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ROBOTIC CONSTRUCTION KITS AT ELEMENTARY SCHOOL EDUCATION

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ABSTRACT

The article deals with the topic the development of key competencies of elementary school pupils by the means of a robotic construction kit in project-based learning. Introductory part of the article introduces the key issues and shows the individual working areas: robotic construction kits, project-based learning and key competencies of the pupils, focusing on the problem-solving competency. It also sets research goals, presents pilot research carried out in primary schools and its results. It also describes the main research, its main objectives, methodology, basics, planning and presentation of the first findings. Individual diagrams describe the course of research and the division of control and experimental groups of students in teaching programming using a robotic kit. The diagram shows the division of the method of teaching between the frontal learning and the project-based learning of pupils. This article provides an insight into the issue of teaching robotic kits in elementary schools.

KEYWORDS

Robotic construction kit, key competences of the pupils, project-based learning, research

1 INTRODUCTION

The article represents the introduction into the issues of educational robotic construction kits and systems, project-based learning and key competences of the pupils. It also outlines a plan for the research dealing with the aformentioned topics. The attention is payed to the evaluation of the pilot research with the help of questionnaires, which provided key information for further research survey. It also shows the main research survey as well as the information about its outcomes and results. The motivation and reason for choosing of such a topic is my own long-range interest in robotics and its teaching, mostly at elementary schools.

If the topic of the paper is further examined, it is posssible to divide it into three main parts. The first part is represented by robotic construction kits, the second by project-based learning and the last part consists of key competencies and their development. In the following chapters I deal with the specification of particular key concepts and their description. Current importance of the topic is evident by increasing interest in modern technologies and IT specialists, which has to be taken into consideration in education. Fortunately it is the part of project PRIM (Czech acronym for Support of the development of informational thinking).

2 THEORETICAL BASIS

2.1 Robotic construction kits

In 1920 Karel Čapek in his science fiction play R.U.R. (Rossumov's Universal Robots) used the word robot for the first time. The word originated from the expression robotovat (archaic term for work) and it was recommended to Karel Čapek by his brother, Josef (Coufal, 2016). The first writer who in his stories about robots for the first time mentioned robotics was Isaac Asimov (Coufal, 2016). According to Tocháček and Lapeš the robotics can be defined as "the field about creating of intelligent machines which integrates several scientific and engineering areas" or as "science about robots, their design, production and applications" (Tocháček, Lapeš, 2012). Robots and robotic sets can be divided on the basis of different criteria, stated by e.g. Novák (Novák, 2005) or aformetioned Tocháček and Lapeš (Tocháček, Lapeš, 2011).

The supply of robotic construction kits or educational robots have been increasing every year and thus the schools can choose the best considering their requirements and possibilities. The list of mostly used robotic kits at schools is shown further in the text. Arduino utilizes single-board computers based on microcontrollers ATmega which can be connected to servomotors, display and a large amount of other sensors. From the very beginning Arduino project is an open-source, which has lead to its extended use and popularity. It is used mainly in teaching of programming at high schools and universities. German robotic kit Fishertechnik, using plastic components, resembles Lego set and offers both robotic and non-robotic models in different versions with the usage of controllers. For programming of assembled models the set uses its own programme which enables programming with icons and it is suitable for elementary schools (Coufal, 2016). A very well-known children construction set Lego has already used several versions of controlling robotic unit which is joined to servmotors and sensors. Programming is also possible with iconographic programme. Similiar yet newer construction kit, using plastic structural components, is American set VEX IQ. It enables to plug much more I/O devices to the control unit and furthermore it can be manipulated by provided remote controller. Programming is again suitable even for elementary school pupils. For older, high-school and university students, is the set available in VEX EDR version, using more efficient control unit and metal construction parts. Traditional Czech construction set Merkur uses mostly metal parts and thanks to connection of electronic components and microcontrollers it is possible to build and programme robotic models on one own's choice.

