Towards Effective Interactive Teaching and Learning Strategies in Robotics Education

Tatyana Tsoy, Leysan Sabirova, Evgeni Magid
Intelligent Robotics Department, Higher Institute of Information Technology and Information Systems, Kazan Federal University
Kazan, Republic of Tatarstan, Russia
{tt, sabirova, magid}@it.kfu.ru

***Abstract*—Robotics education is one of the most emerged and demanding fields of modern engineering education. To prepare skilled specialists for industrial needs it is important to create high-quality educational base. Intelligent Robotics Department takes its first steps in developing and implementing a new robotics educational program. This paper reviews Russian robotics education and describes our current work toward program establishing. To evaluate student motivation of connecting their education and further career with robotics we ran a survey among bachelor and master students, which have selected robotics subjects as elective courses. We present results and analysis of the survey, and elaborate on next steps of program development.**

Keywords—Education; robotics; Master degree program; curriculum; survey analysis;

I. INTRODUCTION

The field of robotics has been constantly growing in recent years and application of robots is not narrowly focused on industrial production and research laboratories. As robotics-related private companies around the world, including large enterprises and small family businesses, keep emerging and expanding, more and more skilled roboticists are required. The growing demand of such specialists and competition on the job market between robotics companies resulted in significant staff shortages. To provide industry with qualified robotics engineers it is necessary to create an effective higher education system.

Robotics is a specific multidisciplinary area of science and education, which brings together several branches of knowledge that include computer science and software development, electrical and mechanical engineering, applied mathematics and physics, artificial intelligence and computer vision, human-robot and human-computer interaction, material science and chemistry, and others [1], [2], [3]. On 8/02/2014, Agency for the Strategic Initiatives and the Moscow School of Management at Skolkovo presented an anthology of promising industries and professions for the next 15-20 years [4]. Among them are robotics and mechanical engineering fields with eight new professions, which are expected to appear at the labor market by 2020. These include designers and programmers of robotic assistants, multifunctional robotic systems operators, specialists on composite materials for parts production, mechanisms, and connecting elements of robotic devices etc. To prepare effective and highly motivated professionals in the field of robotics and mechatronics a novel educational concept is required [5]. Currently, vocational robotics education in Russia is in its starting phase. However, not only Russian but also a global robotics labor market is emerging as consequence of economic trends [6].

On 8/12/2011, the Russian Federation Government enacted Decree № 2227-r on Strategy for Innovative Development of the Russian Federation until 2020. According to this decree, one of the most urgent tasks of education is to create conditions for shaping such competencies as ability and readiness for continuous education, self-improvement, self-training, ability of critical thinking, and knowledge of foreign languages [7]. Designing a competitive and quality-oriented master program in robotics field could serve as a platform for training experts with specialized knowledge and skills. In terms of current Russian robotics education, there are multiple contradictions between knowledge and skills quality that are gained by students at Russian university and requirements of employers. Robotics educational field in particular is still an emerging and flexible area, which gives us an opportunity to use new educational approaches [8].

The team of Intelligent Robotics Department (IRD) of Higher Institute of Information Technologies and Information Systems (ITIS) at Kazan Federal University develops a novel educational program profile for master students, which will specialize in robotics. While a program for robotics profile within Software Engineering (SE) master degree program starts in September 2017, currently IRD offers two robotics-related courses for students of Applied Informatics bachelor degree program and one (robotics-related) research oriented course for students of SE master degree program.

To evaluate student motivation of connecting their education and further career with robotics, we ran a survey among bachelor students, which have selected robotics subjects as elective courses, and master students, which had to take a compulsory course. The survey brought us valuable feedback on educational needs and requirements, successful and unsuccessful methods and approaches used in the classes. Survey analysis helped elaborating on next steps of program development for the next academic year.

The rest of this paper is organized as follows. Section II briefly introduces current teaching environment in Russia. Section III demonstrates our current work on designing and implementing Robotics curriculum. Section IV describes the survey and analyses its results. We conclude in Section V.

