Engineering in Educational Institutions: Standards for Arduino Robots as an Opportunity to Occupy an Important Niche in Educational Robotics in the Context of Manufacturing 4.0

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Abstract. The article reflects the views on the development of the engineering area of education and, in particular, its robotic vector. We do not claim to be *"the ultimate truth"*, but the issue is urgent and it requires extensive coverage and discussion in the community in the context of the development of the educational field of Technology. The question of the methodology and technics on the basis of which robotics courses will be taught, as well as design and construction, is considered. Within the CBLE "Clever" experimental study, an excellent construct and a huge number of author's methodological guidelines were approved, tested and worked out. Educational designers are used, including during the engineering solutions prototyping. We focus not only on Lego products. There is a "technological boom" in the development of free software and hardware platforms, in particular, this is due to the appearance of the Arduino board in its various forms. It really gave rise to a *"breakthrough"* wave in technical creative work. Robbo-ScratchDuino, mgBot, and hundreds of others offer individual components and serious kits for future designers and engineers. Laser milling machines and other CNC machines, robots, quadrocopters, 3D printers and other devices based on microcontrollers flooded the world. The development of electronic prototypes has been simplified many times at schools and a great amount of startups are being created. The educational effect is possible only with the systematic nature of such decisions and at least a certain uniformity in requirements. The main problems of implementing free software and hardware solutions (free educational robotics) into educational courses are offered.

Keywords: Variable models, Free educational robotics, Arduino, Roboplatform, mBlock, Computer-oriented methodological systems of research teaching, Engineering education, Research teaching, Scientific and technical creativity, Smart home, LED, Controller, Photoresistor, Piezoemitter, RIP.

1 Introduction. Analysis and Possible Solutions with the use of Free Educational Robotics for Educational Institutions

Modern trends in the development of education, the emerging demand from the state and society are pushing schools to introduce the basics of engineering into their educational practice.

Modern trends in the development of education, the emerging demand from the state and society are pushing schools to introduce the basics of engineering into their educational practice. It is necessary to create full-fledged conditions for the formation of technical thinking of students in a certain school. This is a whole complex of conditions of a technical, financial, organizational and methodological nature, which allows students to be oriented toward science, research, and engineering education. And many problems of this complex are solved by a team of like-minded people in collaboration with parents, associates and with the support of the educational administration [1].

On the basis of the analysis of international experience, ways of solving problems concerning the design of the learning environment and the construction of variable models of subjects in the natural sciences and mathematical cycle with the use of functional modules of the computer-based learning system (CBLE) are proposed. CBLE "Clever: School of Natural and Mathematical Sciences" is based on scientific concepts, including the results of previous researches of advanced scientists: theoretical aspects of the concept of L. Vygotsky [2], [3] V. Davydov [4], D. Elkonin [5], P. Galperin [6], A. Leontiev [7], S. Rubinstein [8], S. Papert [9], J. Piaget [10] which are the foundation of new state educational standards and are focused on the practical educational and cognitive students' activity, the formation of the younger generation as the basis of a new society of knowledge [11], [12], [13]; scientific and technical creativity and handicraft [14], [15], [16]; international initiatives STEM, MINT, NBIC, TechShop [17], [18] and Others (European Society for Engineering Education, International Federation of Engineering Education Societies, etc.) [19]; Principles of Convergent Natural Sciences and Engineering Education [20]; principles of blended and adaptive learning [22], [23].

Different educational courses "Design and Research", "Robotics", etc. and hobby groups "Young Ecologist", "Young Technician", "Young Forester", "Digital Laboratories" are organized on the basis of educational institutions. They deal with research and project activities, the study of mathematics, physics, biology, chemistry, ecology, geography, as well as information technology and scientific and technical creativity [24]. Teachers of primary school, biology, chemistry, mathematics, physics and IT aspire to lay the foundations of engineering thinking into their students. And here we face one of the problems of implementing engineering into school – the lack of an engineer profile in the educational process.

An important role in the work is given to the usage of modern educational, laboratory and demonstration equipment. In primary school children already have the opportunity to visually study the properties and phenomena of the world around them, they form the entire perception of nature, learn to set up experiments in a playful way and develop skills in setting and achieving goals. A mobile set (15 netbooks) was transferred to primary classes, which allowed students to master working with a project-oriented environment. Students of grades 5-6 study Scratch in extracurricular activities [25].

The development of digital laboratories in high school is carried out in the form of small educational researches, during which students assemble experimental facilities from ready-made sensors and measuring instruments. Students learn to formulate conclusions on the basis of the experiment justifying them with the data obtained.