2.2 Project-based learning

As a complex educational method for my research was chosen the project-based learning. The key component of project-based learning is a project. According to the founder of project method Killpatrick it can be stated that "*project is explicitly and clearly designed task that can be presented to a pupil as vitally important by approaching the real activity of the people´s lives*" (Coufalová, 2006). According to Maňák and Švec in project-based learning the person is solving a practical task, defined by its complexity and connection to the well-known reality of life. Project can be realized both in groups and individually. The essential part is always accurate lesson planning of project-based learning that guarantees avoidance of transforming learning into playing and disruption of educational aims (Tomková, Kašová, Dvořáková, 2009). As Tomková, Kašová and Dvořáková stated "*Project-based learning is a complex method enabling pupils touch the reality, experience new social roles, solve problems, interconnect and apply obtained findings from all fields of study during meaningful and useful work. It gives an opportunity for self-realization, motivates them to work individually, to search and discover, to cooperate and communicate. It shows how to think coherently and how to solve the given task systematically."* (Průcha, 2009).

Speaking from experience with project-based learning I can say at first it is more demanding considering the lesson planning, management and conducting the lesson itself. It also takes much more time, which is not such a big problem in after-school activities, but it can be an issue during the lessons at school. The learning method was also used during weekend camp meetings for the members of the robotic after-school clubs. The learning method is popular in the groups of pupils and students. According to the results, stated further in the article, it is a widespread and desired method when teaching programming with the help of robotic construction kits for both the pupils and older students.

2.3 Competencies of the pupils

Current society places heavy demands on the individual, as Zounek states, the school should represent a place for obtaining required competencies "*If the schools are supposed to become places where the pupils will gain the key competecies needed for their lives within the society, then the ICT devices have to necessarily become a common part of all crucial areas of school functioning as well as activities of all participants within the school education."* (Zounek, 2006, s.12)

The Czech National Curriculum Framework for elementary education introcudes particular key competencies. They are defined as follows: "*Key competencies represent a set of knowledge, skills, abilities, attitudes and values important for personal development and employment of each individual in the society. Their selection and conception are based on the values commonly accepted in the society and from generally shared ideas about which competencies of the individuals contribute to their education, satisfied and suscessful life and to strenghtening of the functions of civil society*." (RVP, 2007). It also shows the list of skills the pupil has at the end of elementary education. The pupil:

- "*perceives different problem situations both inside and outside the school, identifies and understands the problem, thinks about discrepancies and their causes, considers and plans the way of solving the problems and uses his or her own judgments and experience*
- *looks up the information sutitable for solving the problem, finds their same, similiar and different features, uses obtained knowledge and skills for discovering of different ways of solution, is not discouraged by possible failure and persistantly serches for the final solving of the problem*
- *looks for a solution on his or her own; chooses the suitable ways of solution; when solving a problem he or she uses logical, mathematical and empirical procedures*
- *practically verifies correctness of problem solutions, applies tried and tested procedures when dealing with similiar or new problem situations, observes own progress during managing the problems*
- *thinks critically, makes deliberate decisions, is able to defend them, understands the responsibilities for his or her own decisions and evaluates results of his or her actions*" (RVP, 2007)

The research deals with the problem solving competency of the pupils, which is defined by Knecht and Klieme as "target-oriented thinking and actions in such situations when the routine procedures are not available for their handling" (Knecht, 2014). In my research, I want to focus on the influence of the robotic kit on problem-solving competencies in primary school students.

2.4 Current situation of the given issues

The nature of cooperation in groups of elementary school pupils and high school students is examined by Yuen when solving robotic projects at a summer robotic camp. The research study shows how to, with the help of robotics, implement project group solving in education, and introduces the importance of

cooperation in the process of education. The findings of the study will contribute to the usage of robotic projects in education and to the increase in children motivation in STEM area (Yuen, & Timothy, 2014).

The paper of Virmes (2014) is dedicated to educational robotics, its description, division, definition and mostly to the influence on the process of education within the interaction with children. Mutual interaction is divided into four areas. The research was conducted in the year 2006-2011 at different educational facilities. The paper describes educational robots and robotic construction kits. Robotic sets are sorted according to the necessity of programming and controlling with the help of a computer. Goal of the research was to create a theory of children interaction with educational robotics. The research questions focus on observing of the children interaction with educational robotics, deal with the progress of the interaction, sorts of interaction, ways of work with educational robotics and impacts of the interaction. They use Lego Mindstorms NXT robotic set in the research, Topobo construction kit and RUBI social robot. The first research environment was the workshop with robotic set Lego Mindstorms NXT for a group of pupils aged 10-14, together with their teachers at a special school. All the children suffered from different kinds of learning disorders, attention deficit hyperactivity disorders (ADHD), autism spectrum disorders or speech disorders. The second environment was a workshop for kindergarten children aged 4-5, using Topobo construction kit. The third research environment used RUBI social robot in a pre-school educational centre for the children at the age from 15 to 23 months during everyday activities. Paper further presents the results of axial coding in four basic areas of the children interaction with educational robots as well as selective coding which showed different types of used educational robots. As the result it is possible to find the establishment and description of the theory of children interaction with educational robotics.