II. ROBOTICS TEACHING ENVIRONMENT IN RUSSIA

Robotics and mechatronics field in Russia falls behind developed countries by several decades due to a long-term stagnation in all fields of science after the USSR collapse in 1991 [9]. To become competitive in science and technology field, only recently Russia took significant efforts in order to catch up with developed countries. Russian government started to invest in education and science, referring to western educational models of development and trying to build up its own models adapted to local environment [1].

To overcome the crisis in academia, universities and research institutes started to fill in the gaps and catch up with developed countries in already existing scientific fields [1]. Some Russian universities started to establish laboratories,

2161-1343/17 $31.00 © 2017 IEEE
DOI 10.1109/DeSE.2017.38

departments and educational programs related to recently emerged and demanding fields, including robotics. The roots of robotics field in Russia refer to exoskeletons of 1960-ties and industrial robots of 1970-ties, while in 1972 robotics research became a part of state policy. In 1981 a new robotic systems major was introduced within electro-mechanical engineering educational profile in several leading universities in Russia [10]. Recently, Ministry of Education and Science of Russian Federation assigned higher education institutions a task to introduce and integrate field of robotics wider in Russian academic institutions and catch up with current development of the area, so that graduates could compete with engineers in global market. In addition, later after recognizing robotics field importance for economic development and due to rapid technological progress, the government officially proclaimed robotics as one of priority fields of economic development [11].

Today robotics is emerging and continuously developing in various fields in Russia. Educational robotics became popular as additional education for children, and it showed considerable growth of robotics private schools. According to Russian Association of Educational Robotics, since 2002 robot competitions are held in Russia annually and by 2014 over 10,000 schoolchildren took part in these competitions.

Along with our university, currently robotics research and education are rapidly developing in other universities. These include Bauman State Technical University, Research and Development Institute of Robotics and Control System of Southern Federal University, Russian State Scientific Center for Robotics and Technical Cybernetics, The V.P. Larionov Institute of Physical - Technical Problems of the North (Siberian Branch of the Russian Academy of Sciences), Far Eastern Federal University and other universities. In parallel with academic interest increase, private companies started developing and producing robots of various classes, e.g., humanoid robots of AR-600 series by Android Technics, mobile robots Engineer series by Servosila, promotional robots Promobot by Promobot Company, and others. As our consultations with Russian robotics companies, public discussions and events demonstrated, the field is facing a severe shortage of robotics specialists [12].

According to websites for prospective students Vuzoteka.ru and Institute-catalogue.ru, about 40 higher educational institutions offer bachelor and master programs with robotics and mechatronics major. However, all such programs encounter difficulties that are typical for a rather novel robotics field:

- A shortage of experts in robotics field, which prefer academic career to R&D pathway in companies or sales pathway in business. The reason is that robotics teaching (at a competitive with developed countries level) requires from teachers special education in robotics field, broad experience of teaching, constructing and/or programming robotic systems. While salaries in academy are far behind similar positions in industry. In addition, since robotics is a very modern field, robotics educational process requires very frequent update of teaching materials in order to keep pace with robotics advances.
- Limited selection of up-to-date educational materials in Russian language requires using foreign educational sources. In turn, it triggers a necessity to teach robotics classes in English, which requires teachers and students to master good level of English, including speaking, reading and comprehension.
- Overpriced robotics equipment is required for research and education, while most Russian universities' budgets cannot afford such expenses for boosting a single narrow field. Moreover, rapid field development requires at least partial renovation of educational hardware every couple of years.

Due to these reasons, some of robotics related programs in Russia were considered unsuccessful and/or commercially unfeasible because of typically low undergraduate and graduate education fee in Russia relatively to inevitable hardware expenses and teaching process sophistications, and were shut down or significantly slowed down their development.

