

## A review of social robots in classrooms: Emerging educational technology and teacher education

Violeta Rosanda<sup>1</sup> and Andreja Istenič Starčič<sup>2</sup>

<sup>1</sup> PhD student, Faculty of Education, University of Primorska Cankarjeva 5, SI-6000 Koper, Slovenia, E-mail: vrosanda@yahoo.it  
ORCID: 0000-0002-3992-963X

<sup>2</sup> Professor, University of Primorska Faculty of Education Cankarjeva 5, SI-6000 Koper; University of Ljubljana, FGG, Jamova 2, SI-1000 Ljubljana, Slovenia  
Kazan Federal University, Institute of Education and Psychology, Kremlyovskaya St, 18, Kazan 420008, Respublika Tatarstan, Russija, E-mail: andreja.starcic@gmail.com  
ORCID: 0000-0003-0513-5054

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### Abstract

The 21st century is the age of robots, an age in which we are witnessing the development of social robots for education. In the future teachers will be required by the labour market to prepare students for work with robotic technology and co-work and interact with robots. Initial teacher education needs to follow the development of robots and prepare students and teachers in applying robotic technology in teaching. In the review study, we aim to identify how robotic technology is applied in classrooms on different educational levels and subjects. We performed a review of the Web of Science Database for the period between 2006 and 2018. The analysis categories included: the educational level and research participants who experienced social robot activities, subject areas, outcome types and robot-learner interaction time. We also examined the research design and publication source. Findings indicate that the educational-pedagogical aspects in the studies often represent more a vehicle, rather than a final goal of integrating robots into teaching practice. The studies reviewed focus mostly on mixed human-robot interaction (HRI) and educational-pedagogical outcomes. Robotic learning activities are prepared in the function of research goals, and not for the introduction of robots into regular teaching practices. They engage a small number of students in a diversity of learning contexts. Robot-learner interaction takes place primarily as a unique experience or as several short-term ones, during fragmented activities that rarely approach the time unit of the lesson. Robots carry out short, detailed tasks in classrooms for which lengthy studies and preparations have been required. The novelty of this work is in focusing also on (1) The demarcation between the focus of studies on educational-pedagogical outcomes; educational-pedagogical and HRI outcomes; HRI outcomes; (2) study of the robot-learner interaction time dimension.

**Key words:** social robot; co-present robot; artificial intelligence, educational technology; teacher education.

## Использование социальных роботов на занятиях: перспективные образовательные технологии и педагогическое образование

Виолета Розанда<sup>1</sup> и Андреа Истенич Старчич<sup>2</sup>

<sup>1</sup> Аспирант, Педагогический факультет, Приморский университет, Копер, Словения  
E-mail: vrosanda@yahoo.it  
ORCID: 0000-0002-3992-963X

<sup>2</sup> Профессор, Педагогический факультет, Приморский университет, Копер, Словения;  
Люблянский университет, Любляна, Словения;

Казанский федеральный университет, Институт психологии и образования,  
Казань, Россия

E-mail: andreja.starcic@gmail.com

ORCID: 0000-0003-0513-5054

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#### **Аннотация**

XXI век – это время роботов, время, когда мы наблюдаем разработку социальных роботов для образования. В будущем на рынке труда будут востребованы учителя, которые применяют в своей работе роботов, и преподаватели, которые могут подготовить студентов к работе с робототехникой. Руководителям высшего педагогического образования необходимо следить за разработками в сфере робототехники, готовить студентов и преподавателей к использованию роботизированных технологий в обучении. Цель данного исследования – выяснить, как роботизированные технологии применяются на занятиях по разным дисциплинам на разных уровнях образования. Авторами статьи были проанализированы результаты исследований, опубликованных в изданиях, индексируемых в базе данных Web of Science, за период с 2006 по 2018 гг. Категории анализа: уровень образования; участники исследований, знакомые с работой социального робота; предметная область; продолжительность и результаты взаимодействия робота с учащимися. Были также изучены методы исследований и источники публикаций. Результаты анализа показали, что образовательно-педагогический аспект в исследованиях зачастую представляет собой средство, а не конечную цель использования роботов в преподавательской деятельности. В проанализированных статьях основное внимание уделяется смешанному взаимодействию человека и робота (HRI) и академическим результатам. Задания с использованием робота разрабатываются в зависимости от целей исследования, а не для внедрения роботов в практику преподавания. Задания предназначены для небольшой группы студентов, при этом формат занятий разнообразен. Оставаясь уникальным опытом, взаимодействие робота с учениками происходит прежде всего во время упражнений, которые в большинстве случаев не рассчитаны на целый урок. На занятиях роботы выполняют небольшие, конкретные задания, что требует длительной подготовки. Новизна настоящего исследования заключается в том, что в нем дифференцируются научные труды, направленные на изучение а) образовательных результатов, б) академических достижений и результатов HRI, в) результатов HRI. Кроме того, авторами изучен временной аспект взаимодействия робота с учащимися.

