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DEVELOPMENT OF INNOVATIVE SKILLS OF PRIMARY CLASS STUDENTS THROUGH ROBOTICS

Abstract. The purpose of writing the article is to study and identify the impact of robotics education in elementary school on the development of innovative skills of students (skills of communication, interaction, and independent decision–making of students). Given the need for a modern workforce in the 21st century, the article found out how practical robotics activities contribute to creativity, critical thinking, problem-solving, and teamwork in primary school students. Research on the impact of robotics teaching on primary school students is analyzed and shown to contribute to the enrichment of the educational field and the integration of innovative pedagogical approaches to better prepare students for future tasks.

The main results of the study demonstrate a significant improvement in the innovation skills of junior primary school students due to robotics training. Hands-on robotics experiences were accompanied by increased creativity, critical thinking, problem-solving, and collaboration skills. Integrating robotics into the classroom successfully combined theoretical knowledge with practical application, reinforcing core STEM concepts. The impact of this approach extends beyond the educational context, allowing robotics education to be seen as a dynamic platform for developing interest and innovation. Developing children's problem-solving skills through concrete tasks and collaborative learning experiences helps prepare them for a technological future. By understanding the multifaceted benefits of robotics education for developing innovative skills, educators can play an important role in preparing students for success in the ever-changing world of the 21st century. This study makes a significant contribution to the debate on innovative pedagogical approaches by emphasizing the need for holistic education that goes beyond traditional educational structures.

Keywords: robotics, elementary school, curriculum, robotics in education, innovative technology, digital resource, innovative skill.

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Робототехника арқылы бастауыш сынып оқушыларының инновациялық дағдыларын дамыту

Аңдатпа. Мақаланы жазудағы мақсат – бастауыш мектепте робототехника бойынша білім берудің оқушылардың инновациялық дағдыларын дамытуға әсерін зерттеу (оқушылардың қарым-қатынас, өзара әрекеттесу, өзбетінше шешім қабылдау дағдылары) және анықтау. XXI ғасырдағы заманауи жұмыс күшінің қажеттілігін ескере отырып, мақалада робототехниканың практикалық әрекеттері бастауыш сынып оқушыларының шығармашылыққа, сыни ойлауға, проблемаларды шешуге және топтық жұмыс жасауға қалай ықпал ететіні анықталды. Робототехниканы оқытудың бастауыш сынып оқушыларына әсері туралы зерттеулерге талдау жасалып, білім беру саласын байытуға және оқушыларды болашақ міндеттерге жақсы дайындау үшін инновациялық, педагогикалық тәсілдерді біріктіруге ықпал ететіндігі көрсетілген.

Зерттеудің негізгі нәтижелері робототехниканы оқытудың арқасында кіші мектеп оқушыларының инновациялық дағдыларының айтарлықтай жақсарғанын көрсетеді. Қолданбалы робототехника тәжірибесі шығармашылық, сыни ойлау, проблемаларды шешу және ынтымақтастық дағдыларын арттырумен қатар жүрді. Робототехниканы сабаққа енгізу теориялық білімді практикалық қолданумен сәтті үйлестіре отырып, негізгі STEM тұжырымдамаларын нығайтты. Ұсынған тәсілдің әсері білім беру контексінен асып түседі, робототехника бойынша білім беруді қызығушылық пен инновацияны дамытудың динамикалық платформасы ретінде қарастыруға мүмкіндік береді. Нақты тапсырмалар мен бірлескен оқу тәжірибесі арқылы балалардың проблемаларды шешу дағдыларын дамыту оларды технологиялық болашаққа дайындауға көмектеседі. Инновациялық дағдыларды дамыту үшін робототехника бойынша білім берудің көп қырлы артықшылықтарын түсіну арқылы педагогтар XXI ғасырдың үнемі өзгеретін әлемінде оқушыларды жетістікке дайындауда маңызды рөл атқара алады. Мақалада зерттеу дәстүрлі білім беру құрылымдарының шеңберінен шығатын біртұтас білім беру қажеттілігін айта отырып, инновациялық педагогикалық тәсілдер туралы пікірталасқа елеулі үлес қосады.

Кілт сөздер: робототехника, бастауыш сынып, оқу бағдарламасы, инновациялық технология, цифрлық ресурс, инновациялық дағды.

