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Empirical Study on Robotics Application in Lithuanian Schools*

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Modern learning environment may be developed by using innovative tools and methods, e.g. robotics. Benefits and efficiency of robotics in teaching and learning processes have recently been drawing an increasing focus among researchers. Application of robotics is useful for students while studying Computer Engineering and other STEM (Science, Technology, Engineering and Mathematics) subjects. The article pursues twofold research aim: (1) to perform systematic review of the literature on application of educational robots in schools in order to identify the experience in use of robotics in primary, basic and secondary schools, and (2) to conduct empirical study in Lithuania on the attitude towards use of robotic technologies in education, the related experience and demand, and identify the causes of low use of robotics in teaching and learning. Systematic literature review has shown that robotics has been paving its way as a teaching aid in a more intensive and flexible manner. The findings of empirical study have demonstrated the potential in use of robotic technologies and current related implications in Lithuanian schools.

Keywords: robotics; schools; application; systematic review; empirical study; computer engineering education; innovative tools; innovative methods; semantic web; knowledge society

1. Introduction

Modern learning environment may be developed by using innovative tools and methods [1–3]. Benefits and efficiency of robotics in teaching and learning process have recently been drawing an increasing focus among researchers. Theorists of education e.g. [3] believe that robot-aided activities carry great potential for improvement of classroom teaching: a child learns more effectively when he/she is actively engaged in construction of objects of an outer world. Sullivan [4] has emphasised that robot-involving setting and specific educational methods promote development of cognitive and learning skills. Studies by [5] have shown that robots, user manuals and instructions included into problem-solving activities could help pupils link the experience to scientific concepts. Robotics may become a modern teaching aid in various subjects by applying the respective educational methods.

Formation of skills in information technology, communication and algorithms, as well as education of algorithmic thinking by LEGO technological method has been applied in non-formal education at Lithuanian schools since 2002. Educators have started generating ideas and developing this activity by introducing robotics into teaching of various subjects, as not only do LEGO educational robots inspire children's interest, but they also promote scientific inquiry, subsequent verification of the findings and, in particular, enable children to experiment themselves with physical objects.

Twofold research aim has been set based on the claims found in the literature stating that educational robots are adequate means for improvement of learning, namely:

1. To perform systematic review of the literature on use of educational robots in schools in order to:
   (a) identify the benefit provided by use of the educational robots as teaching aid by pupils in various subjects referred in the research articles,
   (b) provide the synthesis of empirical data for validation of the efficiency of learning aided by educational robots,
   (c) present the synthesis of the described data on the diversity of teaching methods aided by educational robots,
   (d) identify the prospects for scientific research related to robotics in education.
2. To conduct empirical study in Lithuania in order to:
   (a) evaluate teacher's attitude towards use of robotic technologies in teaching and learning,

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(b) evaluate the experience of use of robotics in teaching and learning,
(c) evaluate the potential demand for robotics in Lithuanian schools,
(d) study the current implications related to low use of robotics in teaching and learning at Lithuanian schools.

The rest of the paper is organised as follows: research methodogy and design are presented in Section 2, systematic review results and empirical research results in Lithuania are provided in Section 3, and the last Section presents overall conclusion of the presented research.

2. Research methodology and design

Given that the article pursues two aims, namely, to perform systematic analysis and conduct empirical study in Lithuania, research methodology for the both sections of the research is presented in details further.

2.1 Systematic review

In order to identify the possibilities for use of educational robots for educational goals, basic systematic literature review method devised by Kitchenham [6] has been used. The following research questions have been raised to perform systematic literature review under this method:

1. Question: Has the scope of use of robotics in schools changed in the recent 5 years from today's perspective?
2. Question: How is robotics-aided learning studied?
3. Question: How is efficiency of use of robotics in the educational process verified?
4. Question: What are the teaching methods (teaching strategy) applied when using robotics in the educational process?

Search for systematic reviews has been carried out in order to find any similar systematic reviews on use of robotics in education. Only one study on this topic has been found [7]. Review of the study by [7] revealed the first characteristics of use of robotics in education. The researcher chose peer-reviewed articles published in English during 2000 to 2009. The article [7] presented a comprehensive systematic review encompassing the entire system of general education.

Systematic analysis for achievement of the first aim of this study was carried out in January and March 2014 in the citation database *Web of Science* covering 5 international databases: (a) Science Citation Index Expanded (SCI-EXPANDED); (b) Social Sciences Citation Index (SSCI); (c) Arts & Humanities Citation Index (A&HCI); (d) Conference Proceedings Citation Index—Science (CPCI-S); (f) Conference Proceedings Citation Index—Social Science & Humanities (CPCI-SSH). Only peer-reviewed articles in English published in 2012–2013 (studies during the recent two years) were chosen. The following keywords were entered into the search box: (robotic AND curriculum) OR (robotic AND teaching) OR (robotic AND education) OR (robotic AND school). Table 1 presents the protocol on the citation database *Web of Science*.

The following four criteria were used to filter the articles: AQn, n = 1, 2, 3, 4:

AQ1: Robotic technologies used as a teaching aid rather than a subject.
AQ2: The article presents quantitative or qualitative feedback information on learning.
AQ3: Use of robots by direct contact rather than online is described.
AQ4: The study field covers pre-school education, elementary, basic, and secondary schools, i.e. the article does not analyse a different context, e.g. undergraduate setting.