**Ключевые слова:** социальный робот, сопричастный робот, искусственный интеллект, образовательные технологии, педагогическое образование.

#### **Introduction**

The 21st century is the age of robots. The 20th century was the age of computers and information-communication technology; currently, we are witnessing the development of robotic educational technology. Future teachers will face the requirements of the labour market to train skilled professionals for work with robotic technology, and co-work and interact with robots. Robotic technology entered factories, laboratories and is now emerging in interpersonal relationships and day-to-day life (Edwards, Edwards, Spence, Harris & Gambino, 2016). The educational sector could follow a similar development if the initial teacher education curriculum were flexible enough with the introduction of new technologies. In the past, a significant criticism was made of preservice teacher education that it fails to prepare student-teachers for confident use of technology despite the assumed digital literacy of student-teachers and the children they will eventually teach (Starcic, Cotic, Solomonides & Volk, 2015). Presumably, the new generations of students and teachers will already have experienced robotic technologies in their daily lives, which could then be capitalised upon. Future teachers will be required by the labour market to be skilled professionals capable of working with robotic technology and of co-working and interacting with robots.

A German study by (Reich-Stiebert & Eyssel, 2016), examined teachers' attitudes about teaching with educational robots. Findings indicate the teachers' enthusiasm for the motivational potential and source of information that robotic technology can offer. Teachers indicated concerns with the potential interference with teaching processes, increased workload, and the fear of robots engaging in interpersonal relationships.

In this review, we aim to identify how social robotic technology is applied in classrooms at different educational levels and subjects. The introduction of new technologies into education is often accompanied by high expectations, as was also the case with the introduction of the first computers and later information-communication technology (ICT). Hence, what can we expect from the current social robotic technology? The goal of social robotics is to develop a robot that will be able to reasonably communicate (Linert & Kopacek, 2018) and "achieve symbiosis with humans" (Nomura, 2017, p. 1). According to Kanda, Sato, Saiwaki & Ishiguro (2007), we need to establish friendly relationships with social robots. A social robot is defined by Edwards et al. (2016) as "an autonomous, physically embodied robot that interacts and communicates with humans by following social behaviors and rules attached to its role."

Robot education technology raises contradictions: some see great potentials (Benitti, 2012; Mubin, Stevens, Shahid, Al Mahmud & Dong, 2013; Nikolić, 2016; Crompton, Gregory & Burke, 2018); others ask about its meaningfulness and necessity in educational environments (Sharkey, 2016).

Researchers want to equip social robots with intelligence so they can use them in all subject areas (Pachidis, Vrochidou, Kaburlasos & Kostova, 2018). Cheng, Sun & Chen (2018) present three ways to use robots in education: a) as a learning aid, for example for repetitive tasks; (b) to facilitate learning, for example, through attractive and real-life activities, and (c) to promote skills for the 21st century, for example problem solving skills.

Robots are mainly introduced into education in robotics, maths (Mubin et al., 2013; Benitti, 2012), physics (Benitti, 2012; Spolaôr & Benitti, 2017), engineering courses (Spolaôr et al., 2017), computer science (Mubin et al., 2013; Spolaôr et al., 2017), mechanics and digital signal processing (Spolaôr et al., 2017), geometry, foreign language learning, kinematics and music (Mubin et al., 2013). They are used to support teamwork (Benitti, 2012; Spolaôr et al., 2017; Toh, Causo, Tzuo, Chen & Yeo, 2016), problem solving (Benitti, 2012; Cheng et al., 2018), cognitive processes (Mubin et al., 2013; Spolaôr et al., 2017; Toh et al., 2016), concept development in STEM, reasoning skills (Benitti, 2012) and development of conceptual and language skills (Toh et al., 2016).

