# SCHOOLCHILDREN'S PROJECT AND RESEARCH WORK IMPLEMENTATION BY MEANS OF TRAINING ROBOTICS

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## Abstract

Objectives: The article dwells upon a learning robotics course as a resource for performing schoolchildren's project and research work. Methods / Analysis: The article focuses on the project and research methods used to teach schoolchildren to robotics. Mastering training, research and project work is supposed to be one of the skills required from school graduates as necessary to perform their work well. Project and research work with robotic equipment is considered to teach schoolchildren how to use a computer as a means of learning, the ability to combine theoretical and applied computer science foundation's in educational and extracurricular activities, programming engineering systems, as well as developing real/actual working models. The article deals with the content-related and the rules of procedure learning aspects of the basic robotics while training. It is also devoted to students' involvement in a robotics club activity using Lego Mindstorms EV3 kits. These classes are taken to solve design and engineering issues, train object-oriented programming and modeling. 4-8 grade students of school 3 in the town of Sovetskaya Gavan (there were 44 students in a test group and 60 of them in experimental groups) who participated in that survey. Findings: The survey proved that using some aspects of educational robotics in training contributed to the development of students' skills to solve not only sample problems but also cope with non-standard ones, carry out their own research. Since there was the further Lego Mindstorms EV3 development in the club activities, it became possible to perform complicated projects, develop independent (unassisted) technical/engineering innovation activities (Imagineering), and participate in robotics competitions. When evaluating skills in the field of project and research work, the indicator values expressed have grown by an average of 24 per cent in the experimental group according to such criteria as an ability to define objectives and tasks, to observe and discover the basic characteristics of the reported pattern, to carry out an experiment, to generate a hypothesis, etc. Thus the authors can make a conclusion that training schoolchildren in robotics make it possible to achieve improvements in the level of skills development in the project and research work. Applications / Improvements: Further research prospects may concern the expanding and enhancing of the course offered for high-school students according to their competencies in mathematics, physics and computer science.

**Keywords**: Training robotics, schoolchildren's project and research work, Lego Mindstorms, technical innovation activities club.

# 1 INTRODUCTION

People have been using robots in various fields of interests for over the course of decades. The application areas of introducing robots are continually enlarging despite all the difficulties connected with its complexity and high prices. The necessity to promote an engineer professional occupation since preschool age seems to be obvious. One of the means to involve children in engineering creativity can be educational robotics.

Many researchers specify the importance of educational robotics as a resource for nourishing key competencies of students at different learning levels. The authors of a certain book review on using robotics in education (Benitti, 2012) concluded that most researchers raise the effectiveness of such an activity. A significant effect of educational robotics has been identified for such science as mathematics, research and teamwork (Kandlhofer and Steinbauer, 2016).

Robotics is being introduced in many schools as an innovative learning environment enhancing and building higher order thinking skills and abilities to help schoolchildren solve complex problems (Blanchard, Freiman and Lirrete-Pitre, 2010).

The researchers' experience in the field of educational robotics (Filippov, Ten, Shirokolobov, Fradkov, 2017) affirms that the most efficient method to involve bright children in learning mechanical engineering is at first, showing them what an engineer has to do and let them do it with their own hands. It is the studies of robotics in secondary school that can influence the future vocational choice and instill meaningful skills to be applied in any scientific area.

Although, it does not mean it is a traditional model of translating full or prepared knowledge from teachers to students. The organization of project and research work in robotics allows changing the way students acquire knowledge and skills through their own work and experiments guided by a teacher (Tocháček, Lapeš and Fuglík, 2016).

Many authors point out that the best way to arrange project and research work is to perform extracurricular activities and extended educational activities. They give an opportunity to make projects really creative and independent and do not define the idea boundary by only one particular subject. Preferential development of student technical creativity in robotics is pointed out in an additional education system. (Ospennikova, Ershov and Iljin, 2015). Extracurricular work on robotics improves the problem-solving skill level and promotes interest in an engineering career (Nugent, Barker, Grandgenett and Welch, 2016).