The search required to perform systematic literature analysis was carried out in stages. The first stage was aimed at finding all articles on robotics published during 2009–2013. This has generated the total result of 230 articles found. The second stage was dedicated to the analysis of titles and abstracts subject to filtering by the mentioned criteria. Nonetheless, elimination of the articles would have been difficult to implement by mere analysis of the

Table 1. Search results in ISI Web of Science database

Result	Protocol
38	(TS = (robotic AND curriculum)) AND Language = (English) AND Document Types = (Article) *Databases = SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan = 2012–2013*
76	(TS = (robotic AND teaching)) AND Language = (English) AND Document Types = (Article) *Databases = SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan = 2012–2013*
32	(TS = (robotic AND school)) AND Language = (English) AND Document Types = (Article) *Databases = SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan = 2012–2013*
84	((TS = (robotic AND education))) AND Language = (English) AND Document Types = (Article) *Databases = SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan = 2012–2013*

Table 2. Results of the articles selection process

Databases	Search result 1 stage	Search result 2 stage	Search result 3 stage
Web of Science	230 (together with repetitive articles)	22	16

abstracts due to the specific nature of the criteria. It was therefore decided to search for more information in the body of the articles. As a result, the articles meeting the set criteria (AQn) were selected upon comprehensive analysis of the articles carried out as the third stage of the search. Table 2 presents the number of articles at the end of each stage of the selection procedure.

2.2 Empirical research

Empirical study in Lithuania was aimed at evaluating teachers' attitudes towards use of robotic technologies in education, the related experience, demand, and causes of the low use with the following research questions raised:

1. Question: What is the experience of work by using robotic technologies in Lithuania?
2. Question: What is the context of use of interactive robotic technologies in educational processes (frequency of use, grade, taught subjects)?
3. Question: What are the tools and software of robotic technologies used by teachers in the teaching process?
4. Question: What is the efficiency of use of the robotic technologies in the context of various subjects?
5. Question: What are the possible causes of the low use of robotic technologies in the educational process?

To answer the raised questions, questionnaire survey was carried out among the teachers. Only the teachers who had experience in using interactive robotic technologies were selected, as the questions were related to teachers' experience of work by using interactive robotic technologies in the educational process. Teachers at 17 Lithuanian gymnasiums (35%), progymnasiums (23%), secondary and basic (24%) schools as well as non-formal educational centres (18%) participated in the survey. Gymnasiums were represented by the best 6 teachers, other respondents were 4 progymnasium teachers, 3 teachers at informal educational centres, and 2 teachers from secondary and basic schools. Questionnaire survey was held after the competition on robotics during the event ROBOTIADA'2013 on 16 March 2013. The questionnaire was distributed among all teachers of Lithuania who attended the event. 37 questionnaires were sent out by e-mail, with the response rate accounting for 18 questionnaires, 1 of which was returned uncompleted. Demographic distribution of the questionnaires suggested that teachers taking interest in use of interactive robotic technologies in the educational process were spread across Lithuania, including towns other than the major cities.

The questionnaire was devised based on the above questions and was comprised of 8 points.

(a) The purpose of the first points was to gather general information about the teachers participating in the survey. The eighth point was open-ended and aimed at receiving reflections on the implications of introduction of interactive robotic technologies into education.
(b) The second point on the experience in use of interactive robotic technologies provided insight into the teachers' competence and the context of use of robotic technologies by the teachers.
(c) Use of interactive robotic technologies in the educational process is fairly new to Lithuania, which leads to the assumption that teachers who use interactive technologies in the educational process have developed high level of competence in use of ICT in education, and this aspect was not subject to separate evaluation.

Statistical method—frequency calculation—was used in the analysis of the data gathered by the questionnaire survey.

3. Results of systematic review

This section analyses the results of systematic review in order to answer the four research questions raised for the first aim of the research. The results are compared to the ones of the systematic analysis carried out by [7]. During systematic review, Benitti [7] performed search in six bibliographic databases and found 70 articles on effective use of robots as a teaching aid, only ten of which provided quantitative evaluation that enabled conducting feasibility study on the use of robotics as a teaching aid at schools.

Each research question is separately analysed further.

1. Question: Has the scope of use of robotics in schools changed in the recent 5 years from today's perspective?

Progress of robotic technologies provides the possibilities for implementation of various learning activities in the subjects relating not only to Science, Technology, Engineering, and Mathematics (STEM). The majority of studies covered in the review by [7] (80%) were focused on the topics relating to Physics and Mathematics. The articles described actual experience in teaching Newton's law, distance, angles, kinematics, graphic construction and explanation, functions, and geospatial concepts [7].