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Развитие инновационных навыков учащихся начальных классов с помощью робототехники

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Аннотация. Целью статьи является изучение и выявление влияния обучения робототехнике в начальной школе на развитие инновационных навыков учащихся (навыков общения, взаимодействия и самостоятельного принятия решений учащимися). Учитывая потребность в современной рабочей силе в XXI веке, в статье выяснялось, как практические занятия робототехникой способствуют развитию креативности, критического мышления, умения решать проблемы и работать в команде у учащихся начальной школы. Проанализированы исследования о влиянии преподавания робототехники на учащихся начальной школы, которые, как показано, способствуют обогащению образовательного пространства и интеграции инновационных педагогических подходов для лучшей подготовки учащихся к будущим задачам.

Основные результаты исследования демонстрируют значительное улучшение инновационных навыков младших школьников благодаря обучению робототехнике. Практическое занятие робототехникой сопровождалось ростом творчества, критического мышления, умения решать проблемы и сотрудничать. Интеграция робототехники в учебный процесс успешно объединяла теоретические знания с практическим применением, укрепляя основные концепции STEM. Влияние данного подхода простирается за пределы учебного контекста, позволяя рассматривать робототехническое образование как динамичную платформу для развития интересов и инноваций. Развитие у детей навыков решения проблем через конкретные задания и коллаборативное обучение помогает подготовить их к технологическому будущему. Понимая многогранные преимущества обучения робототехнике для развития инновационных навыков, педагоги могут сыграть важную роль в подготовке учащихся к успеху в постоянно меняющемся мире XXI века. Данное исследование вносит значимый вклад в обсуждение инновационных педагогических подходов, акцентируя внимание на необходимости целостного образования, выходящего за рамки традиционных учебных структур.

Ключевые слова: робототехника, начальный класс, учебная программа, инновационные технологии, цифровой ресурс, инновационные навыки.

Introduction

The primary education system is facing a bigger problem as it is guiding the challenges of preparing students for an increasingly dynamic and technologically oriented future. While traditional educational models are effective in conveying fundamental knowledge, They do not teach students the innovative skills necessary to succeed in the 21st century. We are witnessing the rapid development o technology, global interconnection, and the emergence of new challenges, the need to encourage innovation in primary education has never been relevant.

With its emphasis on rote memorization and standardized assessments, the traditional approach to education typically prioritizes the acquisition of existing knowledge over the development of creative thinking, problem-solving, and adaptability. This poses a major challenge, as the ability to innovate is becoming not only vital but also necessary to navigate the complexities of today's world.

The demand for innovative skills is not limited to certain industries or professions; it permeates all aspects of society [1]. From solving environmental problems to finding new solutions to global health crises, innovative thinking plays a central role in overcoming the challenges we face. The formulation of the problem consists of a mismatch between the traditional educational paradigm and the changing demands of the world, which require people to be not only consumers of knowledge but also generators of innovative ideas.

The problem is two-fold: the current education system does not pay enough attention to the development of innovative skills, and the social landscape requires people who can navigate a

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rapidly changing world and contribute to its development. Recognizing and addressing this disparity is critical to ensuring that primary education becomes an active force in shaping students into innovative thinkers who can meet the demands of an uncertain and dynamic future. The need to close this gap forms the basis for learning innovative pedagogy methods, such as robotics training, as a transformative solution for developing the innovative skills of primary school students.

In today's technology-saturated society and ever-changing workforce demands, education plays an important role in preparing young people for successful careers and adapting to a rapidly changing reality. With this in mind, innovative teaching methods such as robotics in elementary grades are becoming increasingly relevant. A key aspect contributing to the growing need for flexible and technically trained professionals is the development of skills such as creativity, critical thinking, problem-solving, and collaboration from childhood.

The main purpose of this study is to explore the role of robotics education in elementary school, which acts as a catalyst for the development of new student abilities. Our goal is to understand how robotics classes contribute not only to improving the level of technical literacy but also to the development of critical thinking, creativity, and teamwork skills in elementary school students.

Based on the results of the analysis of the effectiveness of educational programs in robotics in primary schools, it can be concluded how successfully they can be integrated into the educational process and how they affect the overall development of students. The results of the conducted research can be used to develop recommendations for optimizing the process of teaching robotics in elementary schools, as well as to improve the quality of general education. The research focuses on the study of robotic knowledge as a fundamental element of the formation of innovative competence among younger schoolchildren. The robotics field is a special comprehensive method that combines aspects of scientific research, technical development, engineering and mathematical calculations (STEM), and also includes practical exercises. Such an association allows students to overcome the boundaries of purely theoretical awareness and actively engage in the use of knowledge, which contributes to a more complete and meaningful assimilation of STEM ideas [2].