The most difficult type of activity for teachers and students is the implementation of individual and group projects, including the research part and elements of engineering developments. Such project aims at creation a real product and requires coordination of the work of different participants. Motivation to learning and choice of engineering professions is achieved through the usage of *research and simulation practices*, as well as various types of significant activities. Interactivity is provided by the usage of exhibits, laboratory and demonstration equipment, interactive software, electronic educational content, as well as active forms of organization of educational process, research and design activities of students [24].

Within the CBLE “Clever: School of Natural and Mathematical Sciences” scientific research events on ecological education, planting saplings of trees grown in the school farm are held [1]. The educational work conducted by children as part of their work with forestry is one of the most powerful tools for motivating technical creativity and developing technological competencies. In outdoor events, through active participation in the game, each participant gets the opportunity to try on roles that correspond to different professions in the engineering field: engineering, energy, forestry. As part of a scientific project, students of our schools practise in the areas of: agronomy and agricultural technology, veterinary medicine and zootechnics, forestry [25].

In engineering education of the students, the basic educational areas are: in-depth study of physics, mathematics, biology, chemistry, ecology and other disciplines of the natural science cycle. In order to attract high school students to the basics of engineering education, teachers of several schools (among them, former engineers and electronics engineers) launched a face-to-face distance learning project called “Educational Robotics”.

The programme includes computer repair training and helps teachers in the vocational guidance of students in the field of information and telecommunication technologies. The base of the project is a distance course on a Google website with relevant material and diverse tasks. Students are supervised by their teachers locally. To increase motivation personal and team championships were organized. The work has been going on since March and will last until mid-May.

At school, we are preparing to restart the project “Measuring work on the ground”, which combines humanitarian and natural mathematical disciplines, the main goal is the formation of meta-subject competencies of students that contribute to the development of universal educational actions for understanding a holistic picture of the world. The usage of modern software and technical equipment allows to most fully and effectively carry out a whole range of diverse work on searching the information, its analysis, systematization, evaluation, generalization and visualization.

The project “Measuring work on the ground” is carried out jointly by teachers of geometry, computer science, physics, history and geography, after an extensive material related to this topic has been accumulated in the geometry course. Practical tasks promote the formation of a correct understanding of the nature of mathematics. As you learn the material, the methods for solving problems change; the same problem can be solved in many ways. The following geometry questions are used: equality and similarity of triangles, relations in a right-angled triangle, properties of right-angled triangles, etc. A new unit has been added for the development of engineering thinking: meteorological observations, creation of a soil-climate passport, measurement of the physicochemical parameters of water in a pond and a stream.

The place of the project in the educational process is extremely important in terms of the formation of basic and profound knowledge, skills, and abilities. Interdisciplinary links enhance the overall educational effect of this project.

While working on various projects, we always initially start with existing patterns and templates. I remember my teacher in the radio engineering club. In the second year of study he brought us an old broken receiver, without some details. He asked to restore the model. We did - it seemed to be not bad, everything worked. By the way, an almost new and the same receiver was in the teacher's closet. And when we compared the devices, it turned out - we made the radio in our own way, using other ideas. In his activity, the student goes through the phase of apprenticeship, where instructions, technological maps are simply necessary. Although it's always more interesting to invent, fantasize, sculpt from a scattered pile of parts a device which was conceived only by yourself.

In most cases, the proposed robotics kits cannot be used without reworks *"on the knee"* (done in a slapdash manner) (even soldering is used) and the purchase of components (batteries and chargers). A child or an unprepared teacher is not able to use such a kit, and a prepared teacher will not do this when it is necessary to provide with such kits the whole class.

A common marketing policy for proprietary and free solutions is that the manufacturer offers expansion kits or the ability to purchase the individual components. In this case, the functionality and completeness of the basic version of the kit, as a rule, is cut so much that it becomes almost impossible to use, and the proposed extensions are disproportionately expensive. There is an alternative option - *"all inclusive",* but there is practically no way to increase functionality. And the completeness of the proposed kit is still in doubt.

Some used technical solutions are not suitable for tough operating conditions in educational institutions and lead to a very rapid failure of the equipment. Accordingly, maintainability leaves much to be desired

A robot is a complex *"intelligent"* device, which is capable to perform the function assigned to it and to perform work (!) in changing conditions. The main thing is that during the educational process there is a *"game"* in robots, but you should play as seriously as possible. The robot should be able to connect different executive bodies corresponding to the training *"production"* task. In some training situations, you can go without them, but the set of such tasks is limited and should be well researched methodologically and provided with appropriate hardware solutions. It is important that the educational robot should be able to change, transform, demonstrate complex diverse behaviour in changing conditions, in other words, to fulfill the functions of a personal entertaining robot, maintain and develop children's interest every lesson, which is especially important in the conditions of a non-profile educational institution.