One of the changes that Russian education system implemented after the USSR collapse was a transformation of 5-year higher education standard programs into a combination of 4-year bachelor and 2-year master programs. In fact, after completing 4-year undergraduate level, students cannot possess enough skills to be qualified robotics engineers. Even the best imaginable 4-year curriculum, which contains tightly packed compulsory classes from various fields, allows students to concentrate on robotics only in the last year or two of their education. Moreover, many Russian universities agree on allowing students to concentrate on bachelor thesis writing in the last semester, and for this reason often the last semester would contain a single educational course only, reducing available for specialization time to three full semesters at most. This time is definitely not sufficient for mastering such complicated and demanding field as robotics for bachelors. At the same time, there is a recent tendency that a number of IT specialization students in Russia, which apply to master programs after graduation, significantly reduced in past years as majority of IT field employers does not necessarily require candidates to have advanced level of education. Thus, more master students target to stay in academia rather than to continue career in industry. Moreover, attempts to establish master programs with applied robotics specialization did succeed, since lecture hours were significantly reduced and practical hours were not utilized effectively due to absence or shortage of educational equipment.

Legislatively, on November 21, 2014, Russian Ministry of Education and Science issued a decree on "Approval of Federal State Educational Standard of Higher Education on Education Direction in 15.04.06 Mechatronics and Robotics (for master level)". This decree was followed by a decree on "Approval of Federal State Educational Standard of Higher Education on Education Direction in 15.03.06 Mechatronics and Robotics (for bachelor level)" on March 12, 2015. As only few years have passed, we believe that it is difficult to evaluate these standards yet, and more long-term research of existing robotics programs is required, which is a part of our ongoing work.

III. Robotics Education at Kazan Federal University

IRD develops robotics educational program minor specialization profile for master degree students of SE major program. The new robotics minor will be launched in the new academic year, Autumn-2017 semester. It will be the first step toward creating mechatronics and robotics major master degree program. After pilot run of one-year robotics minor program, its curriculum will be extended toward a major program within the framework of Federal State Education Standard of Higher

Education with assignment of qualification of the Master on Mechatronics and Robotics 15.04.06.

A. New Robotics Program Design

Undoubtedly, for the new program design and implementation, interests and needs of Russian industry play a key role. Yet, our mission as educators is to spark the interest of students in studying such complex discipline as robotics and to keep high motivation of a student throughout the entire educational process. Currently, as our program is emerging, we evaluate effective teaching approaches that consider inter-disciplinary approach in the field of mechatronics and robotics.

As for today, ITIS offers two educational opportunities for the students: 4-year bachelor degree program in Applied Informatics and 2-year master degree program in SE (majors: software development management, SE methods and assets). Before launching Mechatronic and Robotics master degree program, several courses (which are described in the next section) for bachelor and master students were offered by IRD in order to fascinate the students into robotics field. To better understand students' needs and motivation to study robotics and to provide them with effective educational process, we implemented interactive student-oriented approach. Such strategy addresses student needs for being active and engaged in a learning process, to interact with a teacher and classmates. Interactivity of the educational process gives more motivation to students, as it gives them constant tension. Moreover, interactive strategies provide opportunities for students to strengthen their observation and communication skills [13].

Intelligent Robotic Systems Laboratory (LIRS) of ITIS headed by Professor Evgeni Magid started its activities in September 2016 under the auspices of Strategic Academic Unit "Teacher education transformation – 4T". One of the key priorities of LIRS for a period of 2016-2018 is Robotics Engineering Education project RobIO, which targets for creating and implementing a robotics educational program specialization. The proposed program is intended to provide students with knowledge in the field of robotics research and applied projects. It is expected that besides the standard lectures and practical robotics courses during the program students will carry out their research projects within three laboratories of the IRD and other ITIS laboratories, including LIRS, Machine Cognition laboratory, Social and Urban Computing laboratory, Neuroscience laboratory, and others.

B. Implemented Robotics Curriculum

Starting from the second semester of 2016/2017 academic year, bachelor and master degree students of the SE program were offered the following courses, which are taught in English:

1. "Introduction to Robotics", 4-th year bachelors;
2. "Adaptive control systems", 3-d year bachelors:
3. "Scientific research methodology", first year masters.

