EDUCATIONAL ROBOTS IN PRIMARY SCHOOL TEACHERS' AND STUDENTS' OPINION ABOUT STEM EDUCATION FOR YOUNG LEARNERS

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ABSTRACT

The article discusses issues related to STEM education; it is emphasized that the need to prepare students with twenty-first-century skills through STEM-related teaching is strong, especially at the elementary level. The authors stress that workshops, using kits to build and program robots, are a modern form of interdisciplinary education of children and youth. The rationale for conducting such activities in schools is found in the European reference framework in the context of training of key competences. Classes in robotics – properly taught – will have an impact on the development of mathematical literacy and scientific-technical information and social competences. At the same time, competence is understood to mean a combination of knowledge, skills and attitudes appropriate to the situation. Besides, an analysis is presented of basic legal regulations in this matter as well as some results of a survey, conducted in Poland and Ukraine among in-service teachers and prospective teachers.

KEYWORDS

Robotics in school, survey, competences, STEM education

1. INTRODUCTION

The need to prepare students with twenty-first-century skills through STEM-related teaching is strong, especially at the elementary level. However, most teacher education preparation programs do not focus on STEM education. The authors' (Schmidt, Fulton 2016) findings suggest that while inquiry-based STEM units can be implemented in existing programs, creating and testing these prototypes requires significant effort to meet PSTs' learning needs, and that iterating designs is essential to successful implementation.

Other authors (Kim et al. 2015) report a research project with a purpose of helping teachers learn how to design and implement science, technology, engineering, and mathematics (STEM) lessons using robotics. Specifically, pre-service teachers' STEM engagement, learning, and teaching via robotics were investigated in an elementary teacher preparation course. Data were collected from surveys, classroom observations, interviews, and lesson plans. Both quantitative and qualitative data analyses indicated that pre-service teachers engaged in robotics activities actively and mindfully. Their STEM engagement improved overall. Their emotional engagement (e.g. interest, enjoyment) in STEM significantly improved and in turn influenced their behavioural and cognitive engagement in STEM.

Identifying 21st Century STEM Competencies Using Workplace Data (Jang 2016). Gaps between science, technology, engineering, and mathematics (STEM) education and required workplace skills have been identified in industry, academia, and government. Educators acknowledge the need to reform STEM education to better prepare students for their future careers. Jang (2016) pursues this growing interest in the skills needed for STEM disciplines and asks whether frameworks for 21st century skills and engineering education cover all of important STEM competencies. Researchers identify important STEM competencies and evaluate the relevance of current frameworks applied in education using the standardized job-specific database operated and maintained by the US Department of Labor. An analysis of the importance of 109 skills, types of knowledge and work activities, revealed 18 skills, seven categories of knowledge, and 27 work activities important for STEM workers.

The authors Uttal David H. and Cheryl A. Cohen in own research (2012) stressed that there is little doubt that the United States faces a serious challenge to educate citizens who can perform jobs demanding skill in science, technology, engineering, and mathematics (STEM) domains. They explore the relation between spatial thinking and performance and attainment in science, technology, engineering and mathematics (STEM) domains. Spatial skills strongly predict who will go into STEM fields. But why is this true? Researchers Uttal and Cohen in own study (Uttal, Cohen 2012) argue that spatial skills serve as a gateway or barrier for entry into STEM fields.

The global urgency to improve STEM education may be driven by environmental and social impacts of the twenty-first century which in turn jeopardizes global security and economic stability (Kelley & Knowles 2016). The complexity of these global factors reach beyond just helping students achieve high scores in math and science assessments. Friedman (The world is flat: A brief history of the twenty-first century, 2005) helped illustrate the complexity of a global society, and educators must help students prepare for this global shift. In response to these challenges, the USA experienced massive STEM educational reforms in the last two decades. In practice, STEM educators lack cohesive understanding of STEM education. Therefore, they could benefit from a STEM education conceptual framework. Table 1 provides critical elements of distinction between these two views of technology (T) one of the important category of STEM.

