from II International scientific and practical conference: Education and Science in modern conditions.
6. Gaisina IR. 2012. Robotics development in school area. Proceedings from II International scientific conference: Pedagogical skills. Moscow: Buki-Vedi.
7. Yurevich EI. 2005. Robotics basis. St. Petersburg: BHV-Peterburg.
8. Chetina VV. 2017. Features of the introduction of robotics in the educational process. Nauka i perspectivy [Science and perspectives], No 2.
9. Ospennikova EV, Ershov MG. 2015. Educational robotics as an innovative technology for the implementation of the Polytechnic orientation of physics teaching in high school. Pedagogicheskoe obrazhovanie v Rossii [Pedagogical education in Russia], No 3. pp. 33 - 40.
10. Contemporary education: Robotics at school. Available at: http://www.techno-guide.ru/robototekhnika/sovremennoe-obrazovanie-robototekhnika-v-shkole.html
11. Maksimov VP, Kornilov Yu. 2015, 27 November. Analysis of Single-Board computers potentially suitable for use in teaching. Proceedings from VI International Scientific and Practical Conference: Pedagogical skills and pedagogical technologies. Cheboksary: CNS Interactive plus.
12. Ushanov KP. 2017. Laboratory course "Basics of programming the Arduino": qualification of a robot Growing up. state prof-PED. UN-t. Information systems and technologies. Yekaterinburg.
13. Vlasova OS. 2013a. Technologies of educational robotics as a means of development of the subject area "Mathematics and Computer Studies». Nachalnaya shkola do i posle [Primary school before and after], No 10.
14. Vlasova OS. 2013b. The content component of primary school teacher training for the introduction of educational robotics. Vestnik Chelyabinskogo Gosudarstvennogo pedagogicheskogo universiteta [Bulletin of the Chelyabinsk State Pedagogical University], No 11. pp. 47-57.
15. Osadchyi VV, Osadchaya EP. 2014. Analysis of the problem of professional training of the programmer and ways to solve it. Obrazhovatelnie tehnologii i obschestvo [Educational technologies and advocacy]. Tatarstan: FGBOU VPO KNITY, Vol.17, No 3, pp. 362-377.
16. Ilyin IV, Ospennikova EV. 2012. Systematization and generalization of measurement technical knowledge as part of the implementation of the principle of Polytechnic in teaching physics. European Social Science Journal, No 3.
17. Zhuev PV, Koscheeva ES. 2014. The problem of continuity in studying robotics at school and university. Pedagogicheskoe obrazhovanie v Rosii [Pedagogical Education in Russia], No 8. pp. 54-61.
18. Biolchini J, Mian PG, Candida A, Cruz N, Guilherme HT. 2005. Systematic Review in Software Engineering, technical report. Rio de Janeiro.
19. Antman EM, Lau J, Kupelnick B, Mosteller F, Chalmers I. 1992. A comparison of results of meta-analysis of randomized control trials and recommendations of clinical experts. Treatment for myoboardial infarction. JAMA, 268.
20. Lau J, Antman EM, Jimenez-Silva J, Kupelnick B, Mosteller F, Chalmers I. 1992. Cumulative meta-analysis of therapeutic trials for myoboardial infarction.
21. Ellis J, Mulligan I, Sacket DL. 1995. Inpatient general medicine is evidence based. Lancet.
22. Last JM. 1988. International epidemiological Association A dictionary of epidemiology. New York: Oxford University Press.
23. Feigin VL. 1999. Basics of meta-analysis: theory and practice. Mezhdunarodniy zhyrnal medetsinskoi practiki [International Journal of Medical Practice], No 7.
24. Newton S, Fabiane B, Vavassori B. 2017. Robotics applications grounded in learning theories on tertiary education. Computers & Education, No 112.
25. Miguel AR, Hierro CM, Perez A. 2013. Using Arduino to enhance computer programming courses in science and engineering. Proceedings from Conference: EDULEARN 13. Barcelona, Spain.
26. Miguel AR, Rocio RZ, Manoso C, Angel P. 2015. Closing the gender gap in an introductory programming course. Computers & Education, No 82.
27. Ogrutan PL. 2017. Increasing Students’ Interest by encouraging them to Create Original Lab Projects. TEM Journal, Vol. 6 (4). ISSN 2217-8309, DOI: 10.18421.
28. Grover R, Shoba K, Shoup T, Khanbaghi M. 2014. A Competition-Based Approach for Undergraduate Mechatronics Education Using the Arduino Platform. Proceedings from: Interdisciplinary Engineering Design Education Conference (IEDEC).
29. Hurtuk J, Norbert A, Chovanec M. 2017. The Arduino Platform Connected to Education Process. Proceedings from: 21st International Conference on Intelligent Engineering Systems. Larnaca, Cyprus.
30. Venkova LE 2017. Competencies and project activities. Pedagogicheskaya masterskaya [Pedagogical workshop]. Moscow.
31. Kitchenham B, Charters S. 2007. Guidelines for performing Systematic Literature Reviews in Software Engineering. Keele University, Durham University: Joint Report.

Primary Paper Section: I

Secondary Paper Section: IN