EDUCATIONAL ROBOTICS TECHNOLOGIES IN KAZAKHSTAN AND IN THE WORLD: COMPARATIVE ANALYSIS, CURRENT STATE AND PERSPECTIVES

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Abstract: *Educational robotics has been evolving for quite a long time to talk about accumulated practice in the field of teaching methodologies for robotics. Some distinct directions for organizing of robotics courses have taken shape in developed countries and they are closely bound up with robot development platforms. In Kazakhstan, educational robotics began to develop only in the last couple of years, and, in most cases, teaching methods developed based on the existing robotics teaching technologies in conjunction with robotic platforms. Teachers have faced problems of adapting courses and technologies to the existing Kazakhstani education system, which has a number of specifics. The aim of our work was to study the state of educational robotics in higher schools of Kazakhstan on the example of IT majors. The results showed the main difficulties faced by teachers in organizing study process, mainly associated with the complexity of use of constructive learning methods. In most cases, it was revealed that teachers use methods of cooperation in robotics teaching process. According to the respondents, the content of robotics courses presented in conjunction with robotic platforms is not enough to have students develop professional competence, as such areas as programming, physics of robotics, artificial intelligence are not fully covered. Teachers noted that materials quickly become out-of-date due to the rapidly developing robotic platform.*

Keywords: Educational robotics, constructionism, higher school, educational technologies.

Today educational robotics is being introduced in almost all educational systems as an important tool for technical and engineering education. By solving technical problems, students enhance knowledge in different areas. The effectiveness of educational robotics in enhancing interdisciplinary knowledge is confirmed.[1] At the same time educational robotics significantly increase students' motivation.[2] In higher schools

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[1] D. Alimisis, *Robotics in education&education in robotics: Shifting focus from technology to pedagogy, Proc. 3rd Int. Conf. on Robotics in Education (RiE)*, Prague, Czech Republic, 2012, pp. 7-14; C. Julia, J. O. Antoli, „Spatial ability learning through educational robotics", in *International Journal of Technology and Design Education*, no. 26 (2), 2016, pp. 1-19.

[2] K. Zawieska, B. Duffy, „The Social Construction of Creativity in Educational Robotics", in R. Szewczyk, C. Zielinski, M. Kaliczynska, „Progress in Automation, Robotics and Measuring Technique", in *Advances in Intelligent Systems and Computing*, 351, 2015, pp. 329-338; F. Wyffels, M. Hermans, B. Schrauwen, *Building robots as a tool to motivate students into an engineering education, Proc. 1st Int. Conf. on Robotics in Education (RiE)*,

educational robotics is introduced as part of a special professional program and as an interdisciplinary subject.[3]

Since we consider educational robotics as a discipline of educative process, there arises the concept of *„methodology for teaching robotics”*. The basics of teaching robotics is the theory of constructionism, which was written about in the works of Piaget, J. and Inhelder, B.,[4] Papert, S. and Harel, I.,[5] Alesandrini, K. and Larson, L.,[6] Cakir, M.,[7] Sabelli, N.,[8] Wilson, B.[9] The constructionist principle opens opportunities to a student to build his own tools for cognition of external reality. In this principle, knowledge is built and constantly reconstructed upon personal experience. D. Alimisis[10] explained in details why constructionism is the most organic basis for the methods of teaching robotics. Constructionism, as a methodological foundation of teaching methods for robotics, does not determine the specific learning technologies, and, therefore, educational institutions use different teaching techniques related to robot development platforms. Thus, we have approached the

Bratislava, Slovakia, 2010, pp. 113-116; R. Perula-Martinez, J. M. Garcia-Haro, C. Balaguer, A. Miguel, „Developing Educational Printable Robots to Motivate University Students Using Open Source Technologies”, in *Journal of Intelligent&Robotic Systems*, no. 81 (1), 2016, pp. 25-39; L. Alfieri, R. Higashi, R. Shoop, Ch. D. Schunn, „Case studies of a robot-based game to shape interests and hone proportional reasoning skills” in *International Journal of STEM Education*, 2, 2015, article no. 4; M. Petre, B. Price, „Using Robotics to Motivate ‘Back Door’ Learning”, in *Education and Information Technologies*, no. 9 (2), 2004, pp. 147-158.

3 A. M. Vollstedt, M. Robinson, E. Wang, „Using robotics to enhance science, technology, engineering, and mathematics curricula”, in *Proceedings of American Society for Engineering Education Pacific Southwest annual conference*, Honolulu, Hawaii, 2007; D. Alimisis, *Robotics in education&education in robotics,* pp. 7-14.

4 J. Piaget, B. Inhelder, *The Child’s Conception of Space*, New York, W. W. Norton&Co, 1967, pp. 375-418.

5 S. Papert, I. Harel, *Situating Constructionism*, New York, Ablex Publishing Corporation, 1991, pp. 193-206.

6 K. Alesandrini, L. Larson, „Teachers bridge to constructivism”, in *The Clearing House*, no. 75 (3), 2002, pp. 118-121.

7 M. Cakir, „Constructivist Approaches to Learning in Science and Their Implications for Science Pedagogy: A Literature Review”, in *International Journal of Environmental& Science Education*, no. 3 (4), 2008, pp. 193-206.

8 N. Sabelli, *Constructionism: A New Opportunity for Elementary Science Education*, Massachusetts, Massachusetts Institute of Technology, Media Laboratory, Epistemology and Learning Group, 2008.

9 B. G. Wilson, *Constructivist learning environments: Case studies in instrumental design*, New Jersey, Educational Technology Publications, 1996.