The purpose of the survey is to work out an educational robotics course as a resource for organizing project and research work for schoolchildren.

# 2 METHODOLOGY AND RESEARCH DESIGN

There are two types of hardware software platforms suitable for training. They are Mindstorms Education produced by Lego: NXT and EV3. Lego Mindstorms EV3 kits are much more complete due to their system parts and are focused on inquiring into the basic physical principles and basic technical solutions that underlie all modern structural design and devices. The use of Lego Mindstorms EV3 construction products allows one solving not only pattern (sample) problems, but also non-routine ones, examining sensors and robots' behavior, and conducting one's own observations. Further mastering of Lego Mindstorms EV3 makes it possible to carry out complex projects, develop independent technical art, and take part in robotics competitions.

The review of current training programs in robotics has found that most of them emphasize the assembly and programming of simple structures and the solution of common issues that come up while preparing for competitions. The original robotics course proposed by the authors of this paper allows one to arrange project and research work for schoolchildren through educational robotics. The main subject matter of organization of the club work is the progressive complication of classes from engineering modeling to robot assembly and programming supplied by a theoretical summary of the project performance capacity and value.

The purpose of the course is to teach students how to use information technology means to solve design problems and develop skills in project and research work.

The program is developed for two academic years. The first academic year is dedicated to students' basic learning mechanisms for detailed design projects development and programming, carrying out simple studies independently using robotic detector elements. Second year students are to be able to develop their own project and research creation independently having taken a research issue they are interested in.

An example of a curricular for a robotics study group for first-year students is presented in Table 1.

**Table 1. A course schedule for the first academic year**

| Topic | Total of hours | Theory | Practice |
|---|---|---|---|
| Learning Lego Mindstorms EV3 starter kit and software | 2 | 1 | 1 |
| Assembling the first robot, verification of operating detecting devices and the main module capabilities | 8 | 2 | 6 |
| Building and programming robots using 45544 Basic Kit and Lego Mindstorms EV3 Edu software | 15 | 3 | 12 |
| Solving non-routine problems, creativity projects | 10 | 2 | 8 |
| Total: | 35 hours | | |

Syllabus:

Unit 1. Introduction to Lego Mindstorms EV3 starter kit and software.

Introduction to the robotics course. Designers of LEGO Company. Lego Mindstorms EV3 potential.

Unit 2. Assembly of the first robot, examining the sensor operation and the main module special features.

Introduction of Lego Mindstorms EV3 kit 45544 build up. Assembly of a robot linear ram. Large engines. Logging on the peripheral parts to the host attachment module. Starting the module, testing performance in Demo mode. Introduction of EV3 module programming units. Developing simple programs on EV3 controlling panel.

Section 3. Assembly and programming robots using 45544 Basic Kit and Lego Mindstorms EV3 Edu software.

Defining the project topic, target setting. Working out a mechanism based on LEGO EV3 constructor. Assembly of Colorsorter robot. Continuous track, also called tank tread or caterpillar track. Small-size engine. Connection and testing of the light sensor. Servo-motors. Introduction to the Lego Mindstorms EV3 IP programming environment. Color collection mode operation. Color sleep mode. Switch operation with the light sensor. Program debugging. Build up a balanceable robot Gyroboy. Gyroscope transmitter. Ultrasonic transducer. Booting up missing modules.

Unit 4. Dealing with non-routine problems, creativity projects.

A theoretical problem solution. A practical problem solution. Generating engines with robot sensors. Independent development of a program according to the aim. Study of a completed structure. Adaptation and fault correction. Sliding bars applied in programming the light sensor. Setting and selecting the parameters of the light sensor. Robot movement along the black line using the switch parameter. Presentation graphics, theoretical reasoning of a completed/ final structure. Critical project review.

An example of a curriculum for a robotics study group for second-year students is presented in Table 2.

**Table 2. Second year curriculum**

| Topic | Total of hours | Theory | Practice |
|---|---|---|---|
| Introduction to design and research work | 5 | 2 | 3 |
| Construction | 10 | 2 | 8 |
| Programming | 10 | 3 | 7 |

| | | | |
|---|---|---|---|
| Project team working | 10 | 2 | 8 |
| Total: | 35 hours | | |

Syllabus:

Section 1. Introduction to the design and research activities

The notion and the main point of project and research work. The structure of project and research work. Determining the direction of project and research work. Selection of the research topic. Setting goals and objectives of project and research work. Hypothesis.

Section 2. Designing

Layout of project and research work. Summary of successfulness and value of the project. Necessary material evaluation to design a project. The choice of facilities and resources. Splitting a project into multiple steps. Creating a step by step design of the project. Testing the project according to various parameters (speed, capacity, profitability, safety, etc.). Identification of risks, possible problems during programming and operation. Ways to solve potential problems, the possibility of modification.

Section 3. Programming

Theoretical justification of the project potential in terms of programming. General testing of the structure performance. Developing separate soft blocks. Program authoring. Program debugging. Testing the project high end conditions. Sensor updating. Keeping a record book to monitor sensor operation in routine and extreme conditions of a project operation.

Section 4. Project team working

Selection of a project type. Distribution of roles and responsibilities among all teammates. Preparation of project critical design review. Packaging of all necessary equipment to a critical design review. Designing a leader board (banner), writing a system description. Working out a technical datasheet. Final testing of a project, ruling out a possibility of sensor asynchronous behavior. Adapting a project in case of emergency operation. A project critical design review.

Classes in a club form can be arranged depending on the number of students in groups and the idea of the project chosen. Besides, the form of the lesson depends on student skills and a step of designing project and research work.

Class forms are of the following types:

Individual lessons are taught if basic competencies have to be developed; when the theoretical material teaching of each student is important.

Group (pair) lessons are taught when mastering team skills while designing project and research work. Most often it is the pair form of working that prevails, because usually one of the students acts as a technician, the second works as a programmer when developing a project.

Team working is applied for giving lectures and drillings (exercising).

The classes combine different types of activities: discussions, drillings, exercises, classes for practicing public speech, rehearsal, etc.

Mastering project and research work skills are arranged a sequent way, flowing from one stage to another.

At the first stage, a teacher sets a task and outlines the ways to solve it with the students.

At the second stage, the teacher sets a task, but students have to find the ways to solve it the solution.

The third stage is the final and most difficult one. The students offer a problem and look for solutions.

The first and second stages of project and research work are implemented during the first academic year. During the second year, students proceed to the third final stage of the project independently. The outcome of their work is a completed original project.

No matter what stage students are at, the structure of the project being developed consists of the following elements: 1. Search for a problem. 2. Definition of the project topic. 3. Setting a goal of the presented project. 4. Generation of the hypothesis. 5. Setting project tasks, drawing up a project plan. 6. Mechanism

development. 7. Drawing up a program for the mechanism operation. 8. Testing a model, defect and fault clearing. 9. Analytical description of the project principle operation. 10. A critical design review.

The final outcome of project and research work for schoolchildren is a project that they present at an exhibition, a competition or a conference. According to the outcome of a critical design review, it is possible to estimate the learning maturity /competence and the program efficiency.

## 3 DISCUSSION OF THE RESEARCH OUTCOMES

The authors conducted an experiment aimed at testing the hypothesis and found out that the implementation of the developed program allows students increasing their preparation to curriculum and design modeling activities. The experiment consisted of three main steps: ascertaining experiment (2013-2014), scouting test (2014-2016) and formative (teaching) experiment (2016 -2018).