Table 1. Two views of technology

Engineering perspective of technology	**Humanities perspective of technology**
Technology consists of:	Technology can be viewed as:
A distinct body of knowledge	More than a sum of tools, instruments, artefacts, processes, and systems
An activity or a way of doing	Influences the structure of the cultural/ social order regardless of its user intentions
Design, engineering, production, and research procedures	Serving human values and influence value formation
Physical tools, instruments, and artefacts	Autonomous social and economic forces that often override traditional and competing values
Organized integrated systems and organizations that are used to create, produce, and use technology	Capable of unanticipated positive as well as destructive social and economic consequences

Source: Todd R. Kelley, J. Geoff Knowles (2016) based upon Herschbach 2009

Mitcham (1994) combines these two views together when he identified four different ways of conceptualizing technology. He identifies technology as (a) objects, (b) knowledge, (c) activities, and (d) volition. Often, people associate technology as artefacts or objects; unfortunately, many only view technology in this way and overcoming this limited view of technology may be critical for teaching STEM in an integrated approach.

Additionally, the concept of learning as an activity not only leverages the context of the learning but also the social aspect of learning. Lave and Wenger (1991) describe this as legitimate peripheral participation when the learning takes place in a community of practitioners assisting the learner to move from a novice understanding of knowledge, skills, and practices toward mastery as they participate "in a social practice of a community" (p. 29) (Todd R. Kelley, J. Geoff Knowles 2016).

2. ROBOTICS AND CHILDREN. SELECTED LEGAL REGULATIONS

2.1 Proprietary Proposals

Workshops using kits to build and program robots are a modern form of interdisciplinary education of children and youth.

The rationale for conducting such activities in schools is found in the European reference framework in the context of training of key competences.

Classes in robotics – properly taught – will have an impact on the development of mathematical literacy and scientific-technical information and social competences (see Figure 1). Competence is understood as a combination of knowledge, skills and attitudes appropriate to the situation.

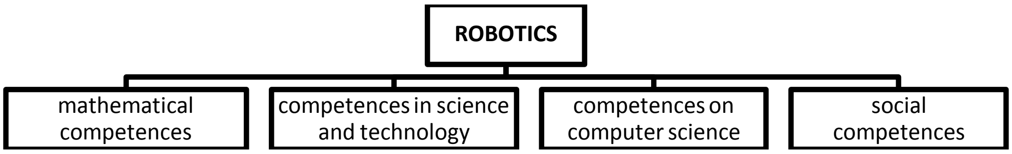


Figure 1. Robotics and training on key competences
Source: Own work

Such workshops can develop in students the skills described in the core curriculum for primary school.

Learners, taught in Polish primary schools based on the applicable core curriculum of 2014, as early as the first stage of education can be taught skills included in the curriculum during the course of robotics, when designing their own robotic machine or vehicle.

Learners at the first educational stage acquire in particular the skills presented in Table 2. For selected learning content examples are provided of activities of the learner when developing and programming the robot. A visual robot programming environment can be installed and run on a computer or tablet.

Table 2. Teaching content of early childhood education
and examples of activities associated with the construction and programming of robots