In another study Slangen asks what the pupils aged 10-12 can learn when using robots, working on the assumption that robotics is a parts of technological literacy. The study includes cognitive and conceptual analysis leading to creating the referential framework for establishing knowledge in robotics. From the point of view of difficulties four perspectives were distinguished: psychological, technological, functional and system controlling. The results are discussed concidering technological literacy of the pupils and learning possibilities in primary education (Slangen, 2011). As stated by Shih (2013) Lego NXT robotic construction kit has been used more and more often in different courses for creating of multimedia education materials. The topic of the research is the understanding of the factors influencing teachers' intentions to use Lego NXT robotic kit at an elementary school. Using TAM model (Technology Acceptance Model) the study gathered data from 17 elementary school teachers in Kaohsiung and Pingtung regions in Taiwan. SEM (Structural Equation Modelling) method helped testing of the hypotheses. Somyürek (2015) deals with the learning of construction skills of the pupils in his study. The published paper explaines the integration of robotics into education. Within the study 66 pupils aged 8-14 participated in experimental research. They used Lego Mindstorms robotic kits. The aim of the study was to analyse construction learning skills of the pupils. Based on the findings they can be divided into four parts: active learning, authentic learning, multiple perspectives and collaborative learning. The study was perceived in a positive way mainly because of following three reasons: exploring and finding of the solution, using of imagination, freedom in production. Also Kvenild (2017) focuses on the development of programming and digital skills in STEM area, for using of robotic construction sets and for expansion of curriculum when mentioning pre-school children to the elementary school ninth-graders.

3 RESEARCH AND RESEARCH AIMS

The aim of research paper is to find out the influence of the robotic construction kits used in project-based learning of programming on the development of pupils' competencies. From the long-term personal experience I suppose that working with robotic kits and systems influences the pupils and it causes changes in their competencies. I further focus on production of educational and methodical materials for different robotic kits and systems used in teaching of programming at elementary schools in the Czech Republic.

3.1 Aims of the reseach

- Analysis of the development of pupils' competencies mostly in areas of technical and algorithmic thinking in programming of robotic constructrion kits.
- Analysis of the influence of project-based learning of programming with the help of robotic sets on the development of competencies of the pupil.
- Establishment of the conditions of robotic kits and systems available at elementary schools and mapping of used teaching forms and methods.
- Writing of the list of existed researches in the area of using of robotic construction kits at elemenetary schools focusing on the key competencies of the pupils both in the Czech Republick and in the world.

3.2 Research questions

- What is the influence of education with robots or robotic construction kit on the development of key competencies of the pupils?
- How is the problem-solving competency influenced by education with robots of robotic construction kits?
- Is project-based learning suitable for all lessons in teaching of programming using robotic construction kits?

In the individual subparts of the research study we defined secondary research questions, focusing on the way and methods of teaching robotics, used robots or robotic sets and other key competencies of the pupils.

4 ORIGINAL RESEARCH

Original research dealt with findings and mapping of the situation considering used robotic construction kits and systems at elementary schools. It also focused on used forms and methods of education with the help of robotic sets. Original research included six secondary aims.

Regarding established aims the method of quantitative research was chosen to be the method in original research, including a questionnaire survey. Selected method is suitable for obtaining of the information from more significant amount of respondents.

4.1 Research sample and research method

When selecting the reserarch sample I proceeded with respect to the established aims, I chose elementary schools in the Czech Republic where the teachers used robotic construction kits in their lessons. This information was found on the websites of given schools, from the lists of robotic competitions members organized in the Czech Republic, e.g. First Lego League, Robosoutěž, Robotiáda etc. In total more than 150 schools were approached.