In education, most commonly used are:

- mechanical robot design kits Lego (Benitti, 2012; Mubin et al., 2013; Pachidis et al., 2018; Xia & Zhong., 2018), more precisely Lego Dacta, Evobots (Lego), Lego Mindstorms (Benitti, 2012; Karim et al., 2015; Spolaôr et al., 2017), Lego NXT Mindstorm kit + GPS (Benitti, 2012) and Thymio (Mubin et al., 2013);
- electronic robotic kits, such as BoeBot (Mubin et al., 2013; Spolaôr et al., 2017), Parallax and Arduino (Mubin et al., 2013), and
- humanoid robots such as NAO (Belpaeme, Kennedy, Ramachandran, Scassellati & Tanaka 2018; Mubin et al., 2013; Pachidis et al., 2018), and Robovie (Mubin et al., 2013). In special education, the robot NAO prevails (Pachidis et al., 2018).

Research on the use of educational robotics focuses on the younger population. Hong, Chew & Meng (2016) determine the focus on educational levels from kindergarten to middle schools, Xia et al. (2018), the age group between 3 and 18 years of age; (Belpaeme et al., 2018) with an average age of 8.2 years (SD, 3.56). Researchers are mainly focused on the study of the affective domain, but less on the evaluation of the cognitive domain (Belpaeme et al., 2018). Researchers recruit a small number of participants (Benitti, 2012;

Xia et al., 2018). According to Xia et al. (2018), 66.67 % of the samples were made up of less than 80 participants. Real experimental criteria were taken into account only by 20% of studies (Benitti, 2012). Mubin et al. (2013) point out that there are no well-defined curricula and learning materials for teachers when using robots in education.

### *The focus of the review*

Our review investigates the implementation of copresent social robots with teaching purposes in classroom settings and specifically in areas other than the teaching of subjects that are closely related to the field of robotics. For the study, we focus on copresent social robots, which create the expectation of being able to engage in social interaction. By implementing robotic technology in the human image of robots in the classrooms, we expect human-like activity. In the classroom, a robot can either take a passive role of a learning tool or an active role as a "source of instruction in its own right" (Edwards et al., 2016, p. 628). We were interested in a robot with an active role. Johal, Castellano, Tanaka & Okita (2018) explain, "the breakthrough of robots in everyday teaching practice is not yet visible." What is the use of the chosen robotic technology, therefore, from research studies? Social robots behave in the classroom in accordance with the social role assigned to them (Edwards et al., 2016). Copresent robots are physically embodied and physically present in the user's space (Li, 2015). Fong, Nourbakhsh & Dautenhahn (2002) distinguish four categories of embodied robots – anthropomorphic, zoomorphic, caricatured, and functional. They ultimately find that the robot's form, structure and physical appearance are important when it comes to the human's interaction with the robot. This is particularly true concerning the way humans treat the robots and in the development of social interactions.

#### The appearance of robots

- a. directs the way of communication and relationships of people with robots (Phillips, Ullman, de Graaf & Malle, 2017);
- b. shapes the expectations of people about the robot and its abilities (Phillips et al., 2017), in particular the expectations of the robot's ability to establish human relationships (Sharkey, 2016), which affects the interaction between human and robot. Expectations lead people to decide on potential further interaction with a robot (Phillips et al., 2017). Kanda et al. (2007) found that this interaction in the classrooms is often extinguished after initial enthusiasm, because in the long run, the robot teacher does not meet the expectations of pupils beyond robot's ability;
- c. the appearance of robots also affects people's expectations of what roles and jobs should a robot perform (Phillips et al., 2017).

Social interactions are important for the learning process and the cognitive development, it hence also needs to be considered in the case with learner-robot interaction (Belpaeme et al., 2018; Mubin et al., 2013). According to Mathur & Reichling (2016), human-robot social interaction is governed by the elements of human psychology. According to Phillips et al. (2017), people expect the robots of the future to look like a human. Perhaps therefore, in the communication between robots and humans, the following factors are important: a robot's ability to communicate, the capacity to approach human ability to communicate (Kanda et al., 2007), the coherence of its verbal expression and gesturing, and the behaviour appropriately assigned to them. It is assumed that "people prefer to interact with machines in the same way that they interact with other people" (Fong et al., 2002, p. 4). However, robots are capable of social interaction only "within scripted activities" (Serholt, 2018, p. 250), which will be particularly important for robots in education.

We based our review on the following research questions:

- 1) At which educational levels, were social robot learning interventions conducted?
- 2) How many learners experienced social robots learning activities?
- 3) Which type of results were researchers aiming at?
- 4) What was the duration of social robot-student interaction time?

## Method

The review study was conducted in two stages, at the first stage; an automatic search was conducted in Web of Science. At the second stage, a manual search was performed in selected journals that were identified as having the most relevant papers published.