10 D. Alimisis, *Robotics in education&education in robotics,* pp.7-14.

necessity to explore methodology of teaching robotics in order to project this experience to teaching robotics in Kazakhstan.

As known, training techniques includes pedagogical approaches,[11] as well as so-called educational technologies,[12] which help to organize learning process focused on achieving goals. The primary research analysis in the field of educational robotics shows that most study works only describe learning outcomes without defining educational technology, used to teach robotics.[13]

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[11] W. F. De Boer, *Flexibility support for a changing university*, Doctoral dissertation, Faculty of Educational Science and Technology, University of Twente, Enschede, NL, Twente University Press, 2004; J. R. Bourne, E. McMaster, J. Rieger, J. O. Campbell, „Paradigms for on-line learning", in *Journal of Asynchronous Learning Networks*, no. 1 (2), 1997, pp. 38-56.

[12] G. K. Selevko, *Contemporary educational technologies. Teaching guide*, Moscow, Public Education, 1998; V. V. Guzeyev, *Educational technology: from acceptance to philosophy*, Moscow, Prosveshenie, 1996.

[13] A. Pina, „Improving learning and motivation of students (10-14 years old) by using educational robotics in different scholar scenarios", in *Informatization of education International Scientific and Practical online-conference*, 2015, pp. 14-18; R. Perula-Martinez, J. M. Garcia-Haro, C. Balaguer, A. Miguel, „Developing Educational Printable Robots to Motivate University Students Using Open Source Technologies", in *Journal of Intelligent & Robotic Systems*, no. 81 (1), 2016, pp. 25-39; C. Julia, J. O. Antoli, „Spatial ability learning through educational robotics", in *International Journal of Technology and Design Education*, no. 26 (2), 2016, pp. 1-19; D. Alimisis, *Robotics in education&education in robotics,* pp. 7-14; T. Kanda, T. Hirano, D. Eaton, H. Ishiguro, „Interactive robots as social partners and peer tutors for children: a field trial", in *Human-Computer Interaction*, no. 19 (1), 2004, pp. 61-84; S. Y. Okita, V. Ng-Thow-Hing, R. Sarvadevabhatla, *Learning together: ASIMO developing an interactive learning partnership with children. The 18th IEEE International Symposium on Robot and Human Interactive Communication, September 27-October 2*, Toyama, Japan, 2009, pp. 1125-1130; F. Tanaka, S. Matsuzoe, „Children teach a care-receiving robot to promote their learning: field experiments in a classroom for vocabulary learning", in *Journal of HRI*, no. 1 (1), 2012, pp. 78-95; J. Yoo, „Results and outlooks of robot education in Republic of Korea", in *Procedia-Social and Behavioral Sciences*, no. 176, 2015, pp. 251-254; L. Alfieri, R. Higashi, R. Shoop, Ch. D. Schunn, „Case studies of a robot-based game to shape interests and hone proportional reasoning skills", in *International Journal of STEM Education*, no. 2, 2015, article no. 4; B. S. Barker, G. Nugent, N. F. Grandgenett, „Examining fidelity of program implementation in a STEM-oriented out-of-school setting", in *International Journal of Technology and Design Education*, no. 24 (1), 2014, pp. 39-5; I. R. Nourbakhsh, K. Crowley, A. Bhave, E. Hamner, T. Hsiu, A. Perez-Bergquist, S. Richards, K. Wilkinson, „The Robotic Autonomy Mobile Robotics Course: Robot Design", in *Curriculum Design and Educational Assessment. Autonomous Robots*, no. 18 (1), 2005, pp. 103-127; M. Ucgul, K. Cagiltay, „Design and development issues for educational robotics training camps", in *International Journal of Technology and Design Education*, no. 24 (2), 2012, pp. 203-222; P. Samuels, L. Haapasalo, „Real and virtual robotics in mathematics education at the school–university transition", in *International Journal of Mathematical Education in Science and*

As educational technologies contain a systematic algorithm, there arises a need in determination of educational robotics technologies for projection of experience.

Today robotics is gradually becomes a part of curriculum in secondary school and in higher education system. It is not only due to popularity of STEM education in the world. Kazakhstan is an industrial region with large metal and oil production and processing factories operated by automated industrial robots. The country requires experts who can not only control robots, but also program them. Moreover, robotic applications are becoming more and more common in medicine and services. In this regard, cycles of special disciplines on robotics are organized in higher education system, forming ICT-professional competence in accordance with the level of robotic environment.

Introduction of robotics course into education system requires profound analysis. We have national peculiarities of education, which predetermine difficulties in teaching this discipline.

Purpose of the study is to determine how teachers understand and apply educational robotics technologies in Kazakhstan, as compared to global experience. This topic is important in order develop nation-specific educational technologies for teaching robotics, so that they affect the quality of education.

Despite the large number of research works in this field, issues that teachers of robotics face in higher schools are not addressed in Kazakhstan. Thus the research questions explored through this study were: *„What is the understanding of educational technologies for teaching robotics? How are they applied in Kazakhstan? What are the difficulties in applying them?”*.