Answers from the respondents were aquired with the help of semi-structured questionnaire, available in two different versions – paper and electronic. Electronic version of my questionnaire was created in Google Forms application, where the application itself contributed to processing the results of questionnaire survey. The questionnaire was divided into four subparts according to research survey areas of interest. Semi-structured questionnaire enables obtaining the set of structured responses as well as answers to open-ended questions. The questionnaire, including the link to the form, was sent via email to all selected schools.

4.2 Results of the original research

The results of the original research were thoroughly statistically processed and evaluated in detail. Based on the given results, it is obvious, the most commonly used robotic construction kit at elementary schools is Lego Mindstorms, representing 74,2 %, followed by Fishertechnik set on the second place and then other robotic and construction kits Merkur, VEX IQ and Micro:bit.

From the obtained data is apparent most pupils work in groups containing 2-3 members, and such a size of working groups is preferred by the children themselves. In most cases (78,12 %) the lessons are led as all-group lesson, beginning with frontal method, adding project-based learning later during the lesson. Most of the respondents have already experienced at least some types of project-based learning. When dealing with their own projects, pupils prefer working in their own pace, having enough time to complete the task, even if they had to stay longer after the end of the lesson.

5 PILOT RESEARCH

Pilot research used obtained findings from original research and from data based on literary review. In practical part the survey worked with created methodical and teaching materials for using robotic kits.

5.1 Purpose of the study

Before the practical part of the dissertation an analysis of literary review data was realized. It focused both on Czech and foreign studies in the field in question. Already in this stage of the study was obvious the lack of large number of relevant published researches. Considering the development and increasing interest in using of robotic construction kits in elementary school education the pupils and their key competencies are being much more influenced. The research should clarify what influence have used robotic sets and project-learning method of teaching on the pupils and their key competencies. Thus its contribution can be seen in an appropriate determination and using of suitable robotic construction kits in education, preferably leading to contributive influence on pupils and their competencies.

5.2 Research sample and research methods

Research pilot testing sample was represented by a group of 18 pupils, attending the sixth grade of elementary school, in IKT subject (Czech abbreviation for Information and communication technologies). Regarding the school options and equipment the group is divided into two sub-groups which attend the lesson separately. The whole group was divided into halves, each of them including nine pupils. The first group was determined to be the control one, the second group was the experimental.

First group (FG) = Control group (CG)

Second group (SG) = Experimental group (EG)

The given class is taught IKT subject only once each week. The classroom is equipped with standard desktop computers. Pupils worked in groups, each of them including three children. The room offered enough space around every workplace, enabling driving the robotic models.

For the pilot testing was chosen combined research represented by pedagogical experiment with the help of non-standardized semi-structured questionnaire using self-evaluation questions. The scheme of pilot research can be seen in Figure 1, showing division of the pupils into two groups and the first testing with the help of a pretest. Another step was teaching of the individual pupils, when the control group was taught by a frontal method, experimental group by a project-based method. Considering the task, the pilot research is represented by explaining the theoretical basis of programming of the robot movement and by solving a complex task including a robot movement in the marked space. After the lesson there followed a posttest, in the same form as the pretest. The tests took into consideration obtaining new skills and knowledge in robot construction, robot programming, problem solving and mutual communication of the pupils in the team. It further included pupil's self-evaluation.