### *Inclusion and exclusion criteria*

We investigate the implementation of a) copresent (Li, 2015) social (Edwards et al., 2016) robots for teaching purposes, b) in classroom setting, c) »in areas other than teaching of subjects that are closely related to the field of Robotics« (Benitti, 2012), d) creating in learners the expectation about their ability to engage in social interaction.

Exclusion criteria were:

- The domain of robotics learning activities, robot building, robot programming, mechatronics (Benitti, 2012);
- Robot used as a tool or subject of study;
- Healthcare training activities;
- Special education;
- Therapy domain;
- Zoomorphic robots;
- Telepresence robots (Telepresence robots are used for telepresence communication between pupils and remote teachers or pupils in different classrooms. (Sharkey, 2016)

### *Coding scheme*

The analysis of the research topic is based on an adapted model by Istenič Starčič and Bagon (2013). We extracted the following information:

- Journal title;
- Publication year;
- Publication source;
- Research type (developmental, descriptive, experimental);
- Type (learners, teachers and other groups) and number of study participants who experienced robot interventions;
- Educational level (pre-primary, primary, secondary, tertiary, lifelong learning);
- Subject area;
- Types of robot-learner activity outcome (educational-pedagogical, HRI outcomes or mixed);
- Robot-learner interaction time in terms of learner-robot interaction session numbers and time dimension;

## Results

In the selection process, we did not set time limits for the year of the first release. The earliest published work appeared in 2006. There was a growing, otherwise non-uniform, interest between 2006 and 2018 in papers studying the selected robot. The growth between 2010 and 2014 was marked (Figure 1).

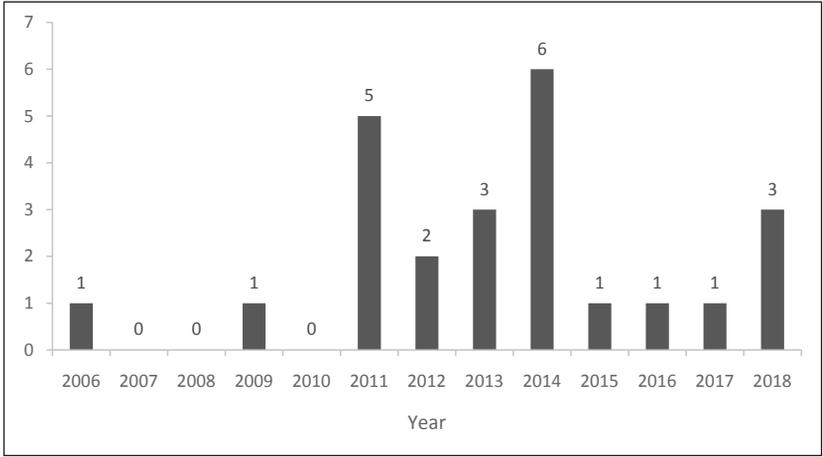


Figure 1: Literature by publication year

*Research design and publication source*

We examined what kind of test aims were set by the researchers and in what areas most papers were published. Most of the publications were in technical sources, which is also indicative of the study of robotic technology in education. The type of sources with the highest number of published studies indirectly indicates the developmental level of robotic technology when it comes to its classrooms utilization. We assume that if the robotic technology were to be advanced enough, the main focus of research, of at least some studies, would focus on pedagogical-didactical issues. We would hence have expected a description of good teacher practices in the utilization of robots in the classroom. This is, however, not the case as all of the research reviewed focuses on robot developmental or experimental design.

Reviewed papers are predominantly the result of developmental research projects aiming to improve HRI or the development of selected robotic technologies for future classrooms utilization. This is also confirmed by the publication sources. Most studies (16 of 24) are published in the IEEE database (see Figure 3), which is the "organization for the advancement of technology" and not in Educational Technology databases.

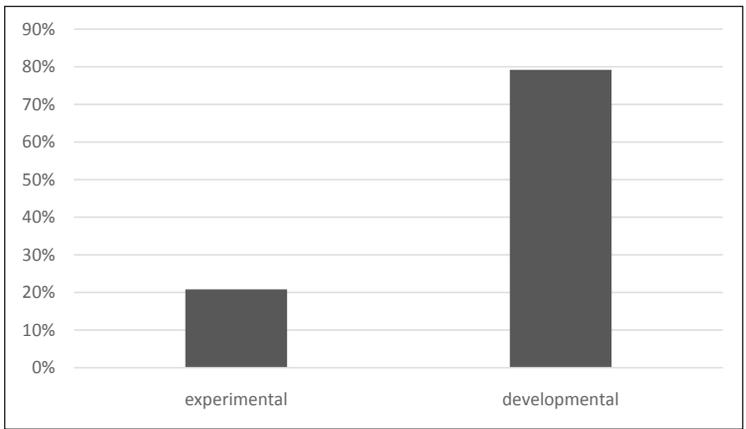


Figure 2: Literature by Research design

As mentioned above, most of the studies (16) were published (see Figure 3) in the IEEE Xplore database, followed by Computers and Human Behavior (3 studies). We have obtained one article from each from the databases of BJET, Computer & Education, International Journal of Advanced Robotic Systems, Journal of Human-Robot Interaction and Plos One. In the remaining databases, we did not find papers addressing our research questions.