International experience in teaching robotics

World experience of teaching robotics in high school and higher education institutions is more than 15 years. A lot of research works about methods of teaching have been done in this period. Most of works are about introduction of robotics courses based on robot development platforms. Most popular of them are the courses based on Lego

Technology, no. 43 (3), 2012, pp. 285-301; A. Giuseppe, P. Martina, „Educational Robotics between narration and simulation”, in *Procedia-Social and Behavioral Sciences*, no. 51, 2012, pp. 104-109; A. C. Sobolevsky, E. F. Sharipova, *Educational robotics: teaching materials*, Chelyabinsk, Chelyabinsk State University of Education, 2014; E. A. Krasnobayev, *Laboratory-based work on „Theoretical basics of robotics”: teaching recommendations*, Vitebsk, P. M. Masherova Vitebsk State University, 2013.

platforms.[14] Other authors focus on the development of robots using improvised material.[15] virtual environment of robot development,[16] integrated application.[17]

Education process is carried out by means of specific teaching approaches, which in pedagogy have been called educational technology. Some authors,[18] share common opinion that educational technology is a

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[14] K. Ceceri, *Robotics: Discover the science and technology of the future with 20 projects*, Vermont, Nomad Press, 2012; D. Kee, *Classroom Activities for the Busy Teacher: A 10 week plan for teaching robotics using the Lego Education EV3 Core Set*, USA, Create Space Independent Publishing Platform, 2013; S. A. Filipov, *Robotics for children and their parents*, Saint Petersburg, Science, 2013; D. Benedettelli, *The Lego Mindstorms EV3 laboratory. Build, program and experiment with wicked cool robots*, USA, No Starch Press, 2014; T. Griffin, *The art of Lego Mindstorms EV3 programming*, USA, No Starch Press, 2014; L. Valk, *The Lego Mindstorms EV3 discovery book*, USA, No Starch Press, 2014; Y. Isogawa, *The Lego Mindstorms EV3 Idea Book*, USA, No Starch Press, 2015; A. Pina, „Improving learning and motivation of students (10-14 years old) by using educational robotics in different scholar scenarios" in *Informatization of education International Scientific and Practical online-coference*, 2015, pp. 14-18; D. Alimisis, *Robotics in education & education in robotics,* pp. 7-14; B. S. Barker, G. Nugent, N. F. Grandgenett, „Examining fidelity of program implementation in a STEM-oriented out-of-school setting", in *International Journal of Technology and Design Education*, no. 24 (1), 2014, pp. 39-52; I. R. Nourbakhsh, K. Crowley, A. Bhave, E. Hamner, T. Hsiu, A. Perez-Bergquist, S. Richards, K. Wilkinson, „The Robotic Autonomy Mobile Robotics Course: Robot Design, Curriculum Design and Educational Assessment", in *Autonomous Robots*, no. 18 (1), 2005, pp. 103-127; P. Samuels, L. Haapasalo, „Real and virtual robotics in mathematics education at the school–university transition", in *International Journal of Mathematical Education in Science and Technology*, no. 43 (3), 2012, pp. 285-301; A. Giuseppe, P. Martina, „Educational Robotics between narration and simulation", in *Procedia-Social and Behavioral Sciences*, no. 51, 2012, pp. 104-109; A. C. Sobolevsky, E. F. Sharipova, *Educational robotics: teaching materials*, Chelyabinsk, Chelyabinsk State University of Education, 2014; R. Perula-Martinez, J. M. Garcia-Haro, C. Balaguer, A. Miguel, „Developing Educational Printable Robots to Motivate University Students Using Open Source Technologies", in *Journal of Intelligent & Robotic Systems*, no. 81 (1), 2016, pp. 25-39.

[15] K. Ceceri, *Robotics: Discover the science and technology of the future with 20 projects*, Vermont, Nomad Press, 2012; Idem, *Making Simple Robots*, Vermont:, Vermont: Nomad Press, 2015; R. Waldron, *Make: JavaScript Robotics*, San Francisco, Maker Media, 2015.

[16] A. Pina, „Improving learning and motivation of students (10-14 years old) by using educational robotics in different scholar scenarios", in *Informatization of education International Scientific and Practical online-conference*, 2015, pp.14-18.

[17] W. B. Matthew, *VBOT: Motivation computational and complex systems fluencies with constructionist virtual/physical robotics*, A dissertation Doctor of Philosophy, Evanston, Illinois, 2008.

[18] N. V. Smirnova, *Philosophy and education: problems of teacher's philosophy culture*, Moscow, Socium, 1997; B. M. Bim-Bad, *Encyclopedic pedagogical dictionary*, Moscow, Great Russian Encyclopedia, 2009; P. G. Perera, *How computer-related technology is incorporated into instructional methods and objectives in the secondary school classroom*, Dissertation submitted in

certain system of activities, a complex of algorithmic steps for organization of cognitive process, based on a certain idea and principles of organization and interconnection of educational purposes, content and methods. Guzeyev V. V.[19] gives a more precise definition of educational technology. He defines technology as a system, including images of input data and expected learning outcomes, diagnostic tools for defining learners' current state, a set of teaching models and criteria for selection of the optimal teaching model. Richey R. C.[20] and Januszewski A. and Michael M.[21] believe that educational technology includes the advanced training practice that allows increasing in productivity through the creation, use and management of technological processes and pedagogical resources.

Having analyzed earlier research works, let us summarize and present our understanding of educational technology: we understand that educational technology is the system consisting of a set of input data and expected learning outcomes, diagnostic tools for defining learners' current state, a set of teaching models and criteria for selection of optimal teaching model for specific conditions and educational technology management system. The analysis of the definitions allows us to say that educational technology enhances effectiveness of teaching methods.

What educational technologies are used to teach robotics?

In Table 1, we analyzed the experience of teaching robotics, specifying the level of education, educational purposes, approaches, principles and technologies. It should be noted that the studies do not clearly indicate the structure of educational technology. That is why we present methodological approaches of teaching robotics, which may be elements of educational technology.