The area of early childhood education	**Didactic content - specific requirements**		**Examples of activities related to construction and programming (in the graphical environment) of robots**
Mathematical education	**The learner**		
	writes digits and reads numbers in the range of 1000; understands the decimal positioning system;		write the time in seconds of engine operation or the number of engine rotations;
	compares any two numbers in the range of 1000 (using the characters <, >, =);		writes command execution conditions: more than, less than;
	measures and writes down the result of the measurement of length, width and height of objects and distances; uses units: millimetre, centimetre, metre;		determines the distance to be covered by the mobile robot; determines (estimates) the distance between the robot and obstacle;
	specifies the location of objects relative to the chosen object, using the terms: up, down, forward, backward, right, left, and combinations thereof.		determines the position and direction of motion of a mobile robot.
Computer classes	**The learner**		
	uses a computer on a basic skills level;		launches (runs) the graphical environment of programming of robot; saves the created program
	uses the selected programs (...), developing her/his interest;		uses, during her/his work, graphical robot programming environment;
	searches for information and uses it: plays (runs) animations and multimedia presentations.		plays (runs) animations and instructional videos placed inside projects in a graphical environment for robot programming.
Design and technology classes	**The learner**		
	knows technical environment to such an extent that is familiar with the ways of production of everyday objects ("how was it made?");		constructs models of everyday objects (e.g. vehicles);
	carries out activities along the "route" from the formation of objects from an idea to a product	presents ideas of technical solutions: plans new activities, selects suitable materials;	constructs models of machinery and vehicles; plans stages of work;
		understands the need to organize technical action: individual and team work;	works in a team (2-4 students);
		has the skills: measuring a required amount of material, assembling of plastic models, using simple instructions and drawing diagrams;	builds on the basis of instructions (series of pictures, schematic drawings) a vehicle or machine, including collecting the necessary elements (components, motors, sensors);
	cares about her/his safety and that of others: maintains tidiness and order around her/him in the workplace; cleans up after herself/himself and helps others maintain tidiness.		tidies up his workplace, sorts parts needed to build a robot.

Source: Own work

What is equally important is the fact that robotics classes can be associated with the implementation of group educational projects (short or long term, inherently interdisciplinary), which are recommended as a form of work with students already at primary school level and required – at high school level.

The Council for the Informatization of Education at the Ministry of National Education (Poland), on 18 June 2015, presented the proposed changes to the current IT core curriculum. The Council's proposal has been made available on the Ministry website for consultation (until the end of October 2015).

The Council adopted the final form of the proposal at its meeting on 10 December 2015. Account was taken of all the opinions submitted during the consultation and reported on several meetings with teachers in Poland and meetings of experts, as well as abroad.

According to the Council for the Informatization of Education, one of the goals of universal information education is to improve the relevance and importance of computer science as an independent discipline as perceived by students and society (...). Early contact at school with computer science and programming should give students the idea of the richness of this field and its applications in other subjects and areas, and to stimulate interest and motivate the choice of future education and a future career in this direction.

Members of the Council are proposing to include, in specific requirements for computer classes for the first stage of general education (among other things), certain provisions in favour of robotics. For example, the proposal states that the student:

- creates a command (command sequence) for a specific plan of action and to achieve the objective; in particular, performs or programmes these commands in a computer application;
- programmes visually simple situations (...) according to his/her own ideas and the ideas developed together with other students, other (Council for the Informatization of Education 2015)

The proposals of the Council for Informatization of Education confirm the advisability of the use of robots (more broadly: creative toys) in the teaching process.

Legal documents on Robotic and STEM education at school include: Ukrainian decree No 188 of 29.02.2016 on the establishment of a working group for the implementation of STEM-education in Ukraine; Regulation of the Ministry of Education and Science of Ukraine of July 2, 2016 № 759 on carrying out experimental work at municipal educational institutions"; Educational Complex № 141 "Educational Resources and Technological Training" in Kyiv (pre-school - school degree - specialized School second degree with in-depth study of foreign languages and information technologies - technological Lyceum) "for 2016-2021 years, with approved experimental work on "Creation and testing of methodology system of teaching the basics of robotics as part of STEM-education."
c. The website of the Institute of Modernization of Educational Content, STEM-education Department, lists only the following documents:

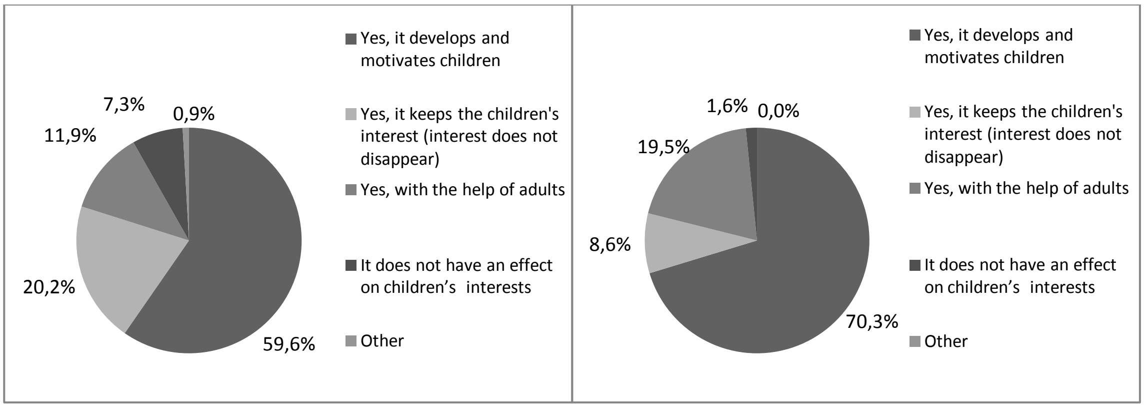
Laws of Ukraine
On education
On preschool education
On general secondary education
On school education
On higher education
On innovation
On scientific and technical activity
Age of children at primary school in Poland – 6-12 or 7-13 years old. In Ukraine: 6-10 or 7-11.

2.2 Methodology and Selected Results

The study was carried out with the participation of 91 primary school teachers and future teachers in the province of Silesia and the University of Silesia Poland and Ukraine and Borys Grinchenko Kiyv University. The survey contained 15 questions about the pedagogical research "Robotics and children." The study was carried out to determine the needs of modern education to introduce the basics of robotics in the educational process of primary school.

2.2.1 Question 1. Do you think that it is interesting for Children to create a Robot by Themselves?

The respondents were allowed to choose one answer out of the answers as shown in Figure 2 (for Poland and Ukraine, respectively); they were also able to provide their own – by selecting "Other".



(a) Poland (b) Ukraine

Figure 2. Respondents' answers to the question "Is it interesting for children to create a robot by themselves?" (a) Poland (b) Ukraine
Source: Own work

Almost 80% of the respondents in Poland and almost 79% of the respondents in Ukraine thought that development, motivation to work and continuing interest of children were possible benefits to be derived from building robots. The first two answers are in a different ratio in relation to each other: 3:1 (Poland), 8:1 (Ukraine).

2.2.2 Question 2. What part of the Foundations (bases) of Robotics should be offered in Primary School?

In this question respondents were allowed to choose one or more from the following options (Figure 3):
A. Design; B. Construction; C. Algorithmization; D. Programming.

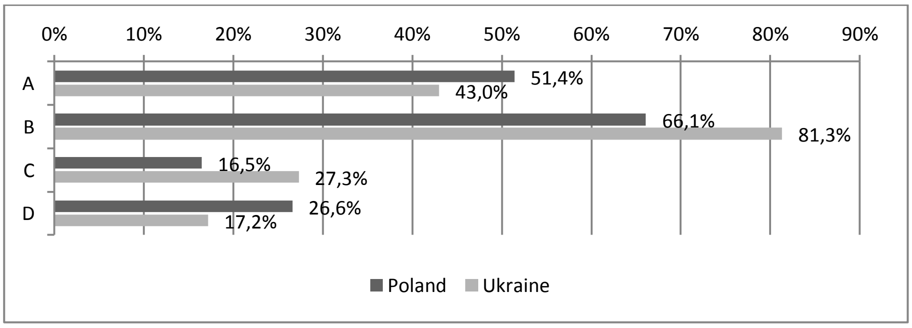


Figure 3. Respondents' answers to the question "What part of the foundations (bases) of robotics should be offered in primary school?"
Source: own work

Both in Poland (over 66%) and Ukraine (over 81%), respondents pointed to construction, as the activity associated with the creation of robots, which – according to them – is the best for elementary school pupils.