Robotics training serves as an innovative pedagogical tool that provides students with a truly interactive platform for research and experimentation. The research aims to investigate how the process of designing, building, and programming robots can stimulate creativity, stimulate critical thinking, and develop problem-solving skills. In addition, many robotics projects are collaborative, meeting the specific requirements of effective teamwork and communication, which promotes the holistic development of innovative skills.

Understanding the impact of robotics education on elementary school students is critical for educators and policymakers seeking science-based strategies to improve educational quality. By focusing on robotics education, this study aims to illuminate a promising path for educating tomorrow's innovative thinkers and thereby contribute to the ongoing conversation about the evolving nature of elementary education in the 21st century.

Research methods and materials

To achieve the study's goal, a mixed method was chosen, including quantitative and qualitative methods. The quantitative part of the study was based on the analysis of data obtained through testing and questionnaires to assess the development of innovative skills of primary school students after introducing robotics into the educational process. The data obtained through selected research methods were analyzed using thematic analysis to identify recurring themes and patterns. This approach makes it possible to combine them with quantitative results to form a holistic view of robotics' impact on students' innovative skills.

Robotics at school is a technology of the 21st century that allows students to develop communication skills, interaction skills, independent decision-making skills, and discover their

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creative potential [3]. In general, there is an experience of introducing the subject of information and communication technology into the curriculum of schools in primary school. For example, England was one of the first countries to introduce ICT during the transition to 12-year education. And since 2012, computer science has been established as a single state standard of education in China. In 2015, the national curriculum was introduced into Australia's primary and secondary education system [4]. In South Korea, the school system consists of 6 years of elementary school. Computer education began in 1971 and computer content became mandatory in 2000 to provide computers to all classrooms [5]. Singapore introduced the mandatory Code for Fun program in 2014 to introduce and inspire computational thinking in school children. Elementary school students can use visual programming languages like Scratch and microcontrollers like the Lego WeDo kit to assess programming, solve problems, and improve logic.

Research has shown that teaching robotics in elementary schools can significantly improve students' cognitive skills and thinking ability [6]. In particular, this discussion focuses on mental tools as a means of using ICT to develop cognitive skills. The stimulating effect of mental tools on students' thinking abilities and mental attitudes is considered. Different types of mental tools and several specific examples are carefully considered. The authors consider how smart tools can contribute to creating ICT-rich learning environments in technology education in primary schools. And project-based learning in robotics has been found to improve students' skills and abilities, as well as their scientific achievement and peer relationships [7], This study examines robotics education to support elementary school science and technology courses at a private Evrim College in Istanbul. This study is a case study of a group of students studying robotics. Robotics education not only provides students with information about robotics but also helps them improve their skills and abilities. The first starting point is to become familiar with electronic circuit design equipment and learn the basic principles of robot design. Integrating robotics and programming in the classroom improves students' computational thinking skills by focusing on developmentally appropriate activities [8]. Chalmers S. studied how Australian primary school teachers integrated robotics and coding in their classrooms and how this affected students' computational thinking skills. These studies formed the basis of our work. In addition, the introduction of robotics into the curriculum in elementary schools has been found to improve learning abilities, cooperation, and teamwork [9].

The study's research design uses a mixed methods approach that combines quantitative and qualitative methods to provide a comprehensive understanding of the impact of robotics learning on elementary school students' innovative skills [10]. This Mixed design allows for data triangulation, increasing the reliability and validity of the study.

Quantitative and qualitative research is the basis for teaching primary school students to develop their innovative skills through robotics. This is because stratified random sampling is used to ensure a diverse demographic when teaching elementary school students. Elementary schools, socio-economic conditions, and educational systems will be introduced in each region.

Participants: The main participants will be primary school students aged 6-9. Parental consent is obtained for each participating student. The independent variable is participation in robotics training, while the dependent variables include creativity, critical thinking, problem-solving skills, collaboration skills, and academic performance. Standardized tests, questionnaires, and academic performance assessments are used to measure variables quantitatively.