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partial fulfillment of the requirements for the degree of doctor of philosophy in the graduate school of education of Fordham University, New York, 2008; R. H. Smith Jr., *Distributed learning in designing curriculum in a one-to-one computing environment*, A dissertation submitted in partial satisfaction of the requirements for the degree of Doctor of Education in Education Technology, Pepperdine University, USA, 2009; D. Middleton, *The Perceptions of High School Graduates of Career and Technology Education Courses*, Doctoral Study Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Education Teacher Leadership, Walden University, 2012.

[19] V. V. Guzeyev, *Educational technology: from acceptance to philosophy*, Moscow, Prosveshenie, 1996.

[20] R. C. Richey, „Reflections on the 2008 AECT Definitions of the Field", in *Tech Trends*, no. 52 (1), 2008, pp. 24-25.

[21] A. Januszewski, M. Michael, *Educational Technology: A Definition with Commentary*, London, Routledge, 2007.

Table 1: Use of educational robotics technologies

Author	Educational purpose	Educational level	Platform	Methodological approaches
A. Pina, 2015, Spain	Educational robotics	Primary school, secondary school	Virtual robots (Scratch, BYOB/SNAP) , First Lego League competition (FLL), LEGO Mindstorms NXT	Project method, problem learning, creative learning
R. Perula-Martinez et al., 2016, Spain	Educational robotics	Higher school	Arduino platform	Motivational, innovational, creative learning
C. Julia and J. O. Anatoli, 2015, Spain	Educational robotics	Secondary school	Universal 3, ROBO LT Beginner Lab, Oeco Tech, ROBO Pro Light software, Fischertechnik -designer software	Problem learning, motivational learning, practical learning, cognitive independence in problem solving, group learning
D. Alimisis, 2012, Greece	Educational robotics	Secondary school	Lego Mindstorms NXT kit,the Lego Mindstorms Education NXT software	to participate actively, curiosity and initiate motivation, designing and manufacturing of real objects,practical activity, regular feedback, team work, laboratory project, encouraging creative problem solving andcombining interdisciplinary concepts from differentknowledge areas (science, mathematics,

				technology, etc.)
T. Kanda et al., 2004; S. Y. Okita, V. Ng-Thow-Hing and R.Sarvadeva bhatla, 2012; F. Tanaka and S. Matsuzoe, 2012,Japan	Educational robotics	Primary school, secondary school	Asimo, Nao humanoid robots	collaboration, team work with a humanoid robot as tutor or co-student
J. Yoo, 2015, South Korea	Professional	Higher school	KAIST humanoid robot	collaboration, preparation and participation in Olympiads, contests
L. Alfieri et al., 2015, USA	Educational robotics	Higher school	Interactive simulator game „Expedition Atlantis”	Model-eliciting activities (MEAs) that encourage students to invent and test models, Teamwork requiring knowledge in natural science and mathematics, case study, game technologies
B.S. Barker, G. Nugent and N.F. Grandgenett, 2014, USA	Educational robotics	Extraclass activities (summer school)	LEGO Mindstorms NXT ArcMap GIS software	Practical activity, experiments, project method, teamwork.
I.R. Nourba khsh et al., 2005, USA	Educational robotics	University students	Lego Mindstorms kit	Project method
M. Ucgul and K. Cagiltay, 2012, Turkey	Educational robotics	Secondary school	LEGOMindst ormsNXT	constructionis m as „learning by making”, training, project learning, case study
P. Samuels	Educational	Higher	LEGO	Learning though

and L. Haapasalo, 2012, Great Britain	robotics	school	MINDSTORMS NXT 2.0 GeoGebra	programming, method of collaboration
A. Giuseppe and P. Martina,2012, Italy	Educational robotics for linguistic purposes	Primary school, secondary school	Lego Mindstorm NXT using devices	Storytelling by robot and imitation, problem learning, motivational learning
A.C. Sobolevsky and E.F. Sharipova, 2014, Russia	Educational robotics	Students, master degree students	LEGO NXT, NXT-2.0	Mini projects, laboratory activities
E.A Krasnoboyev, 2013, Russia	Robotics in Engineering	Students of engineering and physics majors	DAGU ASURO Mobile Robot kit	Project learning, research method

In the above works, robotics is taught using the theory of constructionism. Constructionism is focused on building of knowledge based on student's experience about the real world, [22] when a constructive educational environment facilitates the interaction between students and knowledge through a variety of instruments, putting emphasis on learning.[23]

Alimisis D.[24] and Pina A.[25] review the possibility of using robotics as an educational tool based on constructivism, [26] which allows to organize creative, active and operational training by building new knowledge and grounds of personal experience. The above approaches to teaching robotics allow students to implement projects, setting up links between different ideas and areas of knowledge, while teacher

[22] S. Papert, I. Harel, *Situating Constructionism*, New York, Ablex Publishing Corporation, 1991, pp. 193-206.

[23] H. Yoon, B. S. Kim, „Preservice Elementary Teachers' Beliefs about Nature of Science and Constructivist Teaching in the Content-specific Context", in *Eurasia Journal of Mathematics, Science & Technology Education*, no. 12 (3), 2016, pp. 457-475.

[24] D. Alimisis, *Robotics in education&education in robotics*, pp. 7-14.

[25] A. Pina, „Improving learning and motivation of students (10-14 years old) by using educational robotics in different scholar scenarios", in *Informatization of education International Scientific and Practical online-conference*, 2015, pp.14-18.

