CONFERENCE PAPER
International Conference on Pedagogical Science and Digital Learning 2025

Accepted: October 15, 2025 | **Published:** October 26, 2025 | **Language:** English

Robotics as a Tool for Early Career Orientation of Schoolchildren in Engineering and Technology

Olena Tabinska

Deputy Director for Development, STEM-CLASS LLC, Kyiv, Ukraine

✉ **Corresponding author:**
olena.tabinska7@gmail.com

ABSTRACT: The study is devoted to the impact of using robotics elements on the formation of STEM skills in primary school schoolchildren. The work substantiates the importance of STEM education as a tool that develops critical thinking, teamwork skills, and practical skills.

Two groups of third-grade schoolchildren were involved in the study: a control group and an experimental group. Over a period of six weeks, members of the experimental group learned using various elements of robotics, which contributed to a significant increase in their results – by 34.75% according to the author's assessment scale and by more than 32% according to the author's questionnaire. The control group showed only minimal changes within 5%.

Schoolchildren who studied using elements of robotics showed increased interest in learning, especially in programming robot movements and constructing models. The results confirm that the introduction of robotics into the educational process contributes to the development of knowledge, skills, and abilities, as well as motivation, and leads to an increase in schoolchildren' self-confidence and desire to solve non-trivial problems.

KEYWORDS: robotics, tools, engineering, career guidance, technology, communication skills, education.

How to cite: Tabinska, O. (2025). Robotics as a Tool for Early Career Orientation of Schoolchildren in Engineering and Technology. *International Conference on Pedagogical Science and Digital Learning 2025*, (pp. 276-280). Futurity Research Publishing. https://doi.org/10.5281/zenodo.17791423

Introduction

At present, despite significant advances in science, engineering, and technology, there is a notable shortage of specialists in fields related to physics, mathematics, natural sciences, and computer science. Consequently, the preparation of highly qualified professionals capable of effectively utilizing modern technologies across various domains of human activity has become a pressing concern. These future professionals must also drive the continued development of technologies that contribute to societal welfare and human progress.

The current digital era necessitates that educators adopt new approaches to the educational process designed to engage schoolchildren not only in acquiring new knowledge and skills but also in their conscious practical application. It has been widely documented in Ukrainian media that, since the early 21st century, demand for humanities programs in universities has remained high, while technical specializations have been undersubscribed. This situation underscores the need to support and stimulate technical education; otherwise, within the next 10 to 20 years, Ukraine risks losing its engineering schools and becoming critically dependent on more technologically advanced nations that may impose unfavorable conditions.

Interactive teaching methods, which are increasingly being integrated into educational processes, are designed to ensure direct and active student participation in learning, thereby facilitating the acquisition of essential knowledge and skills (Tsekhmister et al., 2021). One such approach is STEM education, which integrates science, technology, engineering, and mathematics (Papadakis & Kalogiannakis, 2022). STEM education promotes not only systems thinking but also critical information processing, problem-solving skills, teamwork, and the ability to apply knowledge in diverse contexts. Moreover, STEM education serves as a foundational pathway to highly valued professions, including architect, geologist, data analyst, electrical engineer, mechanical engineer, chemical engineer, IT manager, software developer, data scientist, and physicist, among others.

During early childhood, cognitive activity is particularly pronounced, coinciding with heightened interest in natural and technical phenomena and sciences. Therefore, STEM education in general, and educational robotics in particular, are crucial for engaging schoolchildren in acquiring new knowledge and skills through the integration of playful and educational approaches, which also fosters critical thinking and the development of various models and experiments (Kakoulli & Evripidou, 2024).

Research Aim and Research Questions

Given the necessity for schoolchildren to acquire contemporary knowledge, the primary objective of this study was to establish the positive effect of using robotics as a significant tool for developing STEM skills in elementary school schoolchildren. To achieve this objective, the following research questions were addressed:

1. What level of STEM skills do schoolchildren possess prior to the implementation of a robotics

course in the educational process?

2. What level of STEM skills do schoolchildren possess following instruction incorporating robotics?
3. Is there a statistically significant difference between schoolchildren who completed a robotics course and those who received instruction without one?

Research Results

The study involved two groups of third-grade schoolchildren, with 26 schoolchildren in each group. One group served as the control group, while the other was the experimental group. Prior to the experiment, it was established that both groups possessed equivalent levels of STEM skills. This was determined using an author-developed assessment method with a 20-point scale designed for this study.