Findings by the authors of this study have suggested that 69% of studies have dealt with topics relating to STEM. 4 studies moved beyond Natural Sciences: two studies were related to education of social skills of communication in autistic persons [8, 9], one study was related to education of social and cognitive skills in kindergarten [10]; while the fourth study dealt with use of robotics in developing English reading skills [11]; robotics is used as a tool in the study by [12], but is not the object of the study. The study analyses the structure of children's speech under problem-solving methodology by applying robots as a teaching aid in STEM [12]. McDonald and Howell [13] analysed topics related to STEM subjects but obtained positive results and the effect on social skills of communication. Only two studies covered by Benitti [7] in his review are noteworthy considering, as they have moved beyond the area of natural sciences: the first study deals with use of robotics in teaching basic principles of evolution, while another study deals with development of social skills of communication in autistic persons [7]. This information suggests that applicability of robotics in schools is expanding and encompasses non-STEM subjects, such as subjects in Social Sciences and Humanities.

Three articles [14–16] were under particular focus, but did not fall under the scope of the article review due to their failure to comply with criterion AQ2. Nonetheless, these articles may help answer the 4th research question, as they describe actual application of robotics and validate the necessity of development of further experimental activities. These articles provide theoretical guidelines and teaching methods applicable to use of robotics in the educational process.

2. Question: How is robotics-aided learning studied?

In terms of the 2nd question, the context of evaluation (types of robots used, information to the respondents, sample size and context of education) was considered. Analysis of articles included into the systematic review has shown that various models of Lego robots (44%) were used in learning activities. Only one article covered quantitative evaluation of robots as teaching aids by using 4 robot platforms: Khepera robot, YAKS Khepera simulator, ExaBot robot Player/Stage simulator for the ExaBot robot and robot behaviour-based interface developed by the researchers [17]. The projects of four scientific studies offered achieving certain learning outcomes by robot kits other than Lego. The researchers proposed developing biological phenomena and analysing trees by using PicoCricket kits and implementing alternative learning methods: "to combine art and technology, provide possibilities of creation of art by young people, develop links not only between motion, but also light, sound and music" [18]. Two scientific studies employed SPHERES Zero Robotics [19] and Robotic Mission to Mars kits [20] for those learning about space. The researchers offered using UniBoard devices and PICAXE microcontrollers for teaching mechatronics [21]. Researchers of four scientific studies used humanoid robots for social interaction, socialisation, communication (with autistic children) and development of speaking skills [8–11]. However, learning activity covered in the review by [7] was predominantly (90%) implemented by using various models of Lego robots. This suggests that the diversity of robotic tools used in the educational process is growing.

Depending on the research participants, learners covered by the systematic review ranged from kindergarten age to senior grades, i.e. learners aged from 3 to 19. In his review, Benitti [7] noted the lack of studies covering usage of robots as a teaching aid for children of kindergarten age and 11–12 graders. [7] assumed that the lack of research on use of robots in kindergartens was due to the minimum age (7 years) limitation on the Lego robot kit, which did not prove true, as two studies [13, 22] clearly use Lego kits in order to identify the role of technology in early childhood education. Other study focusing on early childhood deals with the effect of the new technology offered to professionals in kindergarten education—humanoid robot based on social interaction and providing aid to the staff in engaging children in educational games [10].

Three studies covered the students of senior grades [17–19]. Thus, the learners' age range has expanded in both directions, covering children of kindergarten age and older pupils. Most experiments involving educational robots were not included into classroom activities, i.e. they are usually used in after-school or summer camp program. Exceptions were introduced by five articles, one of which noting that teachers integrated their work into conventional teaching [23], three articles describing use of robots by teachers in one of their classes [10, 12, 13], while the remaining article evaluating different methods of implementing of the programme into the educational curriculum of 5 schools [21].

The situation is very similar to the findings of review by Benitti [7]. Four articles presented an exception: three articles noted that teachers could have integrated their work into conventional teaching, other article dealt with use of robots in one of their classes [7]. The difference is not significant, but there is obvious tendency of inclusion of the robotics into classroom activities and establishment of links between the robotics and curriculum.

3. Question: How is efficiency of use of robotics in the educational process verified?

The findings of all articles demonstrated the benefits brought by learning aided by educational robots. Cuperman and verner [18] claimed that 78% of students who had not yet engaged in the practice believed that practice involving robotic models would be useful. Upon completion of the course, all students claimed that practice involving robotic models, in particular, robots for design and creation indeed helped them learn concepts of Natural Science and Technology. Huskens et al. [8] have described the ability of a robot to create a predictable and simple situation of social interaction, which relieves stress and pressure incurred by children with ADHD during interaction with other people, and allows create a much more pleasant and effective learning environment. Statistical calculations in the study by [17] showed that over 35% of students who had participated in the activity were studying under the graduate programme of Information Science and Technology. These results suggest a rather significant impact of this activity on enrolment of students into STEM-related programmes. In [19], over 85% of mentors and students noted significantly positive improvement in the areas of STEM and leadership skills. According to the survey results, over 75% of respondents claimed to have improved skills in Mathematics, Physics and Programming, while over 90% claimed to have improved leadership skills and skills in development of strategy. According to [13], development of literacy and computational skills was very positive as well. Children encountered new words related to construction, colours, preposition, place, numbers and more complex words used in Engineering. They could operate these concepts beyond the school context as well. Discoveries related to development of skills in interpersonal communication were the most surprising. Children negotiated and learnt to manage difficulties in communication with peers. Although such concepts as taking turns, sharing and sticking to the assigned roles were sometimes difficult to learn, children could work in groups for more efficient mastering of these modes of behaviour during the implementation period of the project. This conclusion was the most surprising and pleasing to the class tutor. According to [23], 39.8% of pupils had satisfactory assessments in Mathematics, while 11.4% of pupils had the lowest assessment scores during the period of three years (2002–2004) before introduction of the programme into the school. Within three years (2007–2009) upon introduction of the programme into the school, 91.2% of pupils on average received sufficient assessment in Mathematics, and no pupils received the lowest scores. According to [24], one of the greatest factors of the effect of the interface noted was robot motion feedback signal involving turns to the left and to the right, which used to be incomprehensible to pupils (children with eyesight disorders).