[26] D. Alimisis, *Teacher Education on Robotics-Enhanced Constructivist Pedagogical Methods*, Athens, School of Pedagogical and Technological Education, 2009.

facilitates study process through lectures or step-by-step instructions. The idea of *„learning by design"* takes a central place in the study[27] and supported by project-method-based learning approach. Course tasks are arranged as small or large scale projects so that students could design and develop their own products. It gives freedom to all participants to work on the project in accordance with their interests, develops additional problems and involves the participants not only to solve problems, but also to detect those.[28]

Constructionism can be seen as a special educational case in situations, where we make or tinker with an object or entity, in this case with a robot.[29] Most authors use group work technology, collaboration technology, project method, problem- and research- based learning that corresponds to the nature of constructionism.

According to the authors, constructionism-based learning is the best concept of learning robotics, while educational technologies derived from it (project, problem-based learning, collaboration) provide best results of education process.

An important question to analyze the system of teaching robotics is what robotic assembly platform is widely used. Today there are a wide variety of educational robotics platforms that are powerful motivational and research earning tools. The analysis on educational robotics has shown that most teachers use Lego Mindstorms series.[30]

This platform can be applied for different age groups. In primary school and preschool, Lego platform is used for construction and design of robots.[31] In secondary school, students develop simple algorithms for robotic motion and manipulation. In high school, learning process is organized in a way to conduct research activities in robotic projects using high-level programming languages. In addition, along with the Lego Mindstorms platform, high school students and university students use Arduino platform, when circuitry elements are used in the construction of robots.

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27 *Ibidem*.

28 *Ibidem*.

29 A. Pina, „Improving learning and motivation of students (10-14 years old) by using educational robotics in different scholar scenarios", in *Informatization of education International Scientific and Practical online-conference*, 2015, pp. 14-18.

30 *Ibidem*.

31 A. Giuseppe, P. Martina, „Educational Robotics between narration and simulation", pp. 104-109; D. Scaradozzia, L. Sorbia, A. Pedalea, M. Valzanoc, C. Verginec, „Teaching robotics at the primary school: an innovative approach", in *Procedia-Social and Behavioral Sciences*, no. 174, 2015, pp. 3838-3846.

Developed high-tech Asian countries such as Japan[32] and South Korea[33] use humanoid robots with built-in advanced applications of artificial intelligence and knowledge bases as an instrument and platform of educational robotics. Humanoid robot has the ability to act as a tutor or assistant in the educational process.

We have tried to consider most popular robotics training systems in different countries. Many of them are similar (as shown in Table 1) due to the application of constructionism theory in teaching robotics and applied platforms.

Although there is a lot of experience in teaching robotics in the world, educational robotics in higher schools of Kazakhstan began to appear only in 2014 as an elective course. Teachers started to implement existing robotics courses based on Lego platform. In spite of the available documentation and existing global practice in organizing courses on robotics, Kazakh teachers face certain difficulties in adapting programs of the courses and teaching methods based on constructionism theory. In the following sections, we study the principle challenges teachers face in higher schools of Kazakhstan.

Methodology

In order to determine how educational robotic technologies are used in high schools of Kazakhstan, we conducted a survey among teachers. Particular attention was paid to the application of the theory of constructionism in teaching methodology as a fundamental theory of educational robotics.

The study involved 250 Kazakh professors teaching subjects related to robotics (mechatronics, electronics, microtechnology, circuitry, etc.). 50 out of the selected respondents teach robotics. They all teach robotics to undergraduate, graduate and doctoral students of IT-specialties in Kazakh and Russian languages.

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[32] T. Kanda, T. Hirano, D. Eaton, H. Ishiguro, „Interactive robots as social partners and peer tutors for children: a field trial”, in *Human-Computer Interaction*, no. 19 (1), 2004, pp. 61-84; S. Y. Okita, V. Ng-Thow-Hing, R. Sarvadevabhatla, *Learning together: ASIMO developing an interactive learning partnership with children, The 18th IEEE International Symposium on Robot and Human Interactive Communication, September 27-October 2*, Toyama, Japan, 2009, pp. 1125-1130; F. Tanaka, S. Matsuzoe, „Children teach a care-receiving robot to promote their learning: field experiments in a classroom for vocabulary learning”, in *Journal of HRI*, no. 1 (1), 2012, pp. 78-95.

[33] J. Yoo, „Results and outlooks of robot education in Republic of Korea”, in *Procedia-Social and Behavioral Sciences*, no. 176, 2015, pp. 251-254.

The study was conducted in the form of survey and observation during classes. To determine how teachers organize teaching process we made a questionnaire. It included following questions: what methods they use (explanatory and illustrative, problem methods, research methods, project method, experimental acquiring), what forms of organization of classes are often involved (frontal lectures, pair works, small group works (3-5), working in large groups), what difficulties you see in organizing educational process.

The questions have various scales, depending on the type of a question.

Results

The results are presented in graphs and tables, followed by comments on the main conclusions.

Figure 1 below shows which platform is used by respondents: 36% of teachers use LEGO Mindstorms NXT, 56% use LEGO Mindstorms Education EV3, virtual robots such as Scratch, BYOB/SNAP are used by 42% of teachers, 48% use the Arduino and 4% of respondents use Robotino platform.