2.2.3 Question 3. What Competencies Useful in Life can be developed in Children while teaching the Basics of Robotics?

Respondents were allowed to choose multiple answers.
A. The skill of formulating one's own goals.
B. The skill of (the ability to) independent learning.
C. Solving specific problems.
D. Ability to work in groups, sharing experiences.
E. Ability to see the problem, find ways to solve it, generating ideas, planning and organizing activities
F. Forming a type of thinking is useful for solving practical problems unconventional (critical thinking)
G. Taking responsibility.
H. Use of ICT.
I. The ability to reflect (the process of self-examination of activities and their results)

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Almost half of the respondents in Poland indicated the skills (the ability to) independent learning (B) and on the ability to work in groups, sharing experiences (D) as a useful life competencies formed during the course of robotics.

Among Ukrainian respondents: almost 70% of respondents indicated the ability to work in groups, sharing experiences (D); almost 58% – on the formation of the type of thinking is useful for solving practical problems unconventional (F) and almost every other respondent – the ability to formulate their own goals (A). The results of this question are presented in Table 3.

Table 3. Respondents' answers to the question "What competencies useful in life can be developed in children while teaching the basics of robotics?"

	A	B	C	D	E	F	G	H	I
Poland	44,0%	47,7%	45,9%	48,6%	37,6%	31,2%	32,1%	17,4%	21,1%
Ukraine	49,2%	45,3%	32,8%	69,5%	46,9%	57,8%	33,6%	37,5%	32,0%

Source: Own work

2.2.4 Question 4. What Professional Competence can be developed in Children while learning the Basics of Robotics?

Respondents were allowed to choose more than one answer, and also to specify their own answer – by selecting "Other".

A. The personal ability to create models of objects (construction).
B. Understanding basic concepts of algorithms (creating algorithms for different performers).
C. Programming skills (the command to execute, written in a specific programming language).
D. Increase interest in science, the directions of technical (engineering) and informatics.
E. Ability (Skills) to work with computer.
F. Ability (Skills) to work with the use of ICT tools while performing complex tasks.
G. Ability (Skills) to logical thinking.

The results of this question are shown in Table 4.

Table 4. Respondents' answers to the question "What professional competence can be developed in children while learning the basics of robotics?"

	A	B	C	D	E	F	G
Poland	64,2%	40,4%	48,6%	45,0%	53,2%	21,1%	45,9%
Ukraine	80,5%	46,9%	46,9%	53,9%	48,4%	44,5%	75,0%

Source: Own work

Respondents in Poland preferred the option: the personal ability to create models of objects (A) as a substantive competence shaped by the science of robotics.

More than half of the respondents indicated the ability to work with a computer (E) as a substantive competence shaped by science, robotics, but only every fifth respondent combined robotics with the ability to work with the use of ICT tools (ICT) while performing complex tasks (F).

The respondents in Ukraine (as in Poland) most often preferred the option: the personal ability to create models of objects (A) as a substantive competence shaped by science, robotics (more than 80% of the responses, more than 16 percentage points more than in Poland).

2.2.5 Question 5. What Twenty-First Century Skills can be developed in Children while learning the Basics of Robotics?

Respondents were allowed to choose more than one answer; they were also allowed to specify their own answer – by selecting "Other".

A. Solving real problems.
B. Critical systems thinking – thinking we use when solving practical problems during the tests (creative thinking).
C. Communication skills.
D. Effective cooperation.
E. Teamwork skills.
F. Quick search and data processing.

G. Ability to take responsibility.
H. Being active.

The results of this question are presented in Table 5.

Table 5. Respondents' answers to the question "What twenty-first century skills can be developed in children while learning the basics of robotics?"