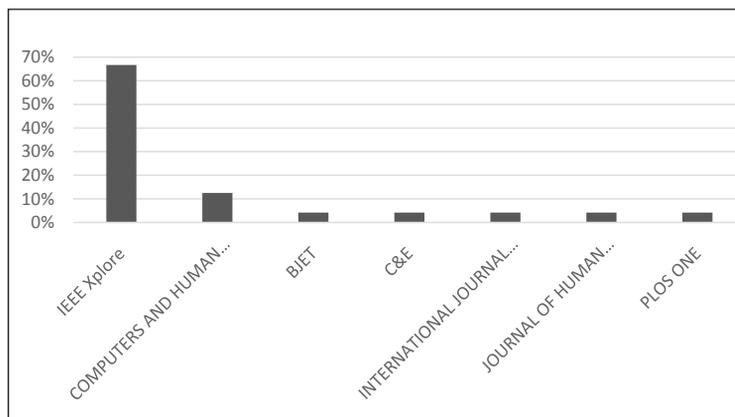


Figure 3: Literature by publication source

### Study participants

Study participants were categorized as learners, teachers, teachers and learners, experts or other groups. 19 papers were engaged with learners, 4 with learners and teachers and 1 with learners, teachers and teaching assistants. In this review, we focused only on aspects that are directly related to robot-learner interaction.

### Number of study participants

Reviewed studies focus mostly on a small number of learners (see Fig. 4), most often between 11 and 20 participants (25 %), with 20.83 % focusing on groups of 21-30 and 20.83 % focusing on 41-50 participants. The minimum number of study participants considered is 6, and the largest is 190 participants. One study does not indicate the number of participant learners.

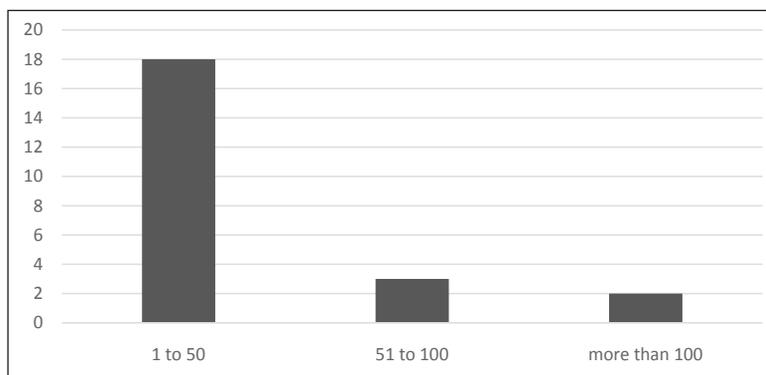


Figure 4: Number of learners

*Participants educational level*

The educational levels at which the robot learning activities were conducted with students were ranked in Pre-primary (age 3-5), Primary-lower (age 6-12), Primary higher (age 13-15), Secondary / High (age 16- 18), University and Lifelong-Learning. Nine studies simultaneously take place at different levels of education; no study is involved in Lifelong-Learning. Most often (14 times), researchers studied the Primary lower educational level, followed by the Preprimary, Primary and University levels (4 times each) and Secondary high, which was studied 3 times. The age of one of the participant's group was not specified.

13 studies treat study participants at one educational level, 9 studies simultaneously address two educational levels, and two studies three levels. The majority of the studies are focused on the 3 to 12 pupil age range. This corresponds to the Primary-lower and Pre-primary educational levels.

*Robot learning subject area*

Robots were used for teaching and/or learning selected concepts in science, technology, and mathematics (9), English (7), geometry (1), computer science (1), sign language (1), subjects of preschool age (2), stone-age items, maths tables, weekly spelling tests (1), geography and sustainable development (1). One article does not specify the subject for which the teacher robot was utilized.