Qualitative research: Purposive sampling is used to select a small group of participants for an in-depth qualitative study. These can be students, teachers, and parents. Data Collection Methods: Semi-structured interviews, focus group discussions, and open-ended survey questions will be used to collect qualitative data on participants' perceptions, experiences, and qualitative aspects of creativity, critical thinking, problem-solving, and collaboration. Data Analysis: Thematic analysis is

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used to identify recurring themes and patterns in qualitative data. It allows for a deeper understanding of the educational impact on robotics.

Experimental and control groups: Participating schools will be randomly assigned to either an experimental group implementing robotics training or a control group following traditional curricula, where possible.

Comparative analysis: the proposed design allows for direct comparisons between students engaged in robotics and those who do not, allowing for a more accurate assessment of the impact of the intervention. Informed consent was obtained from all participants and their parents or guardians before participation. To ensure privacy, members' identities will be anonymized and all data will be stored securely.

Debriefing: Participants will be interviewed after the study to address any concerns and ensure a positive experience.

Using this mixed-methods research design, the study aimed to gain a simple and holistic understanding of the relationship between robotics education and the development of innovative skills in elementary school students. Combining quantitative and qualitative data increases the rigor of the research and contributes to the comprehensive exploration of the research questions.

Thus, we present the following criteria and indicators for the development of innovative skills of Primary School students through robotics (Table 1).

Table 1 – Components, measures and indicators of development of innovative skills for elementary school students through robotics

Component	Dimensions	Indicators
1	**2**	**3**
Generating ideas	Divergent thinking tests: evaluate students' ability to think creatively and create different solutions to a given problem.	The number and variety of ideas generated in robotics classes.
	Creative project results: assessment of uniqueness and originality of students' robotics projects.	Demonstrated originality and creativity in the development and implementation of robotics projects.
Analytical thinking	Assessing critical thinking: assessing students' ability to analyze information, make logical connections, and draw conclusions.	The depth of analysis shown in responses to critical thinking assessments.
	Problem-Solving Objectives: to evaluate and solve the problems presented by students in the context of robotics projects.	Promptness and efficiency in solving problems that arise in the performance of robotics tasks.
Solving problems	Real-Time Problem-Solving Assessment: Assessing how well students perform tasks specific to robotics projects.	Effectiveness in identifying and formulating problems in the context of robotics tasks.
	Observational data: recording the strategies students use to overcome obstacles during robotics lessons.	Creativity and adaptability in implementing solutions.
Teamwork	Observational data: Assessing collaborative student behavior during group robotics projects.	Communication and cooperation demonstrated during group robotics tasks.
	Self-Assessment and Peer Assessment: Getting feedback from students on their own contributions and the joint contributions of their peers.	Ability to resolve conflicts and contribute positively to group dynamics.

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Continuation of Table 1

1	2	3
Desire to learn	Assessment of students' self-reported interest and motivation in learning robotics.	Be enthusiastic and interested in robotics tasks.
	Observational data: monitoring of enthusiasm and activity of students during robotics classes.	Willingness to explore and experiment with new ideas in the context of robotics.

Therefore, these components, dimensions, and indicators form a comprehensive basis for evaluating the development of innovative skills of elementary school students within the framework of robotics education. By examining these components, researchers and educators can gain valuable information about the multifaceted impact of robotics on students' cognitive, creative, and collaborative abilities.

Our primary research methodology involves the use of descriptive methodology, which includes administering student surveys, interpreting survey data, and summarizing findings from the practical implementation of innovative teaching methods. While participating in the educational process at A. Navoi General Secondary School №11 under the Shymkent City Education Department, we analyzed the activities of teachers through documents, surveys, interviews, questionnaires, and tests. It was confirmed that the innovative technologies we presented above have shown effective results in the school's pedagogical process. These technologies not only covered the main elements of the researched problem but also provided an opportunity to teach primary school students and develop their innovative skills through robotics.

Results and discussion

Next, to prove the correctness of the hypothesis about teaching primary school students to develop their innovative skills through robotics, practical-experimental work was conducted with 48 students of A. Navoi General Secondary School №11 under the Shymkent City Education Department.

During the definition phase of the practical-experimental work, a survey, test, and cross-sectional tasks aimed at understanding innovation, and professional activity were offered. Analyzing the results of students' cross-sectional tasks, we present the results of the identification phase of the experiment in the form of a diagram (Figure 1).