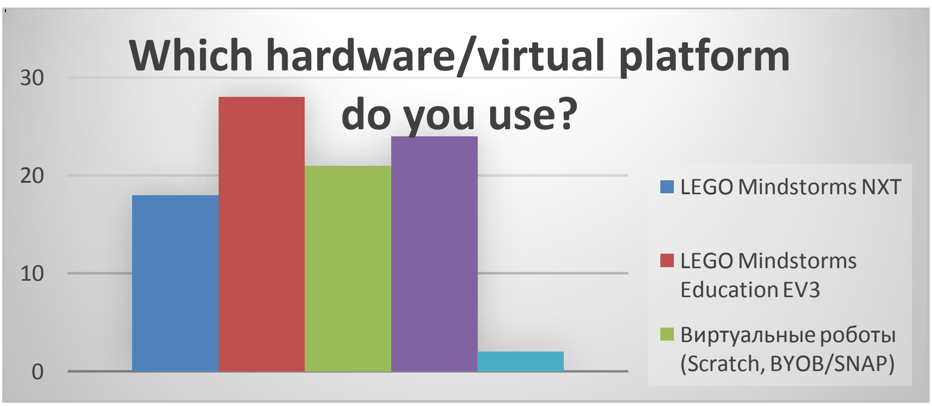

Figure 1: Types of hardware/virtual platform used by teachers

According to Figure 1, all teachers use robot development platforms and the most popular one is Lego and accompanying educational materials.

The following table shows our survey conducted to determine teaching methods and educational technologies used at universities to teach robotics.

Table 2: What educational methods and forms do you use?

Question	Options	Number	percentage
What educational methods do you use?	Traditional (explanatory and illustrative)	44	88%
	Problem-based method	12	24%
	Research method	6	12%
	Project method	16	32%
	Experiment based learning method	6	12%
What forms of education do you use?	Frontal lectures	37	74%
	Work in pairs	31	62%
	Work in small groups (3-	13	26%
	5)	7	14%
	Work in large groups (6 and more)		
Do you experience problems in organization of educational methods and forms in teaching robotics?	Yes, in organizing project activities;	27	54%
	Yes, in organizing group activities;	31	62%
	Yes, in a partially-search method;	24	48%
	Yes, in brainstorming;	37	74%
	Yes, in presentations using aids and discussions;	31	62%
	Yes, in organizing mini-lectures;	24	48%
	Yes, when watching and discussing videos;	17	34%
	Yes, in conducting interviews;	34	68%
	Yes, in organizing feedback structure;	36	72%
	Yes, in organizing lectures with predetermined and	32	64%
	announced mistakes;	20	40%
	Yes, when organizing		
	warm-ups;	28	56%
	Yes, when organizing		
	discussions;	25	50%
	Yes, in a case study		

	method (study of separate operational situations); Yes, in collective creative problem solving; Yes, in organizing business games; Yes, in other forms and methods. No, I had no problems.	37 25 24 0	74% 50% 48% 0%
Do you apply project method in organization of robotics teaching process?	Yes, all laboratory activities are based on project method Yes, partial application No, there's no need	12 16 23	24% 32% 46%
If the previous answer is Yes, what difficulties or shortcomings arise in organization of project methods in the robotics course?	Yes, when forming mini groups Yes, when distributing roles in mini groups Yes, when engaging and activating each student in mini groups for the entire period of work Yes, when identifying the contribution of each mini group participant to the project Yes, when realizing the formative (internal) evaluation of each mini group participant Yes, when organizing project presentations by each participation of small groups Yes, when organizing collaboration between group members Yes, when motivating group members Yes, when kindling interest of all group members	9 11 16 12 12 14 13 16 19	18% 22% 32% 24% 24% 28% 26% 32% 38%
What kind of difficulties do you have when organizing Students' Individual Work (SIW) in	Lack of ability to work in groups (with distribution of roles, exchange of information, in co-operation);	23	46%

robotics?	Autonomy in the acquisition of new knowledge and practical skills; Independent research, analysis and selection of information using new information technologies; The measures taken in non-standard situations, mastering heuristic ways of problem solving; Value-based relationships to each other, teachers, authors of inventions and discoveries and to learning outcomes;	20 23 27 25	40% 46% 54% 50%
How do you deliver theoretical material?	Through lectures By providing printed out materials	44 38	88% 76%
Do you have problems in developing test-and-measurement materials and tools in robotics?	When developing a forming (internal) evaluation; When developing criteria-based evaluation; When developing evaluation independence of students; When developing competence-oriented tasks; When organizing feedback technology; When students actively participate in the organization of their own learning process; When changing the teaching techniques and technologies in order to have different learning outcomes of students.	28 33 24 20 31 37 24	56% 66% 48% 40% 62% 74% 48%

Despite the introduction of competency and personality oriented concept of education in Kazakhstan, vast majority of teachers (88%) use traditional teaching methods and only 12% of teachers use problem, research, constructive methods. 32% of respondents use project method in teaching. A higher percentage of use of project method compared with other innovative methods is due to the fact that official courses on robotics include lists of projects recommended for teachers to work on.

Most popular forms of educational process are frontal lessons (37 teachers use it) and pair work (31 teachers use it), while group work is used by a small percentage of respondents (13 teachers).

To determine what difficulties our teachers face in organizing teaching methods and forms of educational process in the existing formal educational robotics technology, we prepared certain questions. The answers showed that our teachers face difficulties almost in all methods of constructive and active learning. During face-to-face interviews, teachers admitted that they are not proficient in using technology and forms organizing project activities, group method of role-level assignments and completion of assignments by groups. According to the teachers, they had difficulties in organizing brainstorming sessions, presentations using a variety of aids and discussions, discussion of movies, lectures, interviews, feedback, discussions, case-method, collective completion of creative tasks and business games due to the fact that students do not have a sufficient level of critical thinking and the ability to freely express their own point of view.