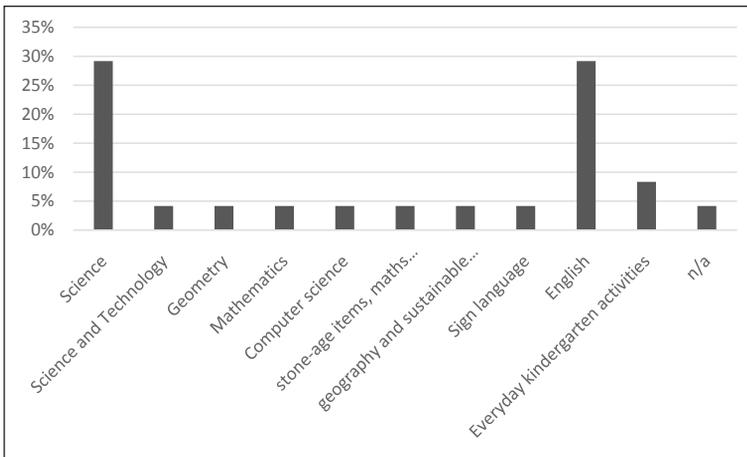


Figure 5: Studies by subject area

Robot learning activities in classrooms were carried out within school subjects as well as in associated and extra-curricular activities. When they took place as part of the school curriculum, they were also occasionally a formal part of the syllabus.

*Outcome types*

The topics used for the teaching activities were usually confined and limited in scope. The main interest of most of the papers reviewed was not the analysis of the effectiveness of the robot's teaching activities, neither was the effectiveness and outcome of the learning process. In an attempt to categorize the learning outcomes of the studies we came to the conclusion that the topics taught, and the pedagogical process was commonly considered merely as a tool to research. Hence the learning achievements of the pupils were not the main focus

of any of the studies reviewed. In many cases, the paper focuses on the introduction of robots into classrooms (Sharkey, 2016) and on how to improve robotic technology almost exclusively.

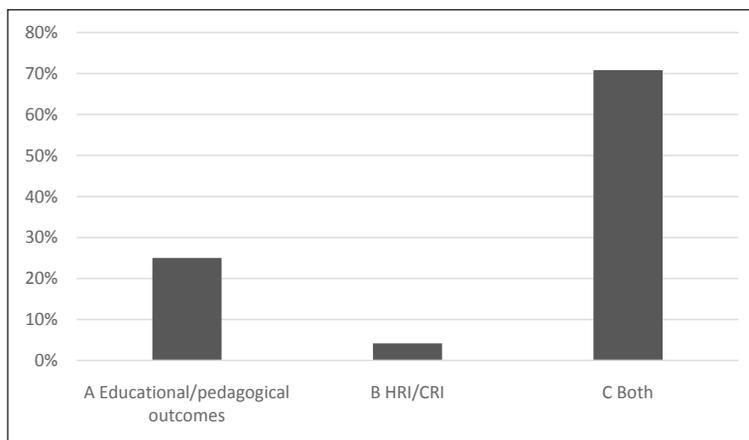


Figure 6: Studies by types of outcome

Therefore the outcomes were categorised in educational-pedagogical; educational-pedagogical and HRI outcomes; HRI outcomes; and other outcomes. Review studies reported more on educational-pedagogical and HRI outcomes (17); than educational-pedagogical (6) and HRI (1) outcomes. None researched other outcomes.

#### *Robot-learner interaction time*

The pedagogical aspects of robot learning activities in the classrooms have not yet come to the forefront. There are too many technical limitations. From the methodology of the reviewed literature, we found that the main goal of most performed investigations was not merely pedagogical. The choice of learning topics was more a function of testing what in the class can be assigned to the implementation of the robot and how. The search for concrete ways of systematic introducing robots in regular courses of individual subjects has not been carried out

That is why we studied the time dimension of robot activity in classrooms or the length of the learner-robot interaction in the classroom. One of the prerequisites for successful teaching activities is the appropriate duration of their implementation. On the other hand, extending the timing of the implementation of the learning activity requires a suitably equipped provider.

In this research, we examined the timing of learner-robot interaction sessions, the number of interaction sessions in this range, and the total time of robot-learner interaction per learner. The introduction of a robot into the classroom is a new and exciting experience for students in the initial phase. Robots easily attract the initial attention and keep it for a while (Fong et al., 2002), but "the novelty effect wears out over time" (You, Shen, Chang, Liu & Chen, 2006, p. 5). This also happens to human teachers. Every successful teacher of any learning activity must, therefore, be able to maintain a good level of interaction with pupils in an appropriate time dimension.

We examined how many studies were limited to a unique robot-learner session in the classroom context, the number of robot treatment sessions that exceeded the unique session, the period between the first and last learning experiences and the total time of robot-single student interaction in individual research. Researchers try to eliminate posi-

tive novelty effects of introducing robots into the classrooms by introducing time delays between individual robot-learner sessions. Of course, when sessions do not run in sequence the stated periods represent only the time length during which the interaction has occurred. They do not, however, reflect upon the continuity of the interaction. Robots maintain a long-term interaction with difficulty because they cannot meet the pupils' expectations in the long run, whereby students' interest in interacting with a robot is reduced or interrupted (Kanda et al., 2007).

10 studies deal with a unique interaction session of a robot with a target group of learners. 6 of these took between 40 and 60 minutes, while the remaining 4 were from 20 to 30 minutes. The shortest lasted between 20 and 25 minutes, the longest four 1 hour each. The robot-learner interaction time dimension can also be the first indicative robot-relevance indicator for integration into regular teaching practice. Most robots with an interaction time approaching the lesson, which is between 30-60 minutes, worked in a teleoperated mode or with a certain level of human supervision. Beer, Fisk and Rogers (2014) categorise robot autonomy in HRI along a continuum ranging from teleoperation robots with less autonomy to fully autonomous robots. Hashimoto, Kobayashi & Kato (2011, p. 766) explain, "since intelligence technologies for robots are still impractical, robots cannot interact with human autonomously even though they can perform effectively in limited environments or limited situations."

In four studies, 2 to 5 sessions were conducted over a period of less than a week to three weeks, with a total interaction time of about 80 minutes per individual pupil. We could not determine the learner-robot interaction time for one study in this group. Two studies were considered with between 6 and 9 sessions, one in a time interval of 6 months, of which 13 weeks were active experimental days, and approximately 137.5 minutes of total interaction time per learner was performed. The other research had an interaction time of 16 weeks, with 360 minutes of actual interaction between a student and a robot. A study with ten interactive sessions lasted 10 weeks, with a total of 10 learner-robot interaction hours. For seven surveys, we do not have data on the number of robot sessions per participant group. For six of these, we do not have any data on the time dimension of the learner-robot interaction, and one can only be defined in time by the fact that the robot was present in the class for "a continuous two week period" (Baxter, Ashurst, Read, Kennedy & Belpaeme 2017, p. 1).

## Discussion

The findings indicate that the implementation of social robots in the classroom is currently mainly in the function of robotics research goals, and not aimed towards the immediate introduction of the robot into regular teaching practice. The studies reviewed focus mostly on mixed human-robot interaction (HRI) and educational-pedagogical outcomes. Robotic learning activities are prepared for these research goals, and not aimed at the introduction into regular teaching practice. They engage a small number of students in different learning contexts. Robot-learner interaction takes place primarily as a unique experience or as several short-term ones, as a set of time-fragmented activities that rarely approach the time unit of the lesson. Robots carry out short, detailed tasks in classrooms for which lengthy studies and preparations have been required. Teacher-educators and teacher-practitioners should take part in the research and development of educational robots. The novelty of this work is in focusing also on (1) the demarcation between the focus of studies on educational-pedagogical outcomes; educational-pedagogical and HRI outcomes; HRI outcomes; (2) the study of the robot-learner interaction time dimension.

From an increase in the number of published research papers, there is an uneven increase in the interest of researchers for our focus on categories of robot. Most the

studies reviewed (19 or 79.19 %) belong to the category of developmental research design. Descriptive articles with descriptions of good teacher practice concerning the use of the robot in the classroom were not found. Robots are, in fact, not yet included in everyday teaching practice (Johal et al., 2018). This is also indicated by the fact that 66.67 % of selected studies are published in the IEEE Xplore database.

Research is mainly concerned with learners, most often aged 3 to 12 years of age. Perhaps robots need to progress throughout the developmental stages from childhood to adulthood, and hence the age groups in which they work show their developmental maturity. Fong et al. (2002, p. 35) refer to the developmental approach, which "suggests that the path to a mature social robot begins with an immature, childlike robot that employs the appropriate learning mechanism".

In most cases, the sizes of the groups used for the research were small and very few groups were used in the research. In some cases, the classes were composed purely for the purpose of the research. Only in a few cases when the robotic teaching activities were led as a part of the normal school curriculum, they were also a formal part of the syllabus.

Learner-robot interaction took place either as a unique session or as several short-term and time-fragmented interactions. The robots carried out short and detailed tasks in the classrooms for which long, sometimes also long-term preliminary technical and psychological-pedagogical studies and preparations were required. In the implementation phase, people involved in the role of a human teacher, robot controller, experimenter, and experimenter who acted as a human teacher needed to be involved. The number of these applications and the level of their participation are different depending on the different mode of robot operation. Most human control is necessary when the robot is running in a teleoperated or remotely controlled mode, which means it is commanded directly by the human operator and executes exactly the operator's instructions. The most autonomous is the operation of robots in autonomous mode. Studies with the longest single interaction sessions in our review, that is, with a time of 30-60 minutes, which usually includes the normal length of a school lesson, used predominantly teleoperated or remotely controlled robots.

Interaction sessions are short due to technical limitations. One of the main issues was frequent breakdowns. Serholt (2017), in her experiment with approximately 137.5 minutes of interaction time between the individual pupil and the robot listed 41 breakdowns, which in most cases had to be solved by the researcher. Also problematic is the long-term preservation of learner-robot interactions. For the use of robots as a source of instruction in 'their right, the ability to perform long-term interaction is an important characteristic. It is already known that after the initial enthusiasm for the robotic novelty in the classroom, the HRI begins to decline because pupil expectations exceed the robot's abilities (Kanda et al., 2007). Most researchers are trying to solve this problem by performing interaction sessions with a distance in time. Examples of continuous long-lasting interaction sessions are rare (Baxter et al., 2017), but they are the only ones approaching the realities of a real classroom environment. Rare are examples of robots operating autonomously without experimental supervision, which the teachers themselves perform during the experiment (Baxter et al., 2017). At the current stage of development, robot technology is not yet able to teach and manage the pupil as a whole, as the teachers do.

Learning outcomes in diverse learning domains of robot learning activities are also questionable. Sharkey (2016) asks, among other things, how a robot should take care of the personal development of students, Serholt (2018, p. 263) notes the child's expectation that the robot will "be able to interpret their intentions, much like human teachers do."

Humans are social beings; the social capabilities of the robots do not, as of now, approach the human capability to understand contexts.

Robot delivered learning content is, in our opinion, aimed at researching robot technology or it is used as a tool for studying the dynamics of introducing robots to the classroom. They mainly do not focus on the educational-pedagogical effectiveness of robot activities. Teaching activities include quantitative and content-limited topics in the fields of science, technology, and mathematics (9), English (7), geometry (1), computer science (1), sign language (1), subjects of pre-school age (2), stone-age items, maths tables, weekly spelling test (1), geography and sustainable development (1). One of the surveys does not define the learning topic. The research goals of individual researches are not predominantly pedagogical. 70.83 % or 17 studies focus on educational-pedagogical and HRI outcomes. We conclude that robots are technically not sufficiently developed to shift research focus from the problems of developing robotic technology to the pedagogical aspects of its use and to developing and evaluating teaching material for robot activities in classrooms.

Robotic activities in the classroom must be very well defined and prepared in detail, technically and didactically in advance. It is also necessary to provide a technical platform for implementation and to ensure the safety of robots and participants in all learning activities. It is not clear what kind of role a teacher should have in the long run in robotic teaching activities. Methods of integrating the robotic technology into the learning process should be shaped in collaboration with teacher practitioners, teacher educators and also student teachers who have the most experience with new technologies.

### **Conclusion**

Based on the answers to our research questions, we conclude that the robot technologies reviewed are still in a technical-developmental phases. Most of the research focuses on the development of robotic hardware and software for education. For this purpose, researchers have designed some teaching materials for the robot teaching activities. These are, in our opinion, in most of the cases, more of a tool than a goal of the study. The educational-pedagogical aspects of the studies are often treated more as a vehicle for the study itself, rather than aimed at the integration of robots into teaching practice. There is also a lack of an appropriate curriculum, of a dedicated role for the teacher working in the class with the robot (Mubin et al., 2013), of an appropriate teaching strategy or methodologies for involving robots in learning activities.

Most of the research still focus predominantly on the problem of further developing robotic technology for educational purposes than on its implementation. The chosen robotic technologies have technically not yet reached the appropriate developmental level for systematic use in everyday teaching practice in a classrooms environment and neither are they capable of supporting various school subjects. Pachidis et al. (2018) note that technical limitations hinder robots, especially when performing complex activities, which undoubtedly include teaching.

This review study about social robotic technology applied in classrooms, on educational levels and subjects, establishes a framework for discussions and considerations when it comes to the introduction of robots in initial teacher education and understanding learning (Starčič, 2019).

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There is no conflict of interest.

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