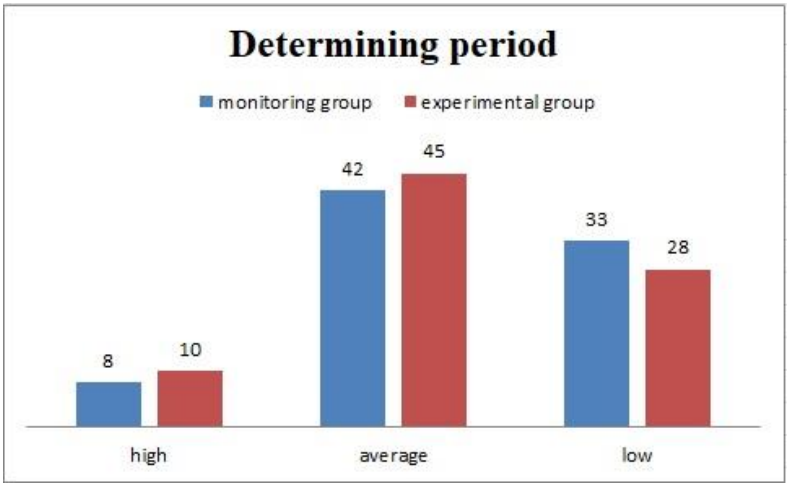

Figure 1 – The level of development of innovative skills for elementary school students through robotics

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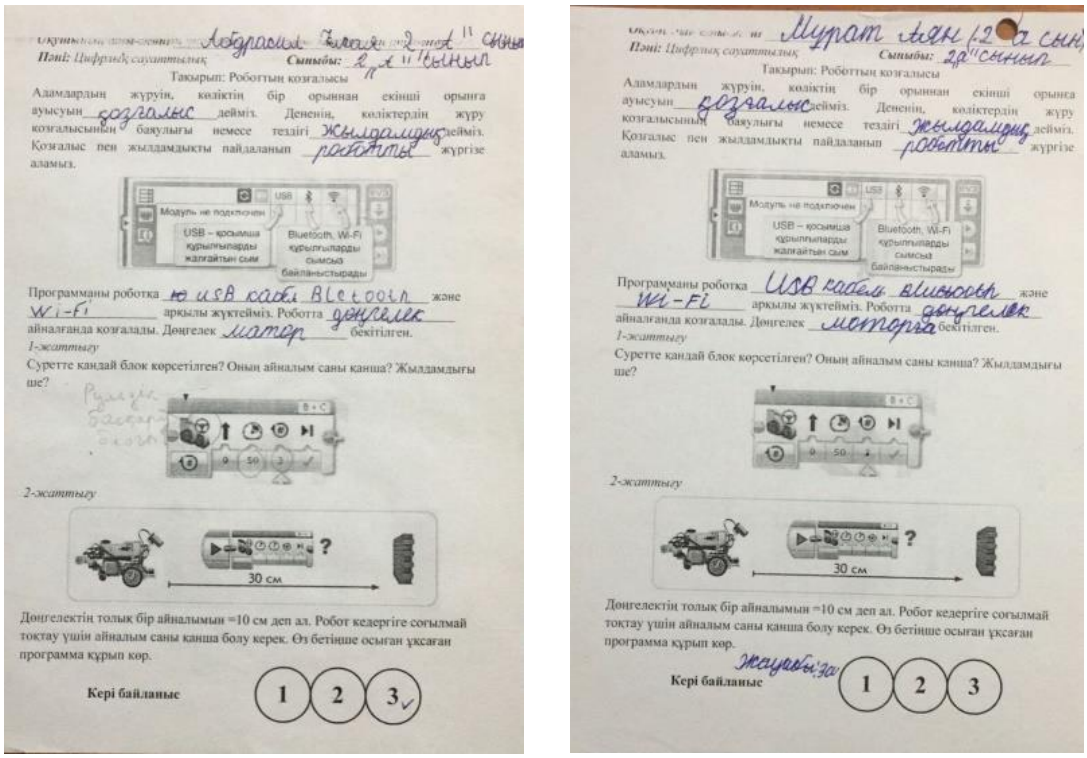
The result of comparative indicators: after the experiment, the knowledge and skills of Primary School students in robotics in the control class were 8%, 42% of middle-level students, and 33% of lower-level students. According to the experimental class - 10% higher, 45% middle, and 28% lower. It should be noted that about 33% of students in both groups could not complete the tasks, a significant part of them were lower-class students. To solve this problem, innovative teaching technologies were tested at the experimental stage to develop innovative professional activities.