We specified questions related to project methods and revealed that some teachers see problems practically in every step, especially in awakening students' interest in completion of group (common) projects (38%).

There are also problems with organization of students' independent work. 54% of teachers indicated that students find it difficult to take action in non-standard situations, mastering heuristic problem solving in robotics. A large number of respondents pointed to inability of students to work in groups while performing individual work.

Almost all teachers present theoretical part of robotics in the form of lectures or deliver text materials for study without taking into account the concept of constructionism in robotics. The experimentation technology, research and development activity and manufacturing practices are use insufficiently.

With regards to testing and evaluation, teachers have issues in accurate multi-criteria evaluation of learning outcomes. Table 2 shows that there are problems almost in all steps of evaluation: in the development of formative assessment, in the criteria-based evaluation, in the formation of evaluation independence of students, in the development of competence-oriented tasks, in the feedback technology, in the active participation in the learning process, when changing technology and techniques of education on the basis of learning outcomes.

Summarizing all the above, we can say that most instructors have difficulties in using methods and forms of instruction based on constructionism. Project method is only partially used; educational material is mainly presented in the form of ready text and step-by-step instructions. Teachers almost do not use teaching principles based on constructionism, allowing students to organize independent educational process.

The above conclusion show that existing methods of teaching robotics, as well as courses related to robotics hardware platforms are difficult to adapt to the educational system of Kazakhstan. We try to answer the why is this happening in the next section of the article.

Discussion

Higher educational system of Kazakhstan evolved in a unique way. Until recently, there was a post-Soviet system, based on the front-end methods and class-lesson system. In 2010, Kazakhstan joined the Bologna process [34] of modernization of education, thanks to which innovative learning technologies began to develop in the higher education system. However, despite such a rapid development of higher education, teaching methodologies as well as teachers' mindset are not easy to reconstruct. It is also mentioned in the works of Fullan, M.[35] about the difficulty to change teacher's educational strategy: it is difficult for a teacher to re-set his or her mind to use the new teaching methods based on constructionism. The main issue of adapting robotics courses and the training methods are due to unwillingness of teachers to organize educational process based on constructionism.

Willingness of teachers can be increased in two ways. First is to train them to use of constructivist theory in teaching robotics. Some scientists[36]have studied this approach.

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[34] „Kazakhstan Joining the Bologna Process. Official web-site of the Ministry of Education of the Republic of Kazakhstan", retrieved from: www.edu.gov.kz, accessed on 12.IX.2017.

[35] M. Fullan, *The New Meaning of Educational Change*, Toronto, Ontario Institute for Studies in Education, 1991.

[36] D. Alimisis *Teacher Education on Robotics-Enhanced Constructivist Pedagogical Methods*, Athens, School of Pedagogical and Technological Education, 2009.

Another way is to plan educational process of teaching robotics by developing own educational technology, adapted to specialty curriculum, with the account of students' and teachers' level of preparedness to learn robotics based on constructionism.

Designing educational technology includes a unified logic of sequence of process steps required to produce a specific result.[37] Educational technology is implemented for a long period, requiring continuous adjustments due to varying internal and external conditions. Market needs, the needs of society and students, the actual state of education in certain institutions, the level of material and technical base are the factors that are taken into account.

The process of designing educational technologies for teaching robotics is shown below (figure 2) as a sequence of steps.

[37] G. K. Selevko, *Contemporary educational technologies. Teaching guide*, Moscow, Public Education, 1998; A. B. Khutorskoy, „Methods of project design and organization of metadisciplinary educational activity", in *Municipal education: innovations and experiment*, no. 2, 2014, pp. 7-23; N. G. Alekseyev, „Designing projects and reflexive thinking", in *Development of personality*, no. 2, 2002, pp. 92-115.