The *“smartness”* of educational robots is very limited, and to maintain the children’s interest, games with remote control should be used more widely, where some of the actions are performed by the robot itself in automatic mode. Such an approach assigns primary importance to the question of a convenient, easily organized and reliable remote control for each robot within the training class. As a rule, the tools used for this in modern robotic sets are far from perfection.

2 Educational (non) Free Robotics. Requirements for Developers of Robotic Kits who Would like to Occupy an Educational Niche in Schools

Based on the analysis of the research results [1], we can state that each developer is trying to create his own configuration that is incompatible with competitors and even with their own products of older versions, while there are a very limited number of logical options. For example, for *Arduino Uno* there is the only motor control scheme from among the common and used ones that minimally limits the possibility of further upgrade *(D5-D4, D6-D7).* It is recommended to accept it as a standard [26] for using in educational institutions. Software developers enter artificial restrictions that prevent the work with unfamiliar or hand-made robotic kits. An alternative is free educational robotics, focused on creating a truly high-quality compatible product which integrates the advantages of different solutions. Positive examples (*MakeBlock, iArduino, MGBot)* are used in the “Clever: School of Natural and Mathematical Sciences” pilot research.

Requirements for developers of robotic kits who would like to occupy an educational niche in schools. Of course, for the development companies it is very financially tempting [1]

A logical motor control scheme, non-use of ports with unique capabilities for performing research tasks [27], which can be assigned to *“ordinary”* ports provides, as a consequence, variability in increasing the capabilities, each product can be easily modified for specific tasks. For example, port *D3* may need to be used to control an additional motor, or to interrupt processing that occurs when the state of the port changes. It is recommended to accept a twin-engine scheme using the *D5-D4, D6-D7* as a single standard.

Focus on the use of ready-made electronic modules with easy convenient connection. A standard common interface for connecting the necessary modules. For example, RJ-25 with the absence of the possibility to connect incorrectly. Freedom while choosing the manufacturing of such modules independently by any student, up to the organization of a company for their production, uploading the corresponding schemes and instructions. The ability to use a cheap common element base for peripheral devices with easy connection without soldering, or with minimal soldering, for example, line and obstacle sensors, Bluetooth modules HC-05, gyroscope MPU-6050. Adjustment without soldering, available to the child. A wide range of ready-made modules. Saving the possibility for experienced users to refine the ready element base by soldering, including the refinement of the robotic controller to solve specific problems. The product line from elementary school to infinity [1], in the same style of the used components (manipulator machines, printers, milling machines, various kinds of robots, quadrocopters, etc.

Low entry threshold in various aspects. First of all, like *Scratch4Arduino, mBlock, Snap*, and for creating *ArduBlock* selfcontained programmes, it is possible to use visual programming languages for working in an interactive mode. At the moment *mBlock* is the only sphere of elaboration that allows you to use both of these modes in the practice of working with children. Therefore, the hardware configuration of the robotic kit provides the easy use in this software sphere. In addition, in the *mBlock* sphere, it is possible to develop specific extensions for alternative hardware components and provide support for their own *robotic controllers*.

The kit includes a complete set of everything you need, including a screwdriver for assembly. You must first resolve the issue with the batteries and a charger. Reliable, durable, as well as beautiful construct, convenient for assembly by children themselves, arouses their interest. Wide design base for further expansion of opportunities. The possibility to transform the structure with different uses (speed, high possibility and stability, balance, etc.) for optimization. Relatively compact sizes, which are important during storage.

The set contains a convenient box for long-term storage of the exploited set. Boxes should be easy to stack and carry for practice. The possibility to install ready attachments, or assembled one from the model kit. The possibility to connect a sufficient number of external engines (2-4 or more, including servos). The possibility to use a simple and complex system of motion control (based on encoder information). The possibility to change the location and orientation of various sensors in a wide range. Ergonomics of use (power switch, button control, LED indication, etc.).

Protection of sensors and electronic schemes, including the presence of a hull. Availability of easy-to-use fault-tolerant solutions for wireless control of a robotic platform from a computer, tablet or additional Arduino-device in the classroom. A wireless connection for training robots should be organized so that its setting does not take time of the lesson.

The presence of a description of the way of connecting modules (sensors, actuators). Support for two options at the same time is desirable: a three-pin *SVG* connection using *Dupont* wires and a method that provides protection against incorrect connection. For example, *RJ-25 or RJ-9.* A set that allows you to complete a full course of study in several versions, even in the basic configuration. The presence of easy justified redundancy of the kit without overloading it with unnecessary parts, an optimal set of electronic modules. *The composition of the starting configuration includes a gyroscope and a rotary head on a servomotor with an ultrasonic or infrared range finder.* These components significantly expand the capabilities of the mobile roboplatform and can stimulate the interest of children due to its greater personification and variability, as well as an interconnected set of educational game tasks.

For example, a piezo emitter was included in the “Smart House” project. The possibilities of using the programme in *mBlock* when working with a piezo emitter were demonstrated. We used a special high-level order of control to create a security siren in the Fig.1. We complicated a little bit the programme by adding a start button control in the Fig.2, Fig.3.

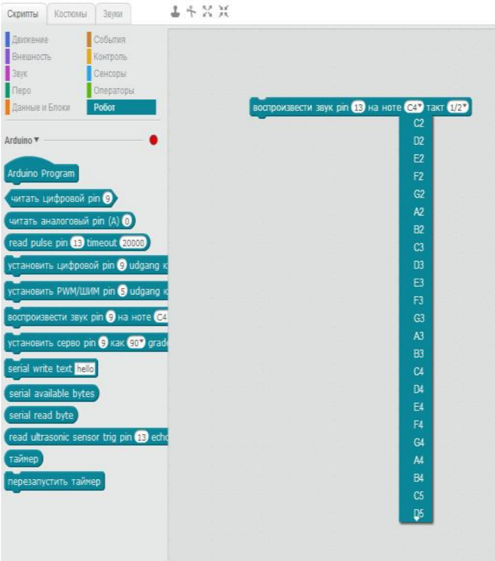

Fig. 1. Programme in mBlock (Siren alarms).

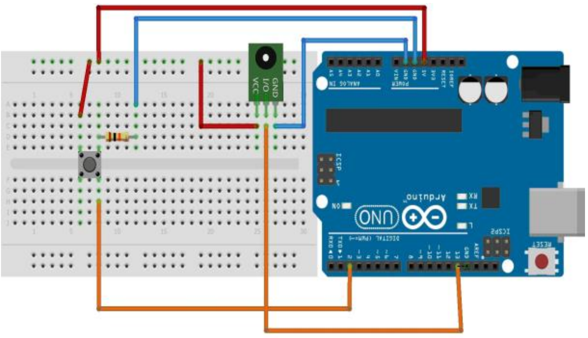

Fig. 2. Assembly scheme.

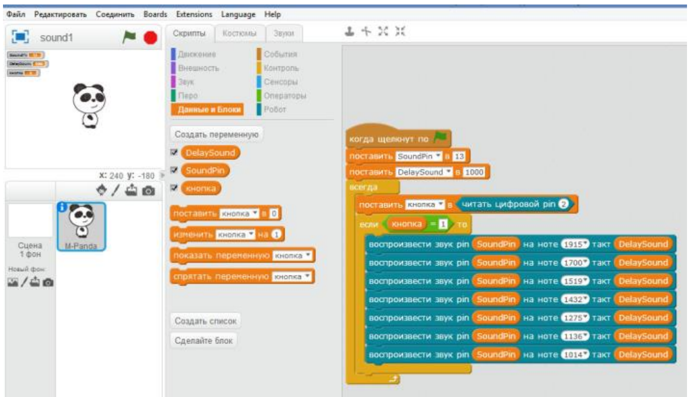

Fig. 3. Programme in mBlock (USB connection).

An example of a programme in creating a musical instrument in which the sound will be changed when the hand blocks the light stream falling on the photoresistor. The connection scheme of the photoresistor to the board in the Fig.4 is given below.

Fig. 4. Photoresistor Module Connections to Arduino.

The button was removed from the assembly scheme, but if it remained from the previous project, it can be used at the discretion, for example, to change the frequency ranges in the Fig.5. In the project, the photoresistor connection pin is changed to A0 in the Fig.5.