	A	B	C	D	E	F	G	H
Poland	35,8%	60,6%	42,2%	48,6%	48,6%	39,4%	31,2%	36,7%
Ukraine	32,8%	63,3%	51,6%	46,9%	53,9%	39,8%	44,5%	18,0%

Source: Own work

For the most part (more than 60% of the responses in Poland and Ukraine), the respondents pointed to thinking used when solving practical problems during the tests (B) as a twenty-first century skill that can be developed in children while learning the basics of robotics.

Almost half of the respondents in Poland chose effective collaboration (D) and teamwork (E).

More than half of the respondents in the Ukraine pointed to teamwork (E) and communication skills (C).

2.2.6 Question 6. Is it Necessary to teach children what they like?

In this question the respondents were able to choose one answer from the following (Figure 4):

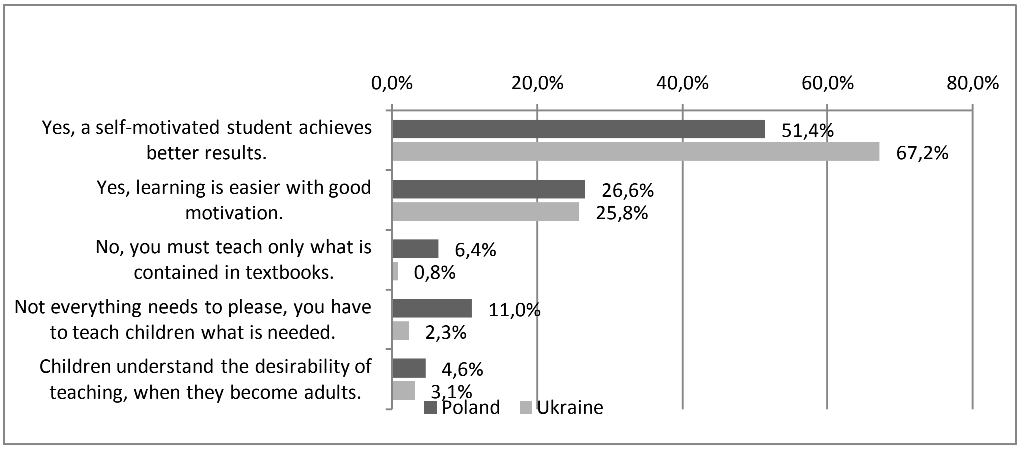

Figure 4. Respondents' answers to the question "Is it necessary to teach children what they like?"
Source: Own work

As can be seen, more than half of the respondents in Poland and more than 67% in Ukraine appreciate the role of motivation to learn.

After analysing the survey results we found that both active and future teachers in primary schools in Poland and Ukraine are aware of the need for implementing robotics in order to increase students' motivation. Competencies which are formed when implementing STEM education have been identified. In Ukraine there is an urgent need to train specialists who will be able to make learning with robots useful and effective, and make it a tool aimed at popularizing STEM education.

3. CONCLUSION

The article presents issues related to STEM education; it is emphasized that the need to prepare students with twenty-first-century skills through STEM-related teaching is strong, especially at the elementary level. The authors stress that workshops, using kits to build and program robots, are a modern form of interdisciplinary education of children and youth. The rationale for conducting such activities in schools is found in the European reference framework in the context of training of key competences. Classes in robotics – properly taught – will have an impact on the development of mathematical literacy and scientific-technical information and social competences. At the same time, competence is understood to mean a combination of knowledge, skills and attitudes appropriate to the situation. The results of survey conducted in Poland and Ukraine among in-service teachers and prospective teachers show that more than 50% respondents understand the important role of the STEM education and the necessity to introduce it the elementary level of education by workshops and other activities. These classes and other STEM education activities could provide successful development of twenty-first-century skills, in particularly key competences. Simultaneously, still open is the question concerning the comprehensive STEM education of prospective teachers pursuing pedagogical programmes, in particular in the specialization of early education

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