The study has shown that use of educational robots for improvement of academic achievement is an effective tool in the area of STEM notions.

In terms of skill development by using robotics, the skills formed are directed towards the following: (1) cognitive skills (observation, evaluation and manipulation), (2) educational process skills/problem-solving methods (e.g., evaluative solution, generation of hypotheses and control of the variables), (3) social interaction/team work skills, (4) motor skills and (5) reading, writing and computational skills.

It should be noted that, compared to results of [7], cognitive skills have been mentioned by one article only, whereas even 6 articles of the present review have noted the fact of formation of cognitive skills. Team work skills have also been mentioned in 6 articles. The review has identified formation of such skills as motor skills, reading, writing and computational skills, which are absent from [7]. The review has shown that nearly all articles view robotics as a tool that enhances pupils' motivation to learn.

4. Question: What are the teaching methods (teaching strategy) applied in the educational process?

The review of teaching methods applied by using robots [15] has shown that the most popular methods are problem-based, constructivist and competition-based learning. Besides these main methods, other methods used are discovery learning, communication-based learning, project-based learning, and competition based learning. In terms of teaching main Engineering concepts (design, simulation, limitations, innovations, system optimisation, experimentation, prototypes, compromise, analysis, problem solving, functionality, visualisation and efficiency), usually taught at the pre-college level, Riojas et al. [16] identified the following three proper teaching methods: (1) direct instruction, (2) problem/inquiry-based learning, and (3) project-based learning. Direct instruction is a deductive teaching method viewing learning as a function of change of pupils' long-term memory. Problem- and enquiry-based inductive teaching methods share a lot of common features when used in teaching Engineering at the pre-college level. As a result, these two methodologies are seldom viewed as separate. Project-based learning method is an inductive teaching method, when students apply their knowledge. Of all the above mentioned teaching methods, competition-based learning was the most efficient method of using robots in Mathematics, Physics and other subjects [15]. This was proven by the systematic analysis conducted earlier [7]. Competitions, on the other hand, are focused on a certain group of learners only, robot competitions are rather expensive to hold, and the number of participants is limited for financial reasons [15]. In view of this limitation, effective ways of using robots in Science, Technology and Engineering-related classes for all learners must be explored. Benefits provided by robots must be applied to the wider audience [15]. For this purpose, in order to expand the effect of the summer programme, the proposed programme was altered, i.e. one-week summer programme was replaced with primary school programme for the third grade. This expanded the scope of the programme and engaged students that were not yet interested in STEM subjects [23]. Hung et al. [11] noted in his study that educational robots may enhance students' motivation to learn, but this learning motivation would be difficult to maintain and be subject to gradual reduction, if new technologies were not introduced into the teaching strategy. The effect will be minimal, where robots are not included in the general curriculum, no methods or tools are used to assess the outcomes of the curriculum. Therefore, two ways of inclusion of robots into the curriculum should be used: robots as a learning object and robots as a tool to learn other subjects [15]. Use of robots in the educational process should not be a one-time project, but rather a continued and progressing process from the primary school all the way to the university level [14]. New methods that empower the use of robots in classes are important. Students' interest in robotics is an important factor of the learning process that allows achieving the learning goals.

Robots with special sensors and communication systems, and innovative robot-based curriculum encourage new ways of interaction among pupils [25]. Effective integration of robots as a tool into the teaching process could lead to the shift of teacher's traditional role from the teacher who passes the knowledge to the teacher as a learning assistant, organiser, leader, learning partner, helper and intermediary at all educational stages, including kindergarten [10]. Hence, robots could be claimed to have great potential that is yet to be fully discovered. Studies selected by the authors have suggested the following factors important for effective integration of robots into the curricula:

- Varney et al. [23] identified 3 aspects of successful integration of the programme: (1) graduate students involved as instructors, (2) students provided with the possibility to have direct communication with a University Professor by means of videoconferences, (3) presentation of works by students at the end of each year at the school level. The last aspect inspires interest of other learners in STEM subjects at the same school.
- Teachers' attitude is the only critical internal "variable" in the success formula of introduction of the programme. This has been best demonstrated by comparison between two schools that are completely different by teaching methods (behaviourist versus humanist), levels of experience (experts versus beginners) and infrastructure (advanced versus beginner), but both managed to successfully achieve the project results [21]. Strategy of implementation of the programme in school was also important. Possibility to successfully introduce the programme into the school curriculum was clearly determined by the common climate and decision-making processes in schools [21].
- Nicholas et al. [21] identified internal and external factors that have influence on implementation of robotics in a school. Internal factors: teaching methods, teachers' attitude, programme evaluation. External factors: (1) infrastructure and computer access, (2) time dedicated to organisation and planning (3) need for more help by experts, (4) need for more funds for professional development, (5) need for purchase of more materials for construction of more advanced devices. Different methods of implementation of the programme into the educational curriculum have been evaluated in 5 schools.

The following positive aspects of integration of robotics into the educational process have been noticed:

- Possibilities for simulation by using robot kits that enable combination of Engineering design and research in Natural Sciences into integrated learning activities [18].
- Encouragement of the use of technologies for reduction of the gap between students from

socially supported and self-sustaining families. Help in development of younger learners' skills for those who do not have favourable conditions of digital access [13].
- Involvement of pupils from different social economic and cultural layers [23].

4. Results of empirical research

1. Question: What is the experience of work by using robotic technologies in Lithuania?
In terms of the first aspect of the research, 29% of teachers who participated in the survey used interactive robotic technologies in schools for one year (the largest share of the teachers). The smallest time frame claimed by respondents was 2 months, i.e. a teacher started using robotic technologies in the educational process only recently. The maximum experience of use of the technologies was 8 years, claimed, however, by a teacher who worked at an informal educational centre. Work experience at informal educational centres (3 schools) is specific, meaning that application of the technologies in question in these centres is different from the one in schools:

- children who already are motivated come to the out-of-school activity groups;
- learning outcome is more targeted towards participation in competitions;
- robotics is viewed more as a subject than a teaching aid.

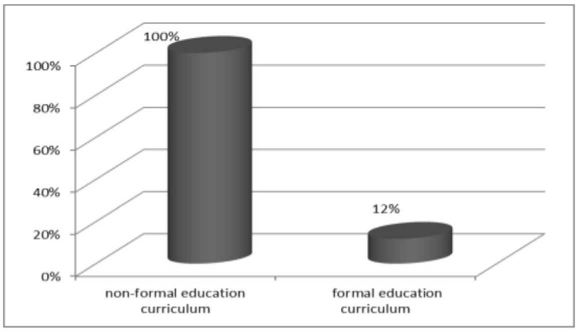

Fig. 1. Application of robotics technologies in curriculum.

2. Question: What is the context of use of interactive robotic technologies in educational processes (frequency of use, class, taught subjects)?
In terms of the second aspect of the research, 100% of respondents used interactive robotic technologies in an informal education curriculum, while only 12% integrated robotic technologies into formal education (Fig. 1.). The latter was claimed by representatives of two schools, where:

- Robotic technologies were integrated into the curriculum of Information Technologies for 9–12 grades, with 8–10 lessons per academic year.
- Robotic technologies were integrated into the educational processes of STEM subjects for 5–8 grades, with 2 lessons per week.

More respondents noted the use of interactive robotic technologies in informal education curricula.

The study found 82% of respondents (14 teachers) using robotic technologies as a teaching aid for the subjects of Information Technologies, Natural Sciences, and Mathematics. Two informal educational centres used these technologies for teaching robotics. One school claimed to have been using robotic technologies as a teaching aid in the subject of Physics (6%).

Robotic technologies were mostly used in 5–8 grades for STEM subjects (65%), 41% in the educational process of primary grades, and 12% in the educational process of 9–12 grades (Fig. 2.).

Pupils of both primary and 5–8 grades (47%) usually had two classes per week.

In Fig. 3, use of robotics technologies for learning Physics in informal leaning is shown:

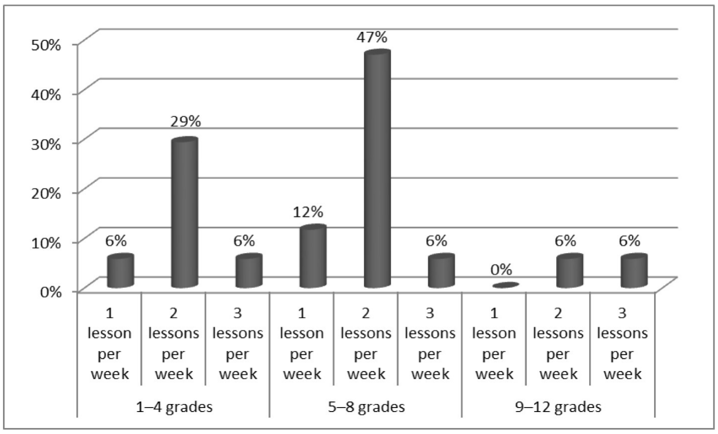

Fig. 2. STEM learning using robotics technologies in different grades.

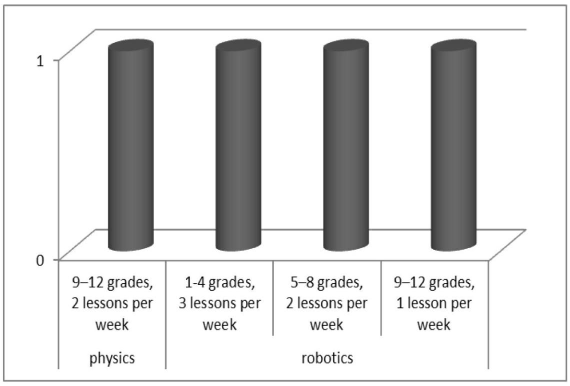

Fig. 3. Robotics in Physics learning in informal curriculum.