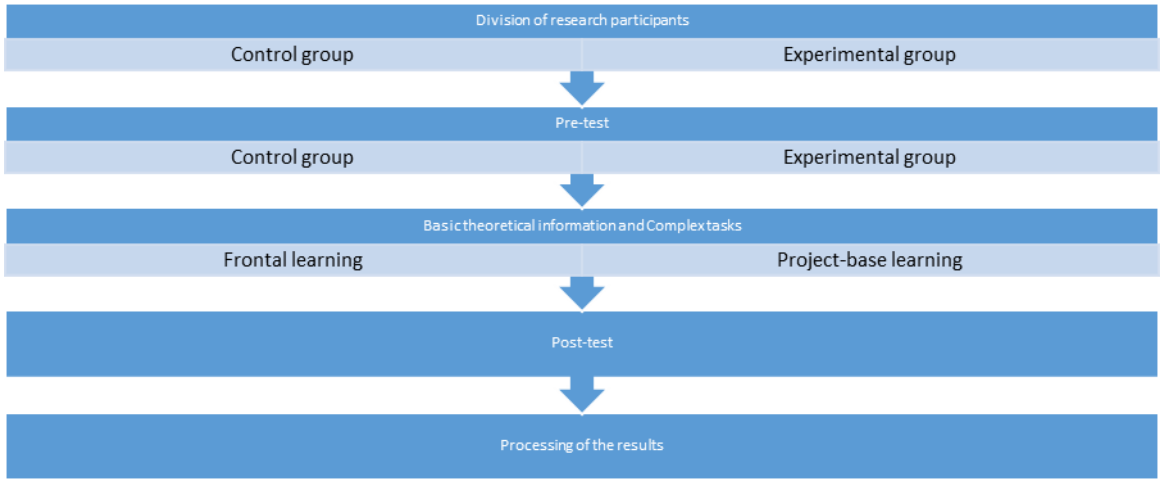


Figure 1 Pilot research scheme *(created by the author)*

Time schedule of the pilot research was split into lessons in 6 follow-up weeks, which was not a lot of time, considering one lesson a week. On the grounds of short time for pilot testing, lessons were focused on the basic controlling and programming of the robot movement, using the uncomplicated construction.

5.3 Results of the pilot testing

Pilot research was conducted on the basis of created teaching materials, under the tutelage of experienced teacher in two groups of pupils, attending the sixth grade of elementary school. In the lessons Lego Mindstorms robotic set was used.

For processing of the results was used Excel application, enabling the author to clearly arrange the findings using of visualization and schemes. The procedures of descriptive statistics were applied. Based on the findings it can be stated that the frontal method of teaching of the theoretical key knowledge about robot movement was more helpful for the pupils in comparison to project-based learning of theoretical basis. On the other hand solving of the complex task in which the robot was supposed to drive through the given space, the project-based method was assessed as much more convenient. Concerning the self-evaluation, pupils considered positively including of communicative competencies and using of problem-solving competencies. Pupils were choosing their agreement level with given statements on the Likert scale. From obtained answers it was possible to assess responses on main research questions. To confirm these results it will be convenient to use the results also from the main research, which will follow. At the moment, however, can be stated that the pupils' development of problem-solving key competence is being influenced by project-based education using the robotic construction kits.

Here occurs the question: What kinds of data influenced the results of the pilot testing? Above all it was the short period of time specified for pilot research, then created teaching materials, teacher's personality and his/her lesson planning, sufficient motivation of the pupils to the work at the end of school year, personal experience of the pupils with robotic construction kits and programming itself. Last, but not least the results were affected by the division of the pupils into separate working groups.

6 MAIN RESEARCH

Main research, reflecting the findings and correcting possible shortcomings in the pilot testing, was launched this spring on a larger scale and scheme. The main research takes significantly longer with more pupils and more teachers in order to reduce the influence of the teacher's personality to a minimum. Another expected change is to insert a test between the individual parts of the lesson (theoretical background information and solving a complex task) in order to determine the level at the beginning of the second part of the lesson.