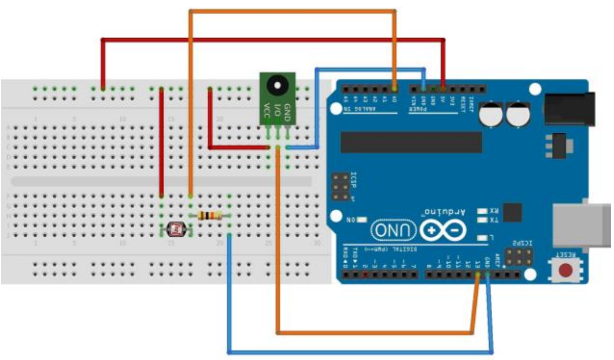

Fig. 5. Assembly scheme.

We introduce the variables: przPin - indicate the connection pin of the photoresistor; przReading - is a variable for storing data from a photoresistor; soundPin - indicate the connection pin of the piezo emitter; soundFreq - variable for storing sound frequency; sound_freq_max - set the maximum emitting frequency; prz_max - set the maximum value of the photoresistor. The programme is given below in the Fig. 6.

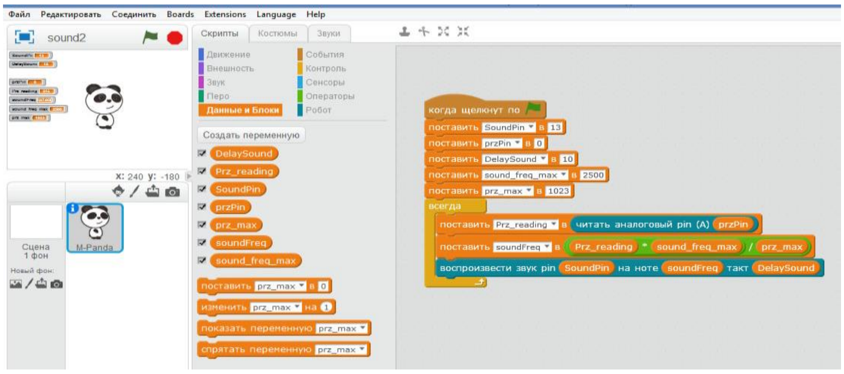

Fig. 6. Example programs in mBlock.

A version of the programme with a decrease of the number of input variables in the Fig. 7.

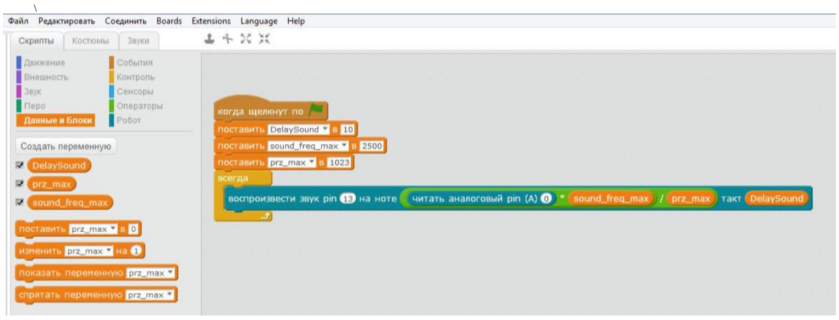

Fig. 7. Example programs in mBlock.

Within the “Clever: School of Natural and Mathematical Sciences” reseach, using Arduino-based training kits, many research projects have been developed (from “Smart House” to “Design Bureau”) taking into account different options for using sound, a piezo emitter, several browsers, and LED control (*ScratchDuino + mBlock or Snap laboratories*) [1], [26].

3 Engineering Projects at School

Table for Sand Animation. In primary school, for a long time, students were engaged in plasticine animation. We came to the idea to do sand animation in order to expand the creative range, to develop the fine motor skills. With the participation of 6-7 graders, a table for sand animation was made. (i.e. a frame and a glass stand). I had to tinker a bit with the backlight and the video system. Along the perimeter there are fluorescent lamps. Web cameras are put into two positions - above the table and under the glass. Fixing video on MTS was performed by using Intel Education Media Camera by Intellisense (A programme for taking pictures and video, initial processing of photos and videos, as well as creating presentation reports based on the footage).

Potter's wheel. After the excursion to the local history museum and the ceramic factory, students were eager to create and sculpt from clay. It was necessary to make a potter's wheel. Information on the Internet and the necessary spare parts (based on a DC motor with a frequency regulator, a small pottery wheel) were searched. It was also important to choose the right clay for vessels not to crack.

A Device for Determining Specific heat by Plastic Deformation. In our educational process, we often adhere to certain patterns. As practice has proven their effectiveness, low time costs, good efficiency. In physics lessons, the specific heat of substance is usually measured using a calorimeter, while the specific heat of the glass material of the calorimeter and the liquid poured into it are considered to be known. Everything has been worked out over the years. However, it is important for schoolchildren to be aware of other methods that make it possible to measure specific heat without using information about the specific heat of other substances. One of these methods is based on the phenomenon of heating of solids during their plastic deformation. In general, we can say that the project was carried out using hand-made equipment, as well as a digital laboratory and a temperature sensor [1].

We often use competition elements in our work. Most guys, of course, prefer team work. There are individuals. You can motivate them to work in a team. To do this, one should create situations in which such a child has to leave his comfort zone. A distinctive feature of our projects is that the solution is often unknown, and students must independently gather information and choose the best solution [27]. The children are encouraged to cooperate not just because of their next home assignment, but because of a real engineering solution that should work. There are situations when you have to work with one child. Therefore, more often we have teams of different ages, when there are children with different skill levels and abilities. We form teams due to the preferences and skills necessary for the project.

In our digital days, when everyone has a mobile entertainment center in his pocket, a means of communication and access to virtual resources of the whole world, the question arises – what is it for to assemble a radio, an electronic toy or to program a sensor? It seems to many of us that these children are trying to do this for themselves, for their pleasure [24].

We bring broken devices, equipment to school and disassemble them with children, trying to repair. For example, once a schoolboy's home iron was modernized. It turns out that in old devices there is no thermal fuse, so the idea came to add an element from the discarded one. And now the fire safety of the home device is ensured. When children work on real projects referring to adulthood, attracting all the power of modern digital technologies, the products created by them as a result are more functional and demanded than our childhood crafts.

The work with children continues during the holidays. Summer school "Clever: School of Natural and Mathematical Sciences" is an already established element of educational activity in our school. The main area of work is a school educational experimental site and a school nursery of seedlings. As part of the work in this area, I'd like to attract 1 student to the design of automation and control tools. Among students in grades 5–7, we use the Tetra educational kit (a ready-made training course for children to learn the basics of programming and modern electronics, Scratch support). With several students of grade 10, they plan to master the Raspberry Pi [1].

Attention is focused on a deep knowledge of programming, computer graphics, robotics, the Internet of things, learning the theory of solving research problems [24]. Indeed, in order to become an engineer, they go through a significant study of various disciplines, where the leading subjects are those of natural mathematical cycle. The formation occurs over the years among a team of specialists, in the process of working on projects of any degree of complexity. Therefore, it is obvious that today a teacher who guides extra classes and clubs of an engineering and technical cycle should have a large amount of knowledge and skills of interdisciplinary area [29]. His competencies as a specialist should allow him to be flexible enough, able to work in the new changing conditions.

4 Discussion

A modern school needs high-quality educational robotic kits, and they exist, but in a very diverse version. Minimum requirements are necessary for the standards of constructing a device scheme, so that students independently and under the teacher's guidance, can work with any educational sets. The base should provide standard tasks. The current discrepancy in the configuration of hardware platforms makes it impossible to create universal methodological materials. Judging from this, the market situation is changing. Prospects for the engineering vector of education development have appeared. Those producers who do not aim at leaders, but continue to work in isolation (each for oneself), risk making sure that nobody needs their products.

However, there is always a lack of technological resources. There are sets of equipment that teachers purchased at their own expense. An appropriate technical base is needed, and this is not only educational robotics. We need interaction of educational institutions and industrial companies in cities, agricultural enterprises in the countryside to perform vocational guidance of children in engineering areas.

When choosing a software and hardware platform for developing new training courses in mobile robotics based on Arduino in primary and secondary schools, we focus on *MakeBlock* kits and *mBlock* software, as the ones that best meet modern requirements for quality, capabilities and applicability in activities with children, we also deal with compatible options (variable models).

We are not fans of *Makeblock* and their *mBlock* software product. If it were a Ukrainian, and not a Chinese company, we would be proud of such thoughtfulness of our products. But while the reality is like this - of all that we could use at school, the *Makeblock* product line came closest to what we would prefer to see at school (*although they are not ideal, sensors must be protected for school use and a servo pack should be included in basic set for ease of purchase, etc.).*

As a part of the study, educational institutions use *"free"* platforms. All *MakeBlock* products are well documented with the possibility for children to revise on their own. The *mBlock* software product based on Scratch 2.0 has versions for *Windows, Mac and Linux*, supports most Arduino boards (and not just the company's own controllers), various connection types, and also has a mechanism for writing extensions by any users [1], [24], which allows to adapt for control a huge number of electronic components in this area. Currently, *mBlock* is the only Scratch-like environment that allows everyone including children to work conveniently with microcontrollers in both interactive and offline mode. This is also worth thinking about for our software developers. Convenient *RJ* connectors are used to connect the electronic components, which makes the assembly as convenient as in Lego, *but at the same time these are ordinary connectors that are easy to crimp on your own.*

Variability and Functionality of Product Line. The product line includes: kits with simple *mBot* robots, kits with a powerful robot *Ranger* (three options for standard assembly), a set of *Ultimate* components (10 standard robots + space for creativity), sets of artist robots (a machine for round objects, a hand, a drawing robot on wheels), kits for assembling plotters (including laser ones) and two types of 3D printers, modular octocopters, extended kits with sensors. The basis is milled aluminum.