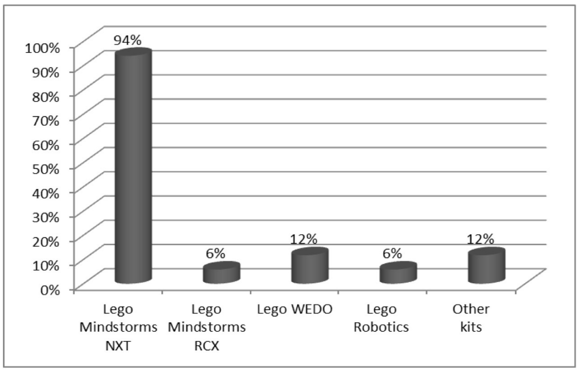

Fig. 4. Used robotics kits.

3. Question: What are the tools and software of robotic technologies used by teachers in the teaching process?
In terms of the third aspect of the research, most teachers have been found to use Lego Mindstorms NXT kits in their practice (94%). A couple of the respondents (12%) use Lego Wedo kits and two respondents (6%) use either Lego Mindstorms RCX or Lego Robotics kits (Fig. 4.). Several respondents have claimed to be using other kits, such as:

- microcontrollers Arduino;
- Raspberry Pi;
- 3pi Robot (Pololu).

This result has suggested the following assumptions:

- Lego Mindstorms NXT kits are used the most for the following reasons:
  - most widely known;
  - the cheapest aid in the market;
  - the best suitable kits as a learning tool because it doesn't require special knowledge;
  - has enough methodological material.
- On the other hand, other robotic kits mentioned in the questionnaire could be used less for the following reasons:
  - less known;
  - expensive;
  - require deeper knowledge of Electronics;
  - shortage of methodological material.

4. Question: What is the efficiency of use of the robotic technologies in the context of various subjects?
In terms of the fourth aspect of the research, the respondents have been found to value the use of interactive robotic technologies in STEM subjects (Fig. 5):

- 70% of respondents believe that use of interactive robotic technologies in the educational process may significantly improve knowledge of students of the entire class or over 50% of the students. Only one respondent believes that use of these

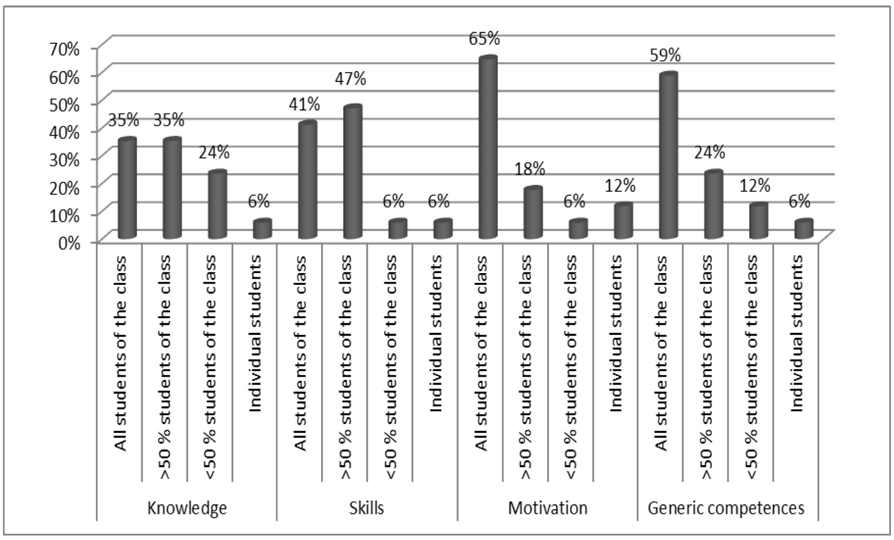

Fig. 5. STEM learning effectiveness using robotics technologies.

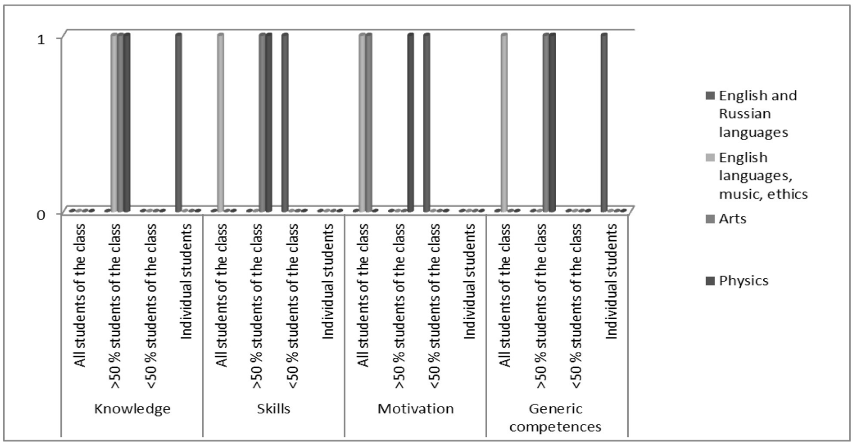

Fig. 6. Other subjects learning effectiveness using robotics technologies

technologies could significantly improve knowledge of individual students.