During the six-week experiment (educational program), the group that utilized robotics in the instructional process demonstrated an overall improvement of 4.1 points (from 11.8 to 15.9, representing a 34.75% increase from baseline). The control group exhibited only minimal improvement (from 11.5 to 12.1, or 5.22%). These data are presented in Table 1 for clarity.

Table 1

Indicators of Schoolchildren' STEM Skills Before and After the Experiment

Group	Period	Mean (M)	%	Standard Deviation (SD)	t	p
Control	Before	11.5	100	2.1	1.62	0.11
	After	12.1	105.22	2.0		
Experimental	Before	11.8	100	2.3	6.74	<0.001
	After	15.9	134.75	1.8		

Source: author's own development

In addition to these tests, schoolchildren in both groups were asked to complete an author-developed questionnaire employing a 50-point scale. This questionnaire was based on the participants' own observations and enabled assessment of schoolchildren' attitudes toward STEM programs. As in the previous assessment, the group that did not use robotics elements showed only minimal improvement. The experimental group again demonstrated substantial growth in mean scores following course completion, with schoolchildren exhibiting enthusiasm during the learning process. These results are presented in Table 2.

The obtained data indicate increased subjective engagement, motivation toward learning, and confidence in their knowledge among schoolchildren in the experimental group. The most substantial improvements were associated with items related to teamwork, willingness to experiment, and heightened interest in programming. Thus, with continued use of robotics in instruction, schoolchildren

will be motivated to progressively advance their knowledge level in order to achieve increasingly impressive results and construct more complex robotic systems. Consequently, there will emerge a need to master not only elementary programming of robot movements but also to learn to write programs for more complex tasks.

Table 2

Average Score on the Schoolchildren' Self-Observation Questionnaire Before and After the Experiment

Group	Period	M	%	SD	t	p
Control	Before	30.4	100	4.6	1.21	0.23
	After	31.2	102.63	4.2		
Experimental	Before	30.1	100	5.1	7.21	<0.001
	After	39.8	132.23	3.9		

Source: author's own development

The software being developed must function correctly, which requires learning to test it quickly for errors. Therefore, schoolchildren will concurrently acquire skills in software testing as a means of solving applied problems related to specific processes of robot interaction with the environment (Hunko, 2024). This is particularly confirmed by research demonstrating that robotics in education enables experimentation with physical phenomena and provides extensive opportunities for practical application of various technologies, implementation of engineering solutions, and resolution of a broad spectrum of applied problems (Terzieva et al., 2024). Consequently, it is logical to pursue activities focused on utilizing storage media in robotic systems and addressing data encryption issues, remote control via smartphones, transmission of sensor-acquired information to online platforms and cloud storage, data backup to servers for system recovery in case of failure, and related applications (Opirskyi et al., 2025). Furthermore, contemporary scientific literature demonstrates that robotics influences the development of critical and logical thinking, as robot programming requires algorithm construction, outcome prediction, error analysis and correction, and establishment of cause-and-effect relationships (Boltsi et al., 2024).

Conclusions

Thus, analysis of the data obtained regarding the impact of robotics integration on the educational process and development of STEM skills in elementary school schoolchildren revealed distinct elements of this innovative approach. It was established that robotics implementation in the experimental group's instruction resulted in elevated levels of STEM skills among participants. In contrast, the control group exhibited markedly minimal changes in such skills. This group demonstrated stability and weak variability in STEM competencies. Based on observations of student engagement, it was determined that the most compelling robotics elements for experimental group members were programming robot movements.

Overall, children in this group demonstrated enthusiasm. Another significant aspect was model construction, primarily involving moving mechanisms. Schoolchildren were captivated by the opportunity to combine creativity with technology. This pertains to the possibility of fabricating structures and forming models from components. Furthermore, it was established that control group schoolchildren noted only marginal improvement in their skills, whereas in the experimental group, the mean score increased from 30.1 to 39.8 following the instructional course, representing an improvement exceeding 32% compared to baseline indicators.

Consequently, substantial growth in subjective engagement, motivation, and confidence was observed among experimental group schoolchildren. Overall, the study demonstrated enhancement of schoolchildren' general knowledge level and practical skills, leading to increased confidence in their knowledge and willingness to solve non-standard problems.

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