The students emphasized the advantages of the controller in a transparent protective box, which has 12 *RGB* LEDs, a pair of light sensors, a buzzer, sound and temperature sensors, a gyroscope, a couple of buttons, a powerful engine with encoders. What is more they admitted the comfort of using modules to create their own sensors. It is important that the control environment is similar to the usual *Scratch*, but it gives the opportunity to control all the electronics. In addition, students are willingly designing octopapers, planes and various cars using *Airblock*.

In the Evolvector construction sets (set of advanced Robot +), it is necessary to admit the presence of a high-quality training manual and thoughtful interesting tasks. The set has its original aspects. For example, the wires are already soldered to the motors. But this construction set cannot be recommended for use within the framework of a non-profile comprehensive school. The orientation towards using the Arduino IDE (instead of visual programming tools like Snap4Arduino, Scratch4Arduino and mBlock) should be taken into account, which drastically reduces applicability and pushes back the entry threshold. A set of tasks for ordinary (not selected) children and teachers should also be different.

For example, as part of the “Clever” scientific project, students play robofootball with pleasure, or solve design research problems with a plot background. Here we talk about creating universal teaching materials suitable for conducting classes using any compatible Arduino robot platform, and the content of these classes is not limited by struggle with the discrepancy described in the methodology and the actually used hardware configuration.

In today’s market, with regard to robotics, the kits and standards for minimum sets are offered: Using the *Makeblock* kit5 you can assemble three modifications: a crawler all-terrain vehicle, a high-speed wheeled balancing robot. It is recommended to add a servomotor pack to each one, making it yourself. Using the *Makeblock* kit we assemble four modifications of drawing robots, including manipulators. This is the easiest option, including a laser (engraver), etc. A kit for the independent manufacturing of *Makeblock* sensors. Using full compatibility with Arduino peripherals and a unified programming environment, we assemble 7 standard robot circuits described in the manuals and many of our project variations [30].

As part of the Clever study, we tried many different options, including during sessions with the use of electronics. Obviously, various modular solutions are optimal for school, for example, a kit with modular basis components with three-legged sensors, SVG, and joystick modules, modular buttons, relays, slide potentiometers, button assemblies, a joystick shield, a prototype shield optimized for connecting three-pin modules, a motor shield, a shield for three-pin sensors, etc.

The experimental results confirm that the use of such key solutions, supplemented by three-pin sensors in SVG modules, makes it easy to assemble circuits even in the primary school. Children willingly make their joystick to play Scratch, or control the robot from a distance, and then a similar assembly becomes a digital laboratory, or an element of a smart home [24]. For kits based on *Orion* and *mCore*, as well as other *Arduino* controllers, you can use the ready-made module and using soldering you can use the GY-521 based on the MPU-6050 chip instead. The *mBot Ranger* kit has a gyroscope, the Auriga controller includes it. Solutions based on *STM32* (including *Iskra JS*) are future of microcontrollers for using during the training process. As part of the study, a complex with a set of training tasks is used for a whole robotics training course.

Domestic developers need to pay attention to compatibility with *MakeBlock* products, and, accordingly, with the *mBlock* software environment. For example, we are talking about compatibility with products: based on *Arduino Uno - mCore, Orion*; based on *Arduino Mega 2560 - Auriga, MegaPi* [31].

Experimental and Research Activities in the Field of Education. Experimental and research activities in the field of education are carried out in order to ensure the modernization and development of the educational system, taking into account the main areas of socio-economic development of the country, the implementation of priority areas of state policy in the field of education. The experimental activity is aimed at the development, testing and implementation of new educational technologies, educational resources and is carried out in the form of experiments.

The research activity is focused on improving the scientific, pedagogical, educational, methodological, organizational, legal, financial, economic, manpower, material and technical support of the educational system and is carried out in the form of research projects and programmes implemented by organizations engaged in educational activities and other educational organizations, as well as their associations.

When implementing a research project, the respect for rights and legitimate interests of participants of educational relations must be ensured, education, the level and quality of which cannot be lower than the requirements established by the state educational standard and state requirements must be provided.

The study developed and tested an algorithm for selecting the optimal set of resources of the CBLE, which involves the use of quantitative criteria to determine the suitability of resources to the requirements of students and teachers. As a result, there is a need to develop variational models of science and mathematics education for students of natural-mathematical, technical profiles that differ in content, methods of teaching, etc. Students' testing that has been conducted for several years, monitoring the quality of knowledge, which was conducted in the process of teaching students, allows distinguishing several groups of students of different quality [1], [24], [25].

The first group consists of students (15.7% of the total number of students enrolled in profile classes), who scored less than 10 points in the test. Based on the results of practical exercises, the students of this group have difficulties in the process of mastering the curriculum, most of them eventually continue their education in ordinary classes and after graduating they enter higher education institutions. *The second group consists of students (42.3%),* who scored from 10 to 15 points in testing. Students of this group do not have well-formed computing skills, do not outstand with singularity of thinking, but in the process of systematic and gradual training they were able to master the basic level curriculum and an additional specific component part. They are able to work well if their actions are algorithmic. In the future, about 70% of the graduates of this group enter technical higher education institutions. *The third group consists of students (24.6%),* who scored from 16 to 18 points in the testing process. These students have mastered the curriculum of secondary school fairly well, but for their further development it is necessary to develop their logical and creative thinking. Mostly all of them enter the chosen higher education institutions. *The fourth group consists of students (17.2%),* who scored more than 18% during testing. This group represents the most prepared part of students who have come to profile classes. They show considerable interest in science and mathematics. All of them 100% enter the chosen leading higher education institutions.

5 Conclusion

A set of variable functional modules of CBLE is selected taking into account the methodological theme and tasks of an educational institution, organizations, etc., its specialization, prospects of development, the need for integration with academic and business structures. During the development of the curricula of natural and scientific and technical course, it is important to choose the topic of research projects in a proper way and their realization would give the opportunity to unite the formulated goals and solve the objectives.

As part of the scientific research, the following activities are offered: Organization of development, testing and implementation of new elements of the content of mathematical education in science and technology (the Mathematical logic, theory of algorithms and games, the set theory, the theory of probability and mathematical statistics, etc.) in organizations engaged in educational activities.

Support of educational organizations including non-standard ones, implementing basic and additional educational programmes for the students who have shown outstanding abilities as well as students who have achieved success in educational activities, scientific (research) activities (gifted children, talented youth, young teachers and scientists (summer, winter, evening schools, etc.)

Creation of publicly accessible databases on educational programmes of the mathematical profile, approximate curricular of out-of-class activities, additional educational subjects of science and mathematical content in various educational subjects, courses for students. Improvement of the education system in Ukraine is possible providing the revealing of the relationships and a pedagogically balanced combination of the traditional system of learning with the individual components of CBLE through the creation of centers for intellectual development and scientific and technical creativity [1]. Using these recommendations will help solve the problem of technological competence development at different stages of the student's life and increase motivation to choose engineering professions, support personal and professional self-determination, project thinking of children, teenagers and young people in the modern mobile society.

*Prospects of Further Research***.** It is necessary to refine the standardization of equipment using a free robotic platform. For example, the possibility of using ports for motors, a minimum list of sensors on certain electronic modules, standardized *RJ* connectors with prescribed crimping logic should be provided. The work on creating textbooks and a textbook on Technology which is not based on Lego is going on. It is recommended to use devices based on Arduino in grades 8-11, including optional classes, clubs. While teaching educational robotics in grades 3-7 (8), it is necessary to introduce propaedeutic and extracurricular courses in grades 3-4, accordingly in 5-7 grades - during the study of Technology, including extracurricular work, too. In this case using a visualized environment such as *Scratch* makes it possible to focus not on the study of programming language but on the design and research activities. Rather complex technological projects with two-way communication systems, PID controllers, the use of a variety of sensors, actuators, etc. appear in these environments.

Currently there are only two visualized environments *mBlock* and *Snap4Arduino* for Arduino projects which allow not only to control the device interactively from Scratch-like environments but also to download programmes for offline work. At the same time the mechanism of creating a sketch for autonomy in *mBlock* is made convenient for a student and does not require unnecessary manipulations. That is why *mBlock* is now chosen as the basis. It is only necessary to refine the offline mode and provide convenient mechanisms for working with software and *Arduino* main boards.

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