"Introduction to Robotics" is an elective course for 4-th year bachelor students and is taught in the last semester before the graduation. This course is intended to provide students with an understanding of basic robotics concepts, to introduce recent applications and prospect of the field. As this is a very short half-semester course for almost graduated bachelors, the idea behind the course curriculum is to spark student interest in robotics in order to continue toward master degree in SE major with robotics minor. The main course book for theoretical part of the course is a classical book of J.J.Craig [14], while for practical tasks in Matlab with Robotics Toolbox we use P.Corke book [15]. In addition to pen-and-paper home assignments and coding in Matlab, students make a number of presentations, including interactive demonstrations of their simulations and a final project. To encourage active learning, students are asked to participate in small group tasks and discussions in the class in real time and then present joint solutions for all participants.

"Adaptive Control Systems" is a full semester elective course, which is intended to provide third year bachelor students with a solid background in robotics and is similar to a typical "Foundations of Robotics" course. Our goal is to excite student curiosity for robotics, while encouraging them to select robotics topics for their bachelor research thesis and giving confidence to conduct such research. This course includes the basic topics of Introduction to Robotics course and then further extends student knowledge for manipulators and practical issues of their usage. In addition to the same course books, a number of other books and research papers are used, e.g., [16]. Students solve pen-and-paper home assignments, code in Matlab with Robotics Toolbox, and use LEGO Mindstorms EV3 robotic kits for practical evaluation of their theoretical knowledge. Java-like LeJos language is used for LEGO kit programming, and it is for the first time in their life (for majority of participating students) that they have to face engineering problems and gain insights into a significant difference between coding pure SE problems and dealing with hardware issues. As in the Introduction course, students discuss particular questions in small groups and perform a number of practical tasks with LEGO kits, which are summarized into a practical manipulation competition that verifies student knowledge in forward and inverse kinematics, sensor usage, manipulator PID control and trajectory planning, and requires teamwork and creativity.

"Scientific research methodology" is a compulsory course for the first year master students and is taught in their second semester. The course familiarizes students with general research concepts and strategies, teach to formulate a research problem and to prepare a research publication. Along with theoretical lectures, students have intensive practical lessons and home assignments, where they apply lecture material, write texts and prepare presentations. The lecturer, Prof. E. Magid, adapts the main textbook material [17] as an introductory part for robotics needs. The main body of the course are built up from publically available essays of top robotics and computer science researchers and are formulated through the prism of lecturer personal research experience his multicultural career in Russia, Israel, Japan, USA and UK. Research papers of Prof. E. Magid in Russian and English languages in various branches of robotics and computer vision (e.g., [18], [19]) serve as practical material for students: knowing strong features and pitfalls of these papers in details helps to explain practical issues with live and easy for understanding examples.

C. Goals and Ideas behind Robotics Curriculum

While bachelor oriented courses are mainly targeting for introducing robotics basics and attracting students toward academic master program, the master program will become a core program of IRD. Launching the program with a new curriculum gives an opportunity to consider major drawbacks of education development in Russia, connect it to Russian and world robotic industry development, and provide

multidisciplinary approach in teaching robotics. The above class modules were designed considering students' background, preliminary discussions and analyses of industry requirements as potential employers. Based on the described in Section II reasons, the following factors were emphasized:

- Teachers/lectors qualifications and experience: the requirements are intensive previous experience in robotics and mechatronics related projects and teaching.

- Bilingual teaching: main teaching in English language with a possibility of giving additional explanations in Russian language. This decision targets for preparing more competitive students in the world industry and academia, so that they are not limited only to Russian robotics school [10], [20], [21] and receive a broader view of the field. Students could use both English and Russian languages in communication during class.

- Equipment for practical tasks. Students will build robots with LEGO kits. In the future, students will access real robots on site under teacher's supervision. As for LEGO kits, every two student team receives a kit for the course and could take it home for the entire semester in order to gain 24x7 access to the kit.

- Student motivation. Along with various motivational teaching methods, students get an opportunity to participate in robotics conferences and competitions, e.g., Eurobot, Promobot Challenge, First, WRO etc.