The ascertaining research stage is directed at investigating content-rich, operational and activity-related components of teaching educational robotics. Experimental teaching involved 18 students. The authors analyzed the potential of educational robotics for organizing project and research work for schoolchildren, developed the structure and curriculum, observed the experiences and teaching findings, questioned students, and explored projects in the elaboration of studying.

To continue the research, the authors made a review of psychological, pedagogical, methodical literature, scientific research on the problem focused, determined the goals and objectives of the studies, developed a primary hypothesis.

The scouting stage of the study was devoted to concrete definitions (details) of the training curriculum, selecting and preparing diagnostic methods.

The formative stage of the experiment was carried out in 2016-2018 academic years. The experiment involved 86 people.

The experimental group consisted of 44 students from grades 5-9, who attended the robotics club. The test group numbered 42 people. It included students in the same school and the same year, but who did not join the robotics club.

The survey proved that the students from the experimental group changed their attitude towards physics-mathematical subjects after attending classes in a club: the majority of them felt a profound interest in those subjects, and the independent learning proportion rose. The students from the experimental group had a profound interest in project and research work not only in the field of robotics, but also in other academic subjects, and the necessary competences also developed. The number of students who need help with project implementation has decreased by almost 4 times (from 85% to 22%).

Diagnostics had been run and made it possible to identify the dynamics of diagnosed measures in the experimental and test groups of students (Table 3, 4).

Statistical review by means of $\chi$2-criterion (Chi-squared test) of participant distribution in the test and experimental groups according to the degree of all components of preparation to project and research work found the differences relevancy between the test and experimental groups at the final stage.

**Table 3. Preparation dynamics to project and research work in student experimental group**

| Constituent elements of readiness for design and research activities | Experimental start (%) | | | Experimental completion (%) | | |
|---|---|---|---|---|---|---|
| | High level | Medium level | Low level | High level | Medium level | Low level |
| Motivationally significant | 13.6 | 63.6 | 22.8 | 40.9 | 59.1 | 0 |
| Intellectually<br>Informative/ Predictive cognitive | 13.6 | 59.1 | 27.3 | 36.3 | 59.1 | 4.6 |
| Emotional-volitional | 9.1 | 68.1 | 22.8 | 36.3 | 59.1 | 4.6 |
| Effectually positive (useful) | 13.6 | 54.6 | 31.8 | 45.4 | 54.6 | 0 |

**Table 4. Preparation dynamics to project and research work in student test group**

| Constituent elements of readiness for design and research activities | Experimental start (%) | | | Experimental completion (%) | | |
|---|---|---|---|---|---|---|
| | High level | Medium level | Low Level | High level | Medium level | Low Level |
| Motivationally significant | 14.2 | 66.6 | 19.2 | 19.2 | 71.4 | 9.4 |
| Intellectually Informative/ Predictive cognitive | 14.2 | 57.1 | 28.7 | 19.2 | 61.6 | 19.2 |
| Emotional-volitional | 4.6 | 71.6 | 23.8 | 9.5 | 76.3 | 14.2 |
| Effectually positive (useful) | 14.2 | 57.1 | 28.7 | 19.2 | 57.0 | 23.8 |

Experimental work showed that implementation of the developed program can increase student preparation to project and research work remarkably: a positive attitude to educational research and projects (emotional-volitional component), motivation to be engaged in curriculum and project activities and awareness of its necessity (motivationally significant component), skills in applying research methods and project method (practical component), develop student creative potential and their cognitive need (intellectually informative component).

## 4 CONCLUSION

Educational robotics is a resource for developing key schoolchildren's competencies, including mastering skills of educational, research and project activities. Robotics club is one of the best ways to organize project and research work. The main contents of organizing the club activity are gradual lesson complication starting from technical modeling to robot assembly and programming based on the theoretical justification of the project efficiency and value. Teaching schoolchildren to use the design and research method makes it possible for them to work out not only original robotic projects but also their preparation for project and research work in various areas of interests.

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