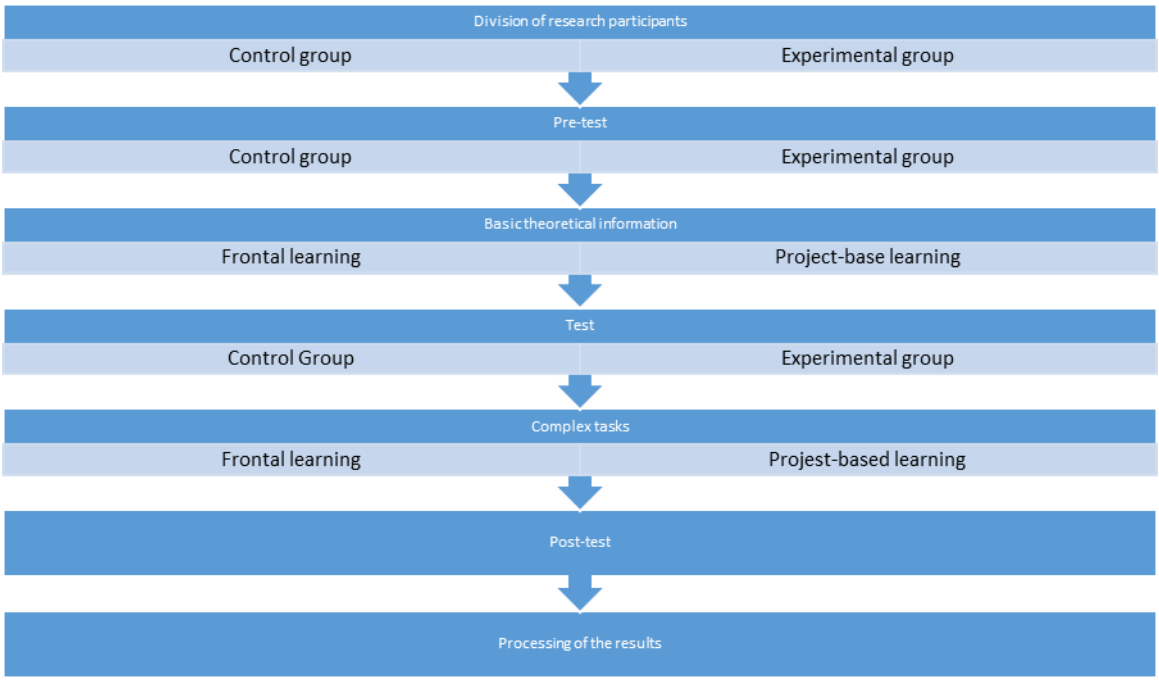
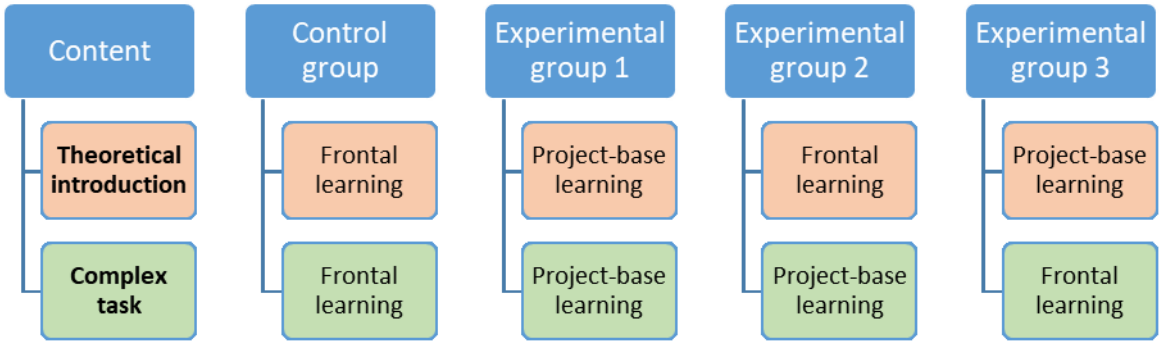


Figure 2 Main research scheme *(created by the author)*

6.1 Extention of main research

I would like to further extent the main research and continue in dealing with other influences on pupils and education when using the robotic sets. In the first stage I would like to increase the number of involved



groups to three experimental groups and one control group. According to the scheme in Figure 3 it is possible to see alternation of given teaching methods.

Figure 3 Scheme of group division *(created by the author)*

Another anticipated extension is connected with the comparison of common education at elementary schools to learning in after-class groups focusing on robotics. This could bring interesting results from the point of view of comparing the influence of pupil's interest in robotics on his or her performance and progress.

This could be followed by a comparison of construction robotic kits during lessons at schools and their influence on the pupils and their progress. Here occurs the possibility of dealing with similiar robotic kits, most importantly commonly used Lego Mindstorms, Fischertechnik construction kit and newer, VEX IQ robotic set. These robotic construction kits are considerably similiar to each other, and necessity of their comparison during the lessons could help the school facilities to decide if to buy them or not.

CONCLUSION

In the article I discussed and introduced theoretical knowledge as the topic of my research paper, specifically robotic construction kits used in elementary school education, project-based learning and key competencies of the pupils. The development of these competencies represents the basis for the practical part of the research paper. The article further shows findings and contribution of the original research, focusing on the situation in employment of robotic sets as well as the teaching forms and methods. All of it was followed by characterization of the pilot research and introducing of the primary results. I also presented a scheme and extension of main research, which is currently limited in schools. Extension of the number of experimental groups and their division and development of types of teaching. Change in the extension of the main research scheme. The results of the main research will provide clear answers to the research questions. The conclusions will be beneficial for the practical teaching of programming using robotic kits in elementary schools.

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