- 88% of respondents believe that use of robotic technologies may significantly improve the skills of students of the entire class or over 50% of the students. Only several respondents believe that use of these technologies could significantly improve skills of individual students or less than 50% of the class.
- 65% of respondents have claimed that motivation of all students of the class may increase significantly. Nonetheless, several respondents believe that use of robotic technologies increases motivation of individual students only.
- 83% of respondents have agreed that use of interactive robotic technologies in the education process may significantly improve generic competences of all students of the class or over 50% of the students.

The study has determined that use of interactive robotic technologies may be effective in teaching various subjects (Fig. 6). 4 respondents have answered to the question on the subjects, the educational process of which could be successfully complemented by robotic technologies. The subjects indicated by the respondents are Physics, English and Russian languages, Music, Ethics and Arts. Fig. 6 presents the respondents' opinion on the extent to which robotic technologies used in the educational processes of the listed subjects could improve students' knowledge, skills, motivation, and generic competences.

These results have suggested the assumption that use of interactive robotic technologies in the educational process may significantly improve students' knowledge, skills, motivation and generic competences not only in STEM, but in other non-STEM subjects as well.

5. Question: What are the possible causes of the low use of robotic technologies in the educational process?

In terms of the fifth aspect of the research, the following possible reasons of low use of interactive robotic technologies preventing from better integration of these technologies into Lithuanian education have been named (Fig. 7):

- 88% of respondents highly agree or agree that interactive robotic technologies are used rarely in the educational process due to their high price.

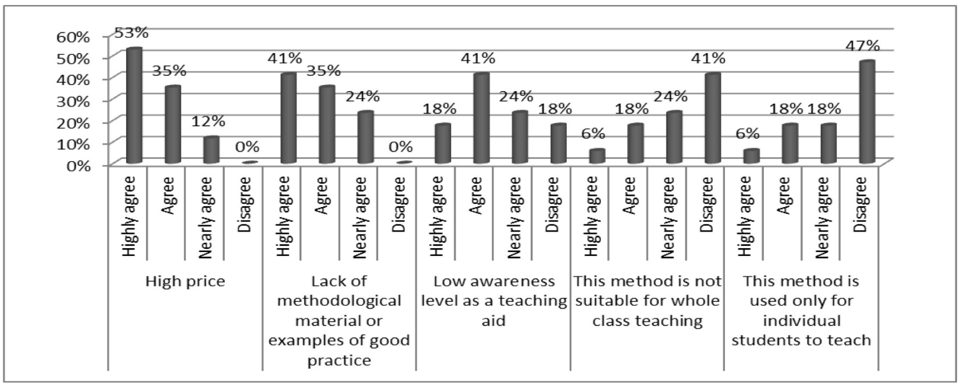

Fig. 7. Possible reasons for low usage of robotic technologies

- 86% of respondents highly agree or agree that there is lack of methodological material or examples of good practice.
- 41% of respondents believe that robotic technologies are little known as a teaching aid.
- 47% disagree with the statement that robotic technologies should not be used for teaching the entire class, while 53% of the respondents disagree with the statement that robotic technologies should be used for teaching individual students only.

These results lead to assumption that:

- Centralised purchase of interactive robotic tools could help schools complete the integration of interactive robotic technologies into the educational process faster.
- Inclusion of methodological material and examples of good practice in the repository of metadata on digital educational resources of the educational portal could provide information on examples of use of the robotic technologies and help use them in the educational process.
- Training of consultants and formation of the network of consultants could lead to regular improvement of competence among teachers wishing to use this teaching aid.
- Dissemination of information on use of interactive robotic technologies in the educational process via the educational portal and regional teacher training centres could promote this teaching aid.
- Interactive robotic technologies in the educational processes are applicable for teaching the entire classes and could be integrated into both informal and formal education.

Analysis of the open-ended question in the questionnaire

The open-ended question of the questionnaire has been aimed at receiving comments or notes on introduction of interactive robotic technologies in education. Ten respondents have provided their comments:

1. *Comment*: "Few schools are able to purchase expensive equipment, and centralised purchase would be needed. Software licenses must also be purchased. There is considerable lack of methodological material not only on the assembly of the robots or their programming, but also possible activities with the chosen robots. All we know there are SUMO competitions, and labyrinth. Training courses involving visits to other countries, where robots have been used in the educational process for several years, would be needed. This would be useful experience indeed".
2. *Comment*: "Schools dedicate too few hours to be able to integrate robotics into other subjects, which means that informal education hours (if any left) are usually dedicated to robotics. Moreover, there is lack of teachers who are able or willing to engage in this activity, this is rather time consuming at the initial stage, when technological possibilities need to be explored and materials need to be prepared. A lot of methodological materials and examples of good practice may be found on the specialised website, active discussions take place in teacher groups. There is lack of material in Lithuanian, but for students who are good in English, resources in English are acceptable. Students perform the best and enjoy the process the most when working in small groups of 2–3 students. In this case, contribution and role of each member is very clear. 5–8 graders note that the most difficult part for them is development of robot control programmes. For a majority of students, this is their first encounter with programing".
3. *Comment*: "Well, I think we should not talk about any specific subject, but rather development of team skills, entrepreneurship and its development, and development of logical thinking. We should also talk about development of duty, responsibility, order and other skills that are not encompassed by individual subjects. All in all, this is a great after-class activity, motivation for better performance at school, timely completion of homework, etc".
4. *Comment*: "Methodological recommendations on use of robots during lessons, in non-formal educational institutions (teachers who have already had experience in this area could be of great help here) should be developed. Development of curricula is integration of robotics into the subjects".
5. *Comment*: "To include Lego robots into the list of mandatory tools at school, to use them by integrating into subjects, to develop methodological material for 2 hours per week of training in informal education".
6. *Comment*: "Using robotics in the educational process (formal, in particular) requires the dedicated premises—space ensuring security of the equipment without the need to put it back into packages each time. The equipment is rather expensive—it is difficult for school to upgrade the equipment, and purchase additional sensors".
7. *Comment*: "One robot is provided for 2–3 pupils, which means that significant funds are needed to work with half of the class, and the school has limited funds. Besides funding, support from innovative managers, eager teacher is needed to speed it all up".

8 *Comment*: "My students and I have been using Lego Mindstorms NXT since the beginning of this academic year. This activity provides motivation to students, they become engaged in learning. We have two robot kits only, which is a significant limitation to their effective use in classes. On the other hand, these tools are expensive, and it is difficult for schools to purchase them without any support. Effective work, however, is achieved in small groups, where 5 students work with one robot. Wide discussions on use of robots in education have started only recently. I think teachers lack workshops, methodological material, which is why I have held a workshop to share my experience with IT teachers in the city of Siauliai".

9. *Comment*: "Only younger students are highly interested in robotics. Among older children, only male students and those interested in engineering sciences become engaged. Students who have chosen Humanities or Social Sciences view this as a game".

10. *Comment*: "Robot is a very relevant, modern teaching aid nowadays. "Comenius Logo" is virtual programming, while robot is visual programming. As soon as we have received our robot, there were a lot of pupils wishing to do programming. Within half a year, the interest did not reduce among students. In order to organise a lesson involving a robot, the principle of work in groups must be used. In my experience, the groups should be comprised of no more than 3 pupils. One pupil measures the field, and another develops the source code, while the third performs the tests. If there are more children in the group, they start interrupting each other's functions. Then it becomes difficult organise the teaching process. This means that at least 5 robots are needed for one class (15–20 students). It's a pity that this is only a dream yet".

Thus, all teachers' notes on introduction of interactive robotic technologies into education are positive. Several remarks on successful use of learning object repository, namely, on adding information into descriptions and introduction of new descriptions, have been provided.

In general, the comments have led to the following assumptions:

- Centralised purchases of the robotic tools and software licenses are needed.
- Methodological recommendations on use of interactive robotic technologies in the educational process in Lithuanian language are needed for organisation of classes of informal and formal education.
- Professional development courses are needed to enhance the teachers' competences.
- Workshops abroad are needed to learn about actual experiences in other countries.
- Support by innovative managers is needed.
- Development of curricula—integration of robotics into the subjects—is needed.

Robotic technologies are a great tool for the following:

- development of skills of teamwork, entrepreneurship, development of entrepreneurship, and logical thinking;
- development of the sense of duty, responsibility, order and other skills;
- motivation for better learning, timely completion of homework;
- after-class activities for children;
- adequate for pupils of any age, in particular, encouragement of younger pupils to take more interest in technological and engineering sciences;
- visualisation and maintenance interest among children.

5. Conclusion

The first aim of this study is to present the systematic review on recent literature dealing with the use of robots in education in order to see the change in the scope of application of robotics as a teaching aid in primary, basic and secondary schools, provide summary of the facts obtained by empirical research and identify the prospective areas of future research.

The results of the study have shown that the scope of application of robotics in schools continues to expand and encompasses not only STEM, but also non-STEM subjects (Social Sciences and Humanities). Wider range of skills developed during use of robotics in education has been noticed as well. The diversity of robotic tools used in the educational process has been expanding. The range of learners' age has expanded and is now 3 to 19 years old, encompassing children of kindergarten age and older pupils. The tendency of inclusion of robotics into classroom activities and establishment of links between robotics and curriculum has been noticed, but more empirical research and the related findings are needed. Moreover, use of robotics is an alternative way of teaching and learning subjects that, as demonstrated by the study, are not closely related to the area of robotics.

This teaching aid may find wide application in the educational context; however, the specific teaching methods adequate for using educational robots in the process must be identified and linked to the general curricula. This study has been based on 16 articles included in the same citation database and filtered by using the selected search criterion. This study may therefore be viewed as an attempt to study the potential and application of educational robots in the Lithuanian educational context.

The empirical study has been conducted in Lithuania for evaluation of the attitude, experience, and demand reasons for low use of robotic technologies in education, and has shown that the main reason for the robots to be used in the educational process in Lithuania is mostly based on the teachers and pupils' impressions. Perception of use of robotics in education may be limited in Lithuania. Nonetheless, robotics may be used as a tool in teaching sciences through inquiry-based or problem-based strategies.

This study has opened new perspectives for future research with the focus on students' experience related to educational robots by linking this experience to general curricula and identifying adequate educational methods. Assessment tools must be developed for this area and applied for large sample. This is the area that still provides inaccurate results.

The conducted study will, hopefully, provide educators, specialists and researchers in education and science with useful knowledge.

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