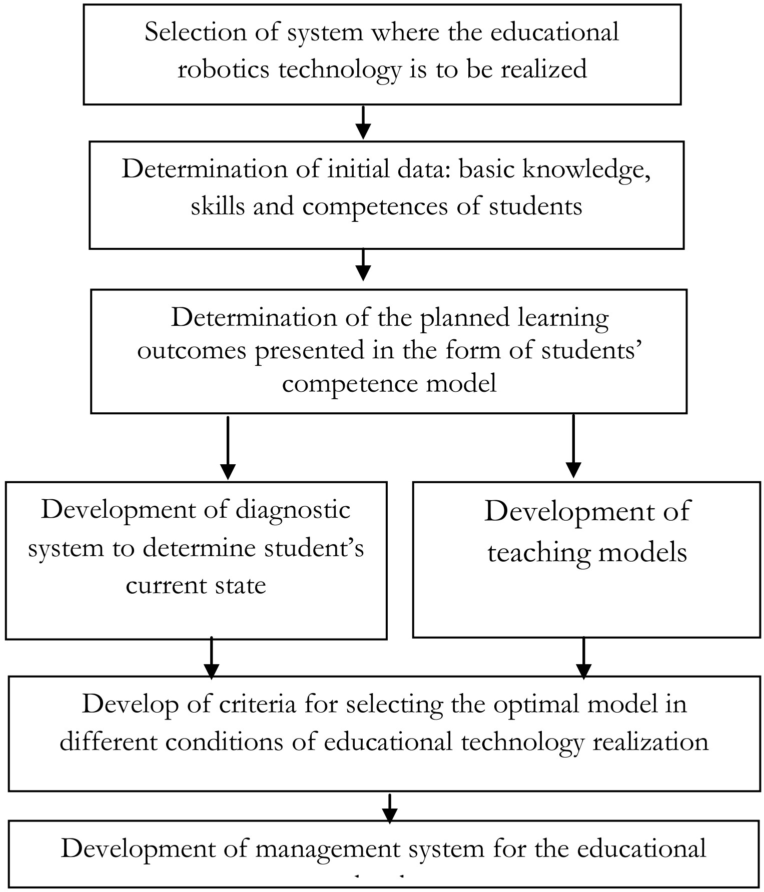

Figure 2: The process of designing educational technology for teaching robotics

In the early stages of designing educational technology teacher clearly defines the industry and place of use of the technology. Any educational technology is implemented in a certain system, in our case, a system of higher education. In the „college-student" system, there are two sub-systems: In the first case, robotics is professionally oriented, is an element of professional competence; it is both an object of learning and a tool of learning. In the second case, robotics is used as an interdisciplinary discipline that integrates knowledge from related disciplines.

Since the two systems are different, educational technologies in robotics will also be different. This fact affects the process of designing educational technology, which is governed by the principles of design.

Therefore, at the initial design stage it is important to adhere to the principle of targeted prospects, which requires a clear understanding of development prospects of robotics. This principle affects the setting of educational purpose, which is for whom and in what system this technology will be applied.

Determination of initial data means that at the beginning of teaching robotics it is necessary to detect basic knowledge, skills and competence of students, which will serve as basics to the educational process. This step is very important, because it sets trends to the development of planned educational outcomes. For example, a student, who did not master fundamentals of mechatronics, will certainly fail in learning robotics program for engineering specialties. Thus, all original competences are closely linked with each other, and realization of an educational model contributes to the transformation of initial data into the final competence model of a graduate from robotics course.

Determination of the planned learning outcomes is based on the principle of orientation to the individual needs, labor market requirements and the state institution's educational position. The internal and external factors determine the list of knowledge, skills, abilities and competencies that student have to master after studying robotics. Labor market dictates what robotics experts are required for the service and manufacture. Being an industrial country, Kazakhstan needs experts in the field of robotics, and employers drive the construction of competence models for future specialists. The theory of constructionism in education also affects determination of planned learning outcomes, because constructionism in fact allows us to develop creative, strategically thinking specialists. Availability of a certain material base in the university also influences the competence model of students. The dynamics of social and labor market requirements determine the need to adjust the educational technologies that is implemented through the principle of dynamism.

Since all stages of the design of educational technology in robotics are interrelated, and designer needs to continually set links between the individual elements of educational technology, take into account successive connections, the design process based on the principles of consistency and continuity. These principles are also specific to the phase of development of diagnostic system to determine students' current state-diagnostic materials are designed in accordance with the competency model and have direct influence on the adjustment of the educational models.

Detecting students' current state provides necessary data to organize teaching process. Different data create different educational models to achieve projected outcomes. Here we see the realization of the principle of plurality, alternativeness of projected solutions, requiring availability of options among similar, effective and up-to-date educational technologies and their components.

The educational model specifies purpose, content, organizational forms, methods and tools of teaching robotics, as well as learning outcomes. It is the phase when methods and forms of study are outlined based on constructionism and in accordance with teacher's and students' preparedness to have cooperation in applying constructivist principles.

In developing educational models, teacher adheres to the principle of modularity (which involves the structuring of curriculum content and ways of mastering relatively independent components, providing variation and individualization of the educational process in robotics), to the principle of concentricity (which defines the teaching system and is based on concenters-levels of training related to each other by the unity of content and varying by their complexity and volume). In our opinion, concentricity is a symmetrical principle of structure, which brings order into the structure of robotics learning model.

An important component of the design process of educational technology in robotics is to develop a quality management system for technology implementation, including instructions with a schedule of implementation, diagnostics, organization of all the subjects of the educational process and motivation of students. Improper implementation of any of the components can lead to poor learning outcomes.

As robotics course contains basic elements regardless of specialty, it is important to determine the invariant and variable components when designing a model. A robotics platform is a variable component, because rapid development of platforms requires updating training materials and is quite difficult to do in a conservative system of education. This is confirmed by the study of Gold N.,[38] who states *„the content is specific to particular platforms or technologies that change (thus requiring frequent re-recording)"*. Variable components of educational technology will also fill in with concrete content for different levels of education, whether primary, secondary or higher school, and various educational programs, modify,

[38] N. Gold, „Motivating Students in Software Engineering Group Projects: An Experience Report", in *Innovation in Teaching and Learning in Information and Computer Sciences*, no. 9 (1), 2010, pp. 10-19.

adapt methodical system of teaching robotics in accordance with the principles of constructionism and with due account of specifics of the development of students' competencies related to cooperation.

Designing of educational technology in robotics allows making concrete steps to guarantee results in robotics course.

Conclusion

This work aims to study methods of teaching robotics, namely the use of educational robotics technology. The study of robotics teaching experience has shown that most effective technologies are the technologies related to development of robotic platforms, the methodological basis of which is constructionism.

Despite the existing global experience, Kazakhstani teachers face challenges related to adaptation to the existing education system, mostly because Kazakhstan has recently moved away from the class-lesson educational system. The results of survey among teachers of robotics in higher institutions for IT professions showed that they experiencesignificant difficulties in teaching robotics when it comes to content, methodological system based on constructionism and the use of robotics platform.

One of the solutions to this problem that we suggest is to consider not just adaptation of technologies, presented in conjunction with robotic platforms, but designing new educational technology, which will take into account predetermined conditions of Kazakh educational system, teachers' and students' preparedness to apply constructivist principles in the educational process.