Table 2 – Descriptive statistics for the control period

Methodology	control class			experimental class		
	high	average	low	high	average	low
1	2	3	4	5	6	7
«Robot movement»	8%	42%	33%	10%	45%	28%

Throughout the practical and experimental sessions, six lessons were conducted, integrating innovative educational technologies into the learning process. These technologies were utilized during discussions of new material and homework assignments. Let's explore the educational materials involving innovative technologies used in the learning process (see picture 2).



Picture 2 – Tasks done by students on the topic of robot movement

However, let's talk about the tasks performed using digital resources. Students here deepen their knowledge acquired during the lesson by performing active exercises (Figure 3).

This program is successful in providing students with knowledge on the topic by showing them clear steps and evaluating their work at the end of the lesson. The advantages of tasks developed using electronic means: it is confirmed that they are an effective means for interacting with multimedia technologies and studying generalized procedures.

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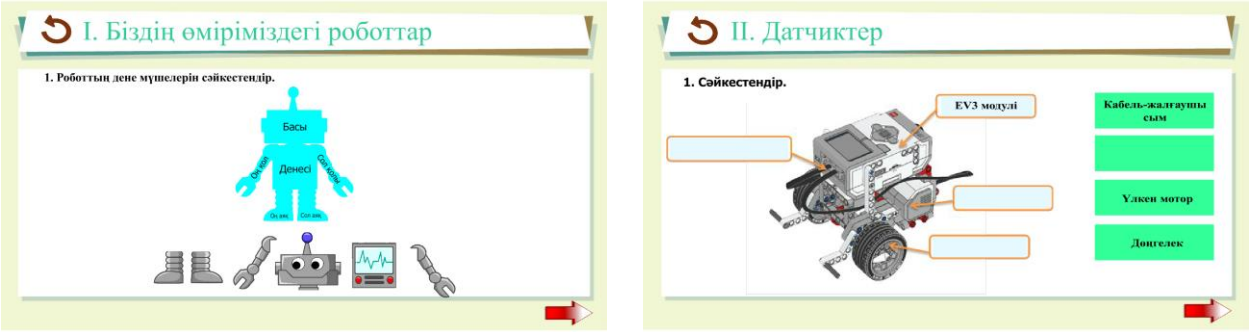
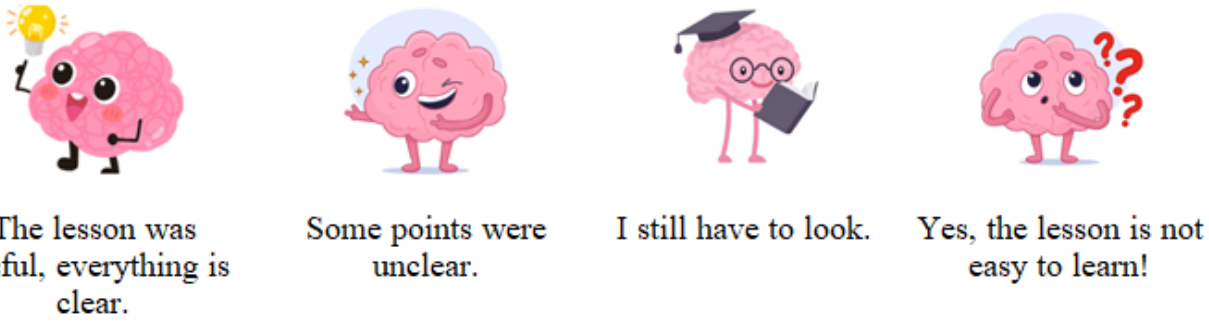


Figure 3 – Tasks performed using digital resources

In addition to the reflection of students at the end of the lesson, an open questionnaire was administered at the end of the chapter and at the end of the quarter. We have listed the survey questions below: 1. Have you ever taken a robotics class at school?

2. Do you have fun and enjoy working with robots?
3. Did the robotics lesson give you new ideas?
4. How do you feel when working with robots?
5. Do you like working with robots?
6. Will learning robotics further develop your imagination?

During the study, students completed the questionnaire in written form. The results show that enthusiasm in the lesson grew with each lesson.



There were also students who responded that they were sorry that they did not understand, but they were in the minority.

Table 3 – Questions asked in the interview

Interview for teachers:	Interview for students:
1. Do you think that introducing robotics into the classroom affected the students' attendance?	1. Do you like robotics classes?
2. Do you think that after the robotics lesson, what changes were there in the students' level of creative and critical thinking?	2. Has your approach to learning changed after the robotics course?
3. Do you think that the relationships between students changed when doing group assignments on robotics?	3. What new skills do you think you acquired in robotics classes?
4. Do primary school students benefit from robotics lessons to develop their problem-solving skills? If so, can you give examples?	4. In the robotics course, was it difficult for you to work in a group? Did you solve the problem together with your classmates?
5. Were there any difficulties in introducing robotics into the educational process?	5. What can you say, will robotics help you better understand math or science?

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Let's give an example of the process: interview. After completing the robotics course at the end of the school year, an interview was conducted (Table 3). Teachers and students were selected from the experimental group. The interview for each was organized in a quiet and separate room in order to provide a comfortable atmosphere for communication. 30 minutes were allocated for interviews with teachers, and about 20 minutes were allocated for interviews with students. The chosen semi-structured format for conducting interviews allowed asking additional questions for a deeper understanding of the respondents' answers. All interviews were recorded with the participants' consent and later transcribed for thematic analysis. The purpose of the interview was not only to identify the actual effects of the introduction of robotics but also to understand the subjective perceptions of this process by teachers and students (Tables 4, 5).

Table 4 – The result of the interview with the teacher

Question	Answers	Frequency of mention	Percentage of participants (%)
Impact on attendance	Improved attendance	4	80%
Changes in creative activity	Creativity was developed	3	60%
Changes in group relationships	Improved interaction	5	100%
Development of problem-solving skills	Improved performance	3	60%
Difficulties in introducing a new methodology	Required additional training	2	40%

Table 5 – Results of student interviews

Question	Answers	Frequency of mention	Percentage of participants (%)
What do you like about robotics	**There were interesting projects.**	40	83%
Has your attitude towards learning changed?	I became more motivated	30	63%
Have new skills appeared?	I improved my programming and teamwork skills	35	73%
Are there any difficulties in teamwork?	There were relationship difficulties	10	21%
Does robotics help in other disciplines?	Yes, it helps with math	28	58%

Based on the diagnosis, analysis, and generalization of the results obtained at the control stage of the experiment, we have identified the positive impact of innovative technologies on the development of innovative skills in younger schoolchildren through robotics. The results of the study showed the effectiveness of the introduction of robotics into the educational process for the development of innovative skills in primary school students. Quantitative analysis based on the proposed tests and questionnaires showed improvements in critical thinking, analysis, problem-solving, and group work, as learning robotics has a positive impact on the development of these skills. Qualitative data obtained through open questionnaires made it possible to study changes in students. Teachers and students noted an increased interest in learning, higher motivation, and active participation in joint projects. The thematic analysis also coincided with the results of the quantitative analysis, identifying key areas such as the development of creative thinking and the improvement of collaborative skills. These data lead to the conclusion that robotics training contributes to the development of innovative competencies necessary for successful adaptation to modern requirements.

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The interview was conducted in a semi-structured format, which allowed for additional questions to be asked if needed to gain a deeper understanding of the respondents' answers. All interviews were recorded with the participants' consent and later transcribed for thematic analysis. The goal of the interview was not only to identify the specific impacts of the introduction of robotics but also to understand the subjective perceptions of this process by teachers and students.

After conducting an experiment in the field of robotics, primary school students increased their levels of innovative skills, this indicator was summarized as a result. Also, this judgment is confirmed by the effectiveness of the experiment. The forecasts of the research work were justified. For the development of robotics skills in primary school students, the introduction of innovative technologies gave the desire for innovation and the need for professional and personal growth.

Conclusion

In summary, it is effective to introduce robotics education in primary schools to develop students' innovative skills. Students develop their critical thinking, creativity, collaboration, and communication skills through hands-on experiences through programming and problem solving with robots.

Analyzing the various studies reviewed in this article, it is clear that robotics has a positive impact on primary school students' cognitive development and academic performance. In addition, this approach has proven effective in increasing interest in lifelong STEM subjects, increasing children's enthusiasm and engagement in learning robotics.

Also, significant resources are needed to successfully implement educational robotics in primary schools, such as qualified teachers, access to robotics kits, and a supportive learning environment. These resources will ensure that education is inclusive and accessible to all students.

We conclude that further research is needed to assess the long-term impact of educational robotics on students' academic paths. Because to maximize the potential of robotics in preparing future problem-solving innovators, innovative teaching methods and curricula need to be developed.

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