- Skills training based on employers requirements.

All these factors will be examined and analyzed during long-term 2 years research. We divided the feedback materials into four parts: application of qualitative research in the form of questionnaire for students, questionnaire for teachers, questionnaire for industry and academia representatives as potential employees, collecting and analyzing data about equipment use during classes. In the next section, we present the results of our first student questionnaire.

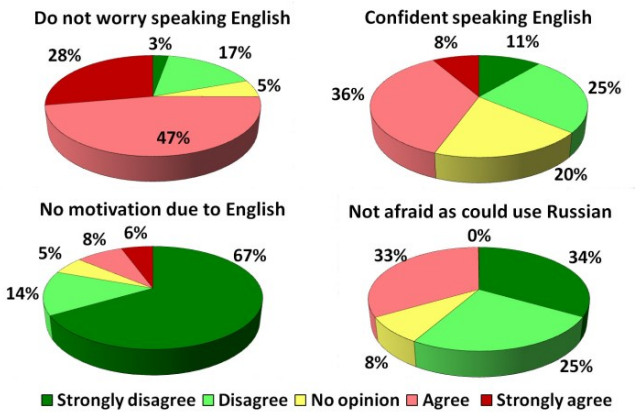
IV. Questionnaire and Analysis

This section presents the data of the first research part, which examined students' background, English language comprehension, and motivation to study robotics. In the survey for each statement we have provided 5 point scale with optional answers: (1) Strongly Disagree; (2) Disagree; (3) No opinion; (4) Agree; (5) Strongly Agree. Percentage indicate number of respondents that have selected the corresponding answers. In this section, for each answer we provide percentage of respondents and the above mentioned scale point (or number of respondents in parentheses when appropriate). The survey also contained a number of qualitative open-end questions, which are not presented here due to space limitation. This first pilot version of the survey was distributed in the middle of the semester and was run in Russian language to ensure that students fully understand the questions.

In total, 36 students that are studying robotics for 3 hours one time per week participated in the survey. The survey contained 88 questions, which were partially repeated in order to reconfirm the answers. The survey targeted to question students' English language background, robotics knowledge that they had been attained before starting the class, student motivation to study robotics and other knowledge background. The questionnaire was arranged on-line via Google forms in such way, that each question appeared on a separate page, a new question became available only after the previous question answer was submitted, and there was no opportunity to return to previously answered questions. Majority of the students (55,5%) had Applied Information Science as their major. Students participated in robotics class were from different programs: 47,2% students were MA1, 36,1% - BA4, 13,9% - BA3, and 2,8% - BA2.

For many students English language study had a long history starting from secondary school. 30,6% of students studied English for 7 to 10 years, 47,2 % - for 11 to 15 years. Although 19,4% of students studied English only 1-5 years. Figure 1 presents the questions that targeted for evaluation of English language comprehension and student difficulties.

Majority of the students claimed that they "did not worry to speak English in the class": 47,2% agreed with the statement and 27,8% strongly agreed (Fig.1, top left). At the same time, for a similar control question of "do you feel confident when speaking English" only 36,1% agreed and 8,3% strongly agreed (Fig.1, top right). This almost 20% difference in positive answers for similar questions points out that worrying and feeling confident has different emotional connotation for students. While we were concerned that English language may become a barrier for educational process, only 13,9% (8,3% (4) and 5,6% (5)) of the students didn't have motivation to go to class for the reason that it was taught in English (Fig.1, bottom left). Probably, the ability to reconfirm in their native language any unclear (in English) material served as a safety margin for the students - 66,6% of them (33,3% (4) and 33,3% (5)) were not afraid of the material complexity, because they could ask for additional explanations



in Russian (Fig.1, bottom right). It turned out that 55,6% students (20 people) never took any technology and science related classes in English before, while 44,4% (10 people) did.

Fig. 1. English language comprehension

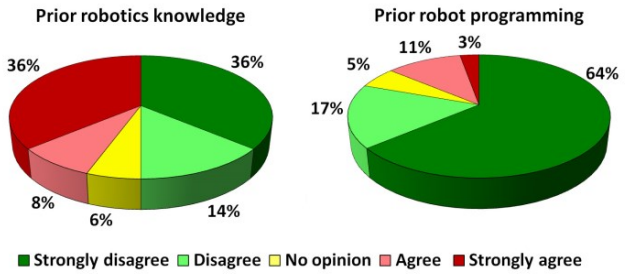


Fig. 2. Robotics knowledge prior to the courses

Next, we checked students' robotics related knowledge attained before starting the class. Only few students participated in robotics related activities previously - 13,9% (4) and 5,6% (5), while half didn't have any prior robotics knowledge (Fig.1, left). 11,1% (4) and 2,8% (5) knew how to program a robot (Fig.1, right), and almost the same number knew how to build a robot 13,9% (4) and 2,8% (5).

A number of questions targeted for evaluation of student efforts in the class. 69,4% (33,3%(4), 36,1%(5)) of the students considered that learning robotics was important as it stimulated their thinking (Fig. 3, left) and for 66,6% (47,2%(4) and 19,4%(5)) liked participating in the courses because the subject requires mental effort in studying and getting prepared for classes (Fig. 3, right).

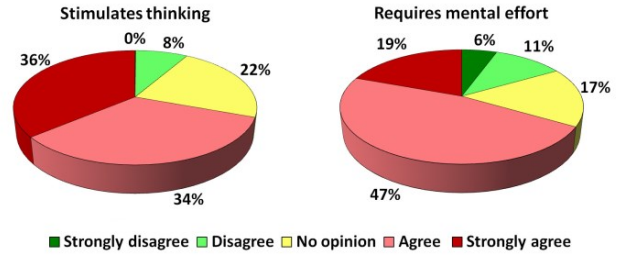


Fig. 3. Student mental efforts in the class

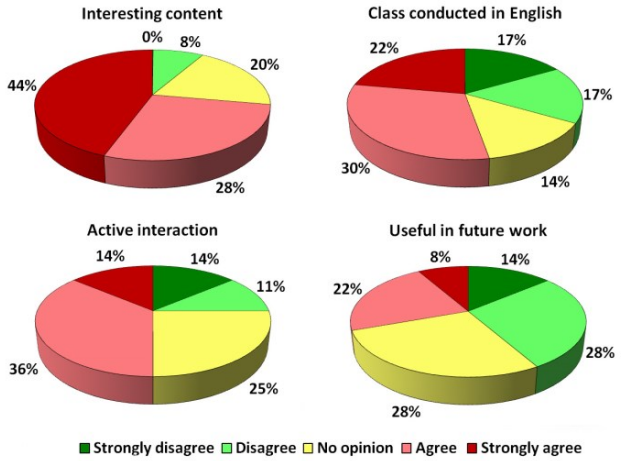


Fig. 4. Course reflections.

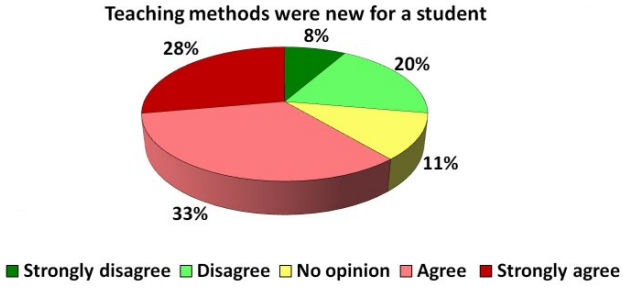


Fig. 5. Teaching methods evaluation by the students

Students' self-efficacy was in general high: only 5,6% (2,8% (4) and 2,8% (5)) answered that no matter how much effort they put in, they couldn't learn robotics. Only few students prefer not to submit homework if it was too difficult for them (16,7% (4) and 5,6% (5)).

Achievement goal. The students felt most satisfied when they could solve a difficult task (27,8% (4) and 61,1%(5)). 38,9%(4) and 55,6%(5) of students felt mostly satisfied when they could understand content of the lecture/class. Obviously, satisfaction was high when they could get good grades for home assignments and bonus tasks 36,1% (4) and 41,7 (5)%. The students reported that home assignments (58,3%(4) and 16,7%(5)) and bonus tasks (50%(4) and 27,8%(5)) were of the appropriate level of difficulty.

The students were quite active in learning robotics as 44,4% (4) and 41,7% (5) were using additional relevant resources that helped them to clarify robotics related concepts when they didn't understand. Also 33,3% (4) and 33,3% (5) would discuss with the teacher or other students to clarify the material when they didn't understand something.

44,4%(5) and 27,8%(4) liked participating in class because the contents of the class were interesting and changeable (Fig.4, top left). 30%(4) and 22%(5) were motivated to take the courses because they were conducted in English (Fig.4, top right), which strengthen our conclusion that English language did not provide a significant additional barrier for student motivation and learning. 41,7%(4) and 11,1%(5) like joining the class because the teacher gives freedom in selecting a topic that is interesting individually for each student.

Regarding performance goal, in general students did not selected robotics class because "it was cool" or because "other students thought that robotics class students were smart", and had clear reasonable motivation. 36,1% (4) and 13,9% (5) answered that they participate in robotics class because it gave opportunity to express their opinion and participate in discussions, however, 25%(3) had no opinion, while the rest 25% were not interested in class discussions (Fig.4, bottom left).

In total, 55,6% of the students liked the theoretical component and 63,9% liked practical component of the class. Majority of the students realized that robotics is a multidisciplinary subject (52,8% (4) and 27,8%(5)). For 33,3%(4) and 27,8%(5) such teaching methods were new (Fig.5), which brings us a hope that the developed classes and course material were useful, interesting and successful.

Unfortunately, regarding robotics learning value only 30,5% (22,2% (4) and 8,3% (5)) of the students believed that learning robotics was important because they could use the gained knowledge in their potential future work, while 27,8% (3) had no opinion (Fig.4, bottom right). We believe that such pessimistic thinking of the students toward the practical application of their robotics knowledge in the future is caused mainly by the low level of robotic technology and robotic devices presence in our daily life in Russia, including industrial robots in factories, assistive robots in hospitals and rehabilitation centers, home robots and promotional robots. While these technologies for over two decades ago became a part of regular environment in developed countries like Japan and South Korea, and are rapidly integrating in daily life for Europe and North America citizens, robotics makes only first steps toward conquering Russian markets and influencing our daily life.

V. Conclusions and Future Work

The paper briefly introduces current teaching environment in Russia and our current work on designing and implementing Robotics curriculum. In 2017/2018 academic year, Intelligent Robotics Department of Higher Institute of Information Technologies and Information Systems (ITIS) will launch robotics minor for the students of master degree program with a major of Software Engineering. To prepare for the program launch and to attract potential students, three pilot courses are run at ITIS this semester. In order to obtain a feedback from students, which will help to spark student interest and motivation to study robotics and to improve teaching, a questionnaire of 88 questions was run in the middle of the semester. The answers indicated an increased interest of students in robotics. Based on the analysis results, we concluded that the combination of teaching methods, courses content and teaching in English language gave positive results in students' motivation to study robotics. Moreover, conducting the classes in English didn't effect students' motivation to participate in class, which gives us the possibility to teach program courses in English language. We also concluded that taught material complexity was not the reason for the students to avoid the classes, and on the opposite, the students desired to study robotics because the subject required significant mental efforts.

Next, we plan to run the same questionnaire in the end of the semester after the final tests and to compare the student answers. We will continue conducting our surveys regularly in order understand students' needs, to improve quality of teaching, student motivation and attained skills of students. In addition, as a part of our on-going work, we analyze industry and academia needs in order to meet labor market requirements by our robotics master program graduates.

Acknowledgement

Part of the work was performed according to the Russian Government Program of Competitive Growth of Kazan Federal University.

