Humanoid Robots in Education: A Short Review

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Abstract

Robots are becoming useful parts of the education ecosystem with their various capabilities ranging from the ability to perceive people and their environment to the ability to reason and rationalize situations and emotions of people. These robots are also equipped with multimodal interaction capabilities and, equally important, have a physical presence. Humanoid robots, with their humanlike appearance, add another dimension of humanlike body language and social signaling capabilities: keys for more natural and intuitive human-robotEducational

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robots interaction. This chapter presents the applications of humanoid robots in education. The aim of this chapter is not to provide a complete review of all ongoing research works in robot-in-the-loop education but to create awareness about various educationally oriented applications of humanoid robots. The chapter will also discuss the set of the key capabilities such robots should possess, some major R&D challenges, and some ethical and social issues. Therefore, the chapter aims to serve as basis for further investigation for the interested readers.

Keywords
Humanoid robot · Educational robots · Robot-assisted teaching · Socially assistive robots · Human-robot interaction · Social robots

1 Introduction: Robot-in-the-Loop-Based Education

For more than a decade, the use of robots in our education ecosystem has been widely experimented and studied [1], and many findings have been analyzed; most of them are encouraging. Robots have been seen as teaching companions for children, means for entertainment-based education, supplements for special education (e.g., children with autism spectrum disorder (ASD)), teaching assistants to reduce the burden of the teachers, engaging agents for children to study, technology for STEM (science, technology, engineering, and math) education, platform to introduce robotics and programming, co-learner to encourage teaching-based learning in children, and so forth. This chapter aims to explore such various dimensions of robot-in-the-loop education from a particular category of robots, humanoid robots, which take on human characteristics/appearance (even partially). We will also discuss some of the needed functionalities of such robots and the associated R&D challenges. The chapter concludes by pointing toward some projects and communities at the intersection of robotics and education, and the ethical and social issues, centered around robot-in-the-loop-based education (Fig. 1).

1.1 Why Humanoid-Robots-in-the-Loop in Education

In [2], the authors have presented a short review of robots in education, mainly based on the dimensions of the subject (science, language, technology) and the role of the robot (peer, tutor, tool). In some such roles, comparative studies have been conducted to explore the effects of using robots in education. A comparative study in [3] shows that, in the context of teaching new words to children, the children strongly preferred learning with the robot and considered the robot to be more like a person than like a tablet. In another study conducted in [4], a comparison was made among the effects of traditional media (books with audiotape-assisted learning and Web-based learning) and the effects of home robot-assisted learning for children. Compared to the other learning programs, the home robot was significantly superior in promoting and improving children's concentration. Moreover, a recent study

Fig. 1 Representational image of Nao humanoid robot in a classroom

about children's imagination of a robot tutor [5] showed that most children expected the robot to contain a good set of humanlike features and a humanlike appearance (e.g., human with robot-like rectangular head). Other studies also show the positive effect of social humanoid robot [6, 7]. Also humanoid robots have body language and abilities to provide more humanlike social signals; such robots are capable of being more engaging [8]. All of these make the interaction more natural and give additional capabilities such as teaching sign language [9], gesture-based interaction, etc. Further, humanoid robot simulators (e.g., [10]) for education applications are facilitating the implementation of idea of a humanoid-robot-in-the-education loop.

2 Classification of Robot Roles in Teaching

This section will explore different roles of the humanoid robots in teaching. We categorize such robots along the dimensions shown in Table 1, based on the main envisioned role of the robot.

2.1 Teacher Assistant

In public schools particularly, the students are increasingly numerous, and the teachers are ever fewer. Because the modern methods of pedagogy require interaction with the students (lectures are no longer adapted before the college), the teacher should spend more time in individual exchanges with the student. During a language lesson, in front of 30 students, the teacher cannot talk more than a few seconds to each student. Digital assistants, in general, and humanoid robots, in particular, are a potential solution to this problem. Robots can interact individually with a student to