References

[1] Y. P. Pokholkov, “National Doctrine of Advanced Engineering Education of Russia in the Context of New Industrialization: Approaches to Development, Objectives, and Principles,” Association of Engineering Education of Russia. Engineering education, vol. 10, pp. 50-65, Oct. 2012.

[2] A. M. Erkmen, T. Tsubouchi and R. Murphy, “Mechatronics education,” IEEE Robot, Automation Mag, 8(2), 4, 2001.

[3] Z. A. Shiller, “Bottom-up approach to teaching robotics and mechatronics to mechanical engineers,” IEEE Transactions on Education, vol. 56(1), pp, 103-109, 2013.

[4] Atlas of new professions. Agency for Strategic Initiatives, an LNA “Skolkovo”, Moscow, URL.: http://www.skolkovo.ru/public/media/documents/research/sedec/SKOLKOVO_SEDeC_Atlas.pdf, 2014.

[5] Kh. G. Tkhagapsoyev, M. M. Yakhutlov, “To the problems of engineering education in modern Russia,” In Quality Management, IEEE Conference on Transport and Information Security, Information Technologies, pp. 224-227, 2016.

[6] I. A. Gurban and Jr, A. A. Tarasyev, “Global trends in education: Russia case study,” IFAC-PapersOnLine, vol. 49(6), pp. 186-193, 2016.

[7] Decree of the Government of the Russian Federation on December 8, 2011 № 2227-r on The Strategy for Innovative Development of the Russian Federation until 2020. // URL: http://www.garant.ru/products/ipo/prime/doc/70006124/, 2011.

[8] M. Rosenblatt, H. Choset, “Designing and implementing hands-on robotics labs,” IEEE Intelligent Systems and their Applications, vol.15(6), pp. 32-39, 2000.

[9] Kh. G. Tkhagapsoyev, M. M. Yakhutlov, “Problems of engineering education in modern Russia: the methods of analysis and ways of solving,” Higher education in Russia. No 8-9, pp. 27-36., 2014.

[10] E. I. Yurevich, “Basics of robotics,” 3nd edition, Saint Petersburg, BKHV Petersburg, 360 p., 2010.

[11] Official message of the President of Russian Federation to Federal Committee, http://kremlin.ru/events/president/news/53379, 01.12. 2016.

[12] Round table “Development of Russian market of industrial robotics”, URL.: http://www.controlengrussia.com/innovatsii/robotics/, 2016.

[13] N. Hativa, R. Barak, and E. Simhi, “Exemplary university teachers: Knowledge and beliefs regarding effective teaching dimensions and strategies,” Journal of Higher Education, vol. 72(6), pp. 699-729, 2001.

[14] J. J. Craig, “Introduction to Robotics,” 3rd ed., Pearson/Prentice Hall, 2005.

[15] P. Corke, “Robotics, vision and control: fundamental algorithms in MATLAB,” Springer, 2011.

[16] G. Dudek, M. Jenkin, "Computational principles of mobile robotics," Cambridge University Press, 2010.

[17] K.S. Bordens, B.B. Abbott, "Research design and methods: A process approach," McGraw-Hill, 2002.

[18] E. Magid, T. Tsubouchi, "Static Balance for Rescue Robot Navigation : Discretizing Rotational Motion within Random Step Environment," Lecture Notes In Artificial Intelligence, Vol. 6472, Proc. International Conference on Simulation, Modeling, and Programming for Autonomous Robot, pp. 423-435, 2010.

[19] E. Magid, E. Rivlin, "CAUTIOUSBUG: A Competitive Algorithm for Sensory-Based Robot Navigation," IEEE/RSJ International Conference on Intelligent Robots and Systems, pp. 2757-2762, 2004.

[20] S. L. Zenkevich, A. S. Yushchenko. “Basics of manipulation robots control,” 2nd edition, M.: Bauman State Technical University publishing, 2004.

[21] Y.V. Poduraev, “Mechatronics: basics, methods, application,” 2nd edition, Moscow : Mashinostroenie, 2007.