Table 1 Categorization of humanoid robot roles in education

Robot role	Main scenario	Examples
Teaching assistant	Humanoid robot is assisting alongside teacher in the teaching process	[5, 7, 8]
Peer and co-learner	Humanoid robot is acting as peer, encouraging student to learn by teaching to the robot	[11–13]
Companion	Humanoid robot is acting as a companion to student	[6, 14, 15]
Entertainer	Humanoid robot is serving as facilitator for education through entertainment	[8, 16, 17]
Telepresence	Humanoid robot is supporting education through telepresence	[18]
Teaching platform	Humanoid robot is served as a platform to learn and experiment with it and its interfaces	[19]

exchange dialogs in foreign languages, to recite a poetry, or to check a multiplication table. Beyond the fact that the robot will be more available, it is not considered as a judge by the student who will be less reluctant to make mistake in front of a robot than in front of a teacher and the other classmates. A game play can be associated to the lesson to improve the commitment of the student.

These arguments are relevant for most of the digital devices that can be used for education, but the embodiment in a humanoid robot shape involves the student in a more physical interaction that is hoped to improve the efficiency of the teaching. One of the best applications of humanoid robots as assistant to the teacher is probably for foreign language lessons. The robots can be permanently available for exchanges in any language even between the lessons. The robot can walk around the school, as a foreign visitor, dialoguing with each student, adapting the content to each one.

In [8], a study has been presented for evaluating the role of humanoid robot in teaching second language to the students of elementary school. Five robot modes for interaction have been designed: storytelling mode, oral reading mode, cheerleader mode, action command mode, and question-and-answer mode. The finding suggested that robots have the potential to be useful in language teaching assistant. Also it has been argued that instructors had more time to guide weaker students when the robot was the main focus of attention. In [7], the humanoid robot *Nao* is serving as assistant in teaching second language with the aim to examine the effect of robot-assisted language learning (RALL) on the anxiety level and attitude in English vocabulary acquisition among Iranian EFL junior high school students. The study showed that the students enjoyed the learning process, and they believe that their learning was more effective, which helped them boost their motivation in the long run.

2.2 Peer and Co-learner

In computer-based learning techniques, there exists the notion of teachable agents (TA), which draws on the social metaphor of teaching a computer agent to help students learn [20]. During interaction with teachable agents, social attitudes, including a sense of responsibility, motivate students to work harder to organize their understanding. TA has been found to improve children's reasoning abilities. In robotics, this idea has been explored in the context of co-learning scenario, in which it is the robot who receives instructions from the human learner (children), with the assumption to achieve learning-by-teaching effect. In this direction, in [11], a care-receiving robot was introduced in an English language classroom for Japanese children (3–6 years of age). In the experiment, the robot was part of different activities, e.g., "wall touch," "favorite card," and "verb learning." Two behaviors of the humanoid robot *Nao* were tested: always giving incorrect answers and thereby presenting many opportunities for children to teach it. In the second behavior, the robot did not make any mistake. The results show that the robot can induce care-giving/care-teaching behavior in the children. Further, there have been positive effects reported for promoting and enhancing children's learning by teaching if the co-learner robot is used within classroom activities guided by human teachers. It also pointed that teachers can use such "care-receiving" robots to fetch the attraction of the distracted children and bring them back on the learning activity. In another application designed in [12], the child teaches the humanoid robot *Nao* how to handwrite and learns by correcting the robot. The child as a teacher also elevates its cognitive reasoning by trying to understand why the robot fails and how the child can better help it. In [13], this handwriting co-learning scenario has been studied for different relative spatial conditions of the child and the robot: face to face and side by side. It finds that in side-by-side conditions, children give more feedback to the robots for its mistake, which points that depending upon the context of teaching, the relative spatial placements of the agents are also important.

2.3 Companion to the Student

The robot can be the teacher's assistant within the classroom during the lecture, but it can stay close to the student when he goes out from the classroom or at home. As the angels in the Wim Wenders' movie "der Himmel über Berlin," the robot can accompany the students in their studies. They can remind the exercise that needs to be done; they can help with the lessons and question the student about it.

In [14], two humanoid robots, *Robovie*, were put in the corridor of an elementary school for a duration of 2 weeks. During recess, the children were set free to interact with both the robots. The finding shows that such interaction encouraged some children to improve their English and that the robot was more successful in engaging children who already knew at least a little English. The authors grounded these findings on previous literature in social psychology, which suggests that having similarity and common ground between interacting agents boost the interaction and learning. In [6], in a Lego Mindstorms learning class, the social humanoid robot *Robovie* was supposed to be a companion to the children as well as managing the class. The robot behaviors were controlled by a remote operator. This study explored the idea of collaborative learning from a learner-centered approach. Therefore, the robot was more acting as companion and only explained minimum information (i.e., using Lego Mindstorms) and lets children engage in problem solving by themselves. The robot was equipped with a set of social behaviors (greeting, encouragement, showing sympathy, stimulation, chatting), and the analysis shows that a social humanoid robot can be successfully used in a collaborative learning class. Further, it revealed a better social acceptance in the case of the presence of social behavior of the robot compared to no social behavior. This suggests that social humanoid robots might be useful to avoid boredom.

2.4 Edutainment

Robots can be used as a fun and entertainment way of teaching. Humanoid robots with its body language and multimodal interaction capabilities are shown as better platform to engage and entertain children while steering them toward the learning side of the interaction, for example, storytelling robots in classrooms [8]. In addition, there are works on developing interactive educational games with robots. In [16], *Nao* Torso robot is used to teach map reading skills to 11- to 13-year-old school students with gamelike scenario on a touchscreen device. The designed tasks are supposed to help the learner develop an understanding of directions, distance, and map symbols for map reading. The EU project named EMOTE [17] also considers a game scenario about environmental considerations, with the aim to elevate the learning about resources and effective ways to use them to support cities. In [21], school children performed a collaborative learning activity about sustainability, by playing a collaborative multiplayer game (Enercities), with a robotic tutor (partially remotely controlled).

2.5 Telepresence Medium

In many situations, due to various reasons (e.g., physical problems, risk of infection, family needs, etc.), a student might not be able to attend physically the classes or lectures. The digitalization of most of the courses is an important improvement in this case; the student can be informed by email of what is going on in school. But for a long period, the lack of participation to the class life and missing the interaction with the teachers and the other students could become a burden that could lower the involvement of the remote student. The telepresence is a technical solution for this problem. Thanks to a simple video conferencing system (e.g., Skype), the student can be integrated in the classroom and see and listen to what is happening there. But being a simple screen in a classroom is constraining: the remote student cannot choose his/her point of view (looking at the teacher or another intervening student) and he/she cannot raise his/her hand to call for attention. Using a humanoid robot as an avatar in the classroom is the ultimate solution to emulate the presence of the remote student in the classroom.

Experiments have already been conducted to explore on the potential and acceptance of tele-operated humanoid robot. For example, in [18], the authors have studied the acceptance and perception of a geminoid delivering lecture in tele-operated manner from proximity and gender perspectives and pointed on the relevance of movement coordination of the robot. Tele-operated robots in general can be used to teach foreign languages remotely by a native speaker (e.g., see [22]) and provide learning environment remotely to the students who for many reasons cannot be present in the classroom, e.g., the PEBBLES (*Providing Education by Bringing Learning Environments* to Students) project (see [23]). The project aimed to combine video conferencing and robots to help hospitalized children stay involved with their classrooms and other students. The robot used was not very humanoid but points to good potential of humanoid in such use case.

2.6 Teaching Platform

Humanoid robots can serve as platform/tool for teaching. For example, the *Nao* robot has been extensively used for such educational purposes (https://www.ald.softbankrobotics.com/en/solutions/education-research). Humanoid robots are also being used to help teaching coding and AI in the classroom (http://www.sciencealert.com/robots-are-about-to-enter-australian-schools-as-part-of-a-world-first-study). One of the first introductions of robotics in teaching was for robotics and technological lectures. When *Nao* appeared in 2006, the targeted market was the researchers, but most of the researchers being also teachers started to use it in the classrooms. Teaching programming to a humanoid robot (e.g., [19]) might be one of the best ways to understand the challenges in motion control, perception, and man-robot interaction. It is also a good way to have a practical experience on the underlying technologies of robotics, e.g., computer science, control, mechanics, and electronics.

Humanoid robot as a platform provides a lot of interesting opportunities for children to comprehend many concepts. The computation of the position of the center of gravity of a complex articulated solid, that is, the humanoid robot, is much more interesting when it is validated on a biped robot that can stand on one foot. The biped robot is also a beautiful platform to experiment the importance of the dynamics. A position that is perfectly balanced can be unreachable at a reasonable speed because of the side effects of the dynamics. The computation of the dynamic model, taking into account inertia and centrifugal forces to keep the balance of a dancing or walking humanoid is one of the practical ways to understand these concrete physical phenomena. Programming the walking motion of a humanoid robot is a great opportunity to have a better understanding of the way we walk (Fig. 2).

Fig. 2 Representational image of Nao humanoid robot as a platform for teaching programming

In a more general way, programming the behavior of a humanoid robot is an opportunity to realize the complexity of the human body and its physical and cognitive control. The artificial intelligence is strongly connected, in the imaginary of people, to the robotics in general and to the humanoid robotics in particular. When a robot looks like a human, it is expected to behave like a human: with intelligence and with humanlike dialog. The first implementations of intelligence that the student experiments are often the obstacle avoidance (that is no longer really considered as artificial intelligence but used to be) and the dialog. Implementing a spoken dialog within a humanoid robot facilitates perceiving the underlying complexity of our language: from the automatic speech recognition in noisy environment to the knowledge hidden in our sentences going through the multiple ways to say the same thing, the different level of languages, and the management of the ambiguity. Robotics in general can be a mean to teach aspects of grammar, syntax, semiotics, but also psychology as soon as the robot is supposed to manage the emotion of the user.

This double aspect of teaching ("how does a humanoid robot work?" and "how does a human work?") makes the humanoid platform a unique device to have a better understanding of our world. The perception of what the human is able to do and the complexity in implementing these features on a robot are probably one of the best means to mitigate the fear of people to about the robots. The more people understand the way robots are working, the less they will be afraid of it.

3 Humanoid-Like Robots in Special Education

There are various other domains and applications of robots in teaching. There are many situations and cases where humanlike body language and kinematic structure and social signaling are important, for example, teaching social interaction skills for children with autism spectrum disorder (ASD), teaching physical activity for stroke patient or elderly people, the presence of an affective education companion for child with life-threatening conditions who needs special support where even parents are not allowed for longer time, teaching sign language for hearing-impaired children, etc.

In [24], a humanoid-like socially assistive robot (SAR) is used as a coach/instructor for older adults with dementia, showing the use of interacting with a social robot in attention and memory tasks. In [25], a human resembling doll robot is used to teach social interaction capabilities in children with ASD. Socially assistive robots (including humanoid robots) have proven to be useful in special education of ASD children. In [26, 27], the effective role of humanoid robots have been studied for teaching the children with ASD the social skills, e.g., how to ask questions or how to be proactive and collaborate. In [28], the social robots teach music to autistic children. There even exist commercial solutions like *AskNao* https://asknao.aldebaran.com/) designed to assist teachers and childcare workers in the support of autistic children. It includes the *Nao* humanoid robot and a range of fun and educational applications specifically written to meet the needs of autistic children. Another such platform is RoboKind (http://www.robokindrobots.com/), aimed to improve social skills in children with autism. In [9], experiments have been conducted in teaching sign language to hearing-impaired children, with embodied humanoid robot, *Robovie* R3 and *Nao* H25. In such situations, humanoid robots are a must to generate humanlike gesture, body, and sign languages. The results are encouraging and show the potentials of humanoid robots in such use cases.

4 Core Functionalities and the Grand Challenges

All the robots and the applications discussed in the previous sections have at least one of these core functionalities: *basic perception of human and scene, gesture and body language, dialog and speech,* and *control for physical interaction.* Also such robots need to have *interface for multimedia visualization* and/or *tele-monitoring* and *tele-operativity*.

Although, most of these robots are either tele-operated or pre-scripted in part or completely, the aim of most of the studies is to show the effect, usefulness, attributes, and desired behaviors of robots for education applications. However, some key R&D blocks still need to be achieved in the long run if we want a higher level of autonomy of such robots. Some of those are outlined below.

Social Interaction Capabilities and Intelligence of the robots is one of the key requirements needing further investigation from R&D point of view. In the study [6], the social humanoid robot *Robovie* managed the class and explained how to use *Lego Mindstorms*. Here the robot was not completely autonomous, but the results showed that the children were encouraged by the social behavior of the robot which also contributed in building relationships and attaining better social acceptance of the robot. There is a great need of making such social behaviors and *monitoring* capabilities of the robot autonomous and intelligent. Further, to properly modulate the behavior of the robot in dynamic environment and situation, *perception* of environment and people and capability to extract some high-level attributes for *context* and *situation awareness* will be very important. *Expressivity* and the capability to *exhibit social supportive behaviors* are another key aspects for the robot to be more effective agent for robot-assisted education. In the study carried in [29], social interaction of the robot (along five behavioral dimensions: role model, nonverbal feedback, attention building, empathy, and communicativeness) has been compared with the case of neutral responses of the robot during the process of language teaching by the robot. The findings suggest that compared to only knowledge transfer, engaging through social interaction is more effective.

If the first acceptance of the humanoid robots in classrooms is pretty good, the advantage of such a device on a long-term period has yet to be confirmed. The novelty and the surprise brought by the humanoid robot can help garner the students' attention, but the day the robot becomes a regular tool for education, will it be as efficient as during the first weeks of experimentation? Therefore, *measuring and maintaining engagement and interest* are the paramounts for long-term acceptance and usefulness of the social humanoid robots for education. Some works (e.g., [3]) are already showing that the robot with social behaviors alone has been found useful for the first two lessons. This suggests that there is a greater need to have the robot capable of engaging children beyond the novelty effect. Studies on expectations and satisfaction of children toward an empathic robot tutor (e.g., [21]) will be helpful in deriving some metric for their measurement. Also the robot should be able to create the notion of *trust and reliability* for a successful and trustworthy educational relation with the learner, with the teacher, and with the parents.

Furthermore, investigation in the *appropriate role of the humanoid robot* for a particular context and goal is also a very important. Some recent studies such as [17] suggest that the kind of task assigned to children is one of the key parameters for the appropriate role the humanoid robot should be assigned. In the study conducted, the aim was to teach programming to the children through social humanoid robots. Preliminary findings suggest that children are quicker in completing the task when the robot is a peer but learning in children is more effective when the role of the robot is as a teacher. Work on *learner modeling* [30] is another key needed capability of the robot to better adapt to a particular learner and be more effective. This will facilitate *personalization and adaptivity*, on of the needed features for a robotic tutor [40]. Some recent studies examined if there is any influence of robot gender on learning. For example, the study in [31] uses stereotypically female and stereotypically male learning tasks and finds that a mismatch with robot's perceived gender increases engagement willingness in learning with robot. Further investigations in this direction are also needed to shape and project the *robot's personalities*.

There is also a need to explore in the direction of *autonomy* of such humanoid robots, which are used in education. Recent studies (e.g., [32]) point toward the importance of autonomy, by comparing a robot which is fully remote controlled. It shows that semiautonomy of the robot does not compromise the engagement level with the children and gives more flexibility to the teacher to focus on interaction with the child, instead of focusing on operating the robot. On the other hand, a robotic avatar raises some different kind of technically interesting problems: how can the student, probably with some physical constraints in his/her own motions, have a simple way to control the several degrees of freedom of a humanoid robot? A simple joystick with a video feedback can be used to drive the robot. Some navigation assistance and autonomy will be necessary to avoid collisions with the people and obstacles around the robot. The remote student not necessarily being a professional tele-operator, the driving system should be very robust. Once in the classroom, he/she should mainly focus on the lecture not on driving the robot. To benefit the embodiment of the robot, the remote student should have a simple way to control the head of the robot, to focus its visual attention on specific locations (teacher, board, other students). Coupling the motion of the robot's head to the motion of the student's head seems to be the most intuitive way. But turning his/her head, to turn the robot's head, the remote student will lose the visual contact with the video feedback on the screen in front of him/her, unless he/she wears an immersive helmet. Unfortunately, this kind of helmets has two drawbacks: they are still uncomfortable and heavy for a long usage and being immersive they prevent the remote student to do something in his own world, like taking notes, for instance. The control of the head motion of the robot could be done through a joystick, but then the hand is no longer available for note takings. Therefore, there is a very interesting problem to solve about the *shared control* and autonomy of different parts of the robot.

If at some point of time, there will be multiple robots, and perhaps of different types, to accompany the child (e.g., one in classroom, other in home), there is a technical need to *synchronize* among such robots. So that the complete system could be a solution for the teacher and parents to ensure the continuity of learning process in the classroom and home. It will require some extra work for the teacher to specify the program of the companion robot. Today, the teacher gives homework to the student; tomorrow he/she should have to program it and download it onto the robot's "memory." The editors of education software would be in charge of providing powerful *easy-to-use tools* to make this process as simple as possible. If the process requires too much extra work for the teacher, the system might not be accepted.

A study in [33] suggests some preliminary pointers about which type of *learning situation* with robots are preferred. It shows that people prefer initially for the robots to be applied in individual learning scenarios and not with other people. Learning in a group scenario with education robots was placed second. Therefore, there will be further need to investigate in the learning situation and whether there are *social and cultural biases* in such findings.

5 Social, Ethical, and Legal Concerns

The robot is, and will probably stay for a while, an expensive device. It is likely that all the classrooms, all over the world, will not be able to buy a robot as soon as the technology is ready. This digital divide could be increased by the introduction of humanoid robots in wealthy institutions and their absence in others. Then the equal chances to receive a robot-assisted education would not be given to all the children. But depriving all classrooms from robots cannot be used as countermeasure, especially if the new tools are available and prove their efficiency for a better teaching. It will be the responsibility of education institution to progressively acquire this technology in every classroom; the service provider should be responsible to provide affordable technologies to the countries with lower economic strength.

The big fear of the replacement of the human, as a teacher, by a robot has to be managed. We presented above the way the robot can be an assistant to the teacher, but it is difficult to imagine the robot replacing completely the teacher. Although some experiments have been conducted (http://www.telegraph.co.uk/news/4942136/Robot-teacher-that-can-take-the-register-and-get-angry.html) where the robot replaces the teacher in some tasks, the efficiency of it has to be evaluated, including the issue of managing discipline in the classroom. The physical human teacher presence might be difficult to be replaced completely. But it could be a way to determine the depth of a teacher's authority. Analyzing the behavior difference between teachers' authority could be a way to implement the good behavior into a robot. In any case, it will take time to elevate the robot's capabilities to be able to understand each student's particular case. Meanwhile, by relieving the teacher from simple tasks, the robot can enable the teacher to focus on his/her pedagogic added value.

Some other dimensions to consider are as follows: Will a child be deprived from social skills or be more isolated because of education through robot? What if the child starts imitating the voice, tone, prosody, or motion of the robot, instead of only learning phonics or actions of the robot? There are social acceptance barriers as well. EC Eurobarometer 382 survey [34] shows that 34% of respondents believe robots should be banned in education (Luxembourg (58%), France (56%), Belgium (51%), and the Netherlands (50%), a majority of EU citizens). In a recent study conducted in [35], it shows teachers' somewhat negative attitudes toward robots in education, but by the same token, the teachers preferred to use robots in STEM (science, technology, engineering, and math) domains. In this study, some of the concerns of the teachers were limited and restricted access to robot that might create unhealthy competition among children, fading of novelty effect, extra workload of maintenance of robot, high cost, and risk of compromised social skills development of children.

Computers, interactive blackboards, and then tablets all became part of a student's life. The introduction of humanoid robot could be seen as one more step in the endless chase of the teachers to focus the children's attention on their studies.

Further, there are more general concerns about the children exposed to digital education (http://www.liberation.fr/debats/2016/09/02/philippe-bihouix-avec-l-ecole-numerique-nous-allons-elever-nos-enfants-hors-sol-comme-des-tomates_1478435) [36], which argues that "with digital teaching, the children lose the taste of effort," "the more you are in front of screens, the less you understand written texts," and, also what should be priority in teaching, "teaching to program is less important than teaching grammar and orthography, as perhaps in next 15 years the leading programming language might be completely different but grammar and orthography will remain unchanged." Such discussions are also raising the ultimate question: are we losing contact with the priority of education – the children also have to make efforts to learn thing, not only the teachers and the technology providers.

6 International Activities, Projects, Associations, and Initiatives in Robot-in-the-Loop-Based Education

There are various initiatives worldwide exploring the use of robots in education. A 3-year research project, led by *Swinburne University of Technology*, aims to identify ways that robots might both help and distract students, in order to establish guidelines for their educational usage in the future (http://www.swinburne.edu.au/news/latest-news/2015/08/swinburne-researches-effective-use-of-robots-in-schools.php). *European Union* (*EU*) project *L2ToR* (http://www.l2tor.eu) focuses on using humanoid robot for teaching second language to children [37]. Another *EU* project *DREAM* (http://www.dream2020.eu) focuses on exploring the role of humanoid robot for robot-enhanced therapy for special education of children with autism spectrum disorder (ASD) [38]. The *Emote* project (http://www.emote-project.eu) aimed to improve the use of humanoid robot as artificial tutors as learning-facilitator tools. There are dedicated groups and pioneering activities worldwide for robotic technologies (including humanoid robots) for education, e.g., socially assistive robotics (http://robotshelpingkids.yale.edu) (SAR) technology for education, funded by *NSF Expeditions in Computing* program. There are robotics competitions (e.g., RoboCup with Humanoids (http://wiki.robocup.org/wiki/Humanoid_League)), which also provide mechanisms for students to learn by programming and interacting with robots. There is a dedicated topic group on "education" within euRobotics (http://www.eu-robotics.net/), which focuses on education about robotics and education with robots, including humanoid robots. A *Topic Group* (*TG*) (https://www.eu-robotics.net/sparc/topic-groups/index.html) in *euRobotics* aims to shape the future of robotics in *Europe* in partnership with *European Commission* (*EC*) through *SPARC* (http://www.sparc-robotics.net/) (one of the largest civilian-funded robotics innovation program in the world) for Horizon 2020 (H2020). There are other topic groups in euRobotics (e.g., *Socially Intelligent Robots and Societal Applications* (*SIRo-SA*), *Natural Interaction with Social Robots*, *AI and Cognition in Robotics*), which are supporting the investigation of some of the key scientific and technological challenges toward elevating the necessary building blocks of such robots. There is also a conference series named

"RiE: International Conference on Robotics in Education (ttp://rie2016.info/)," which encourages topics like "humanoid robots in education." With all such initiatives and worldwide awareness, humanoid robot technologies are expected to be ready to play a more prominent role in the field of education.

7 Conclusion

Through a walkthrough of applications and studies of the use of humanoid robot in education, we pointed toward robot in the education ecosystem as a promising domain in application/services of humanoid robots. However, there are still questions to explore and answer, e.g., cost of the robot, extra work for teachers, technical and scientific problems to solve, and long-term effect. Further investigations are required to validate the technical solutions and the pedagogic advantages. Combination of interdisciplinary techniques and technologies, e.g., humanoid robot simulator [10] and teachable agent technique [20], and works on automated system for Assessment of Students' Answer Scripts [39] could open new avenues for affordable and useful humanoid-robot-in-the-loop education applications.

There are also aspects from a pedagogic and ethical point of view: is it relevant to continue making learning easier for students? Will it be possible and acceptable to learn without efforts? That will help in defining, what should be the exact role of the robot in educating? However, it is important for everyone to have some minimal understanding of the way robots work, to modulate their development and find the suitable places for them in the society.

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References

1. D.P. Miller, I.R. Nourbakhsh, R. Siegwart, Robots for education, in *Springer Handbook of Robotics* (Springer Berlin/Heidelberg, 2008), pp. 1283-1301.
2. O. Mubin et al., A review of the applicability of robots in education. J. Technol. Educ. Learn. **1**, 209–0015 (2013)
3. J.K. Westlund et al., A comparison of children learning new words from robots, tablets, & people, in *Proceedings of New Friends: The 1st International Conference on Social Robots in Therapy and Education,* 2015
4. J.-H. Han et al., Comparative study on the educational use of home robots for children. J. Inf. Process. Syst. **4**(4), 159–168 (2008)
5. M. Obaid, W. Barendregt, P. Alves-Oliveira, A. Paiva, M. Fjeld, Designing robotic teaching assistants: interaction design students' and children's views, in *Social Robotics: 7th International Conference, ICSR 2015*, Paris, October 26–30, 2015, Proceedings (Springer International Publishing, 2015), pp. 502–511
6. T. Kanda, M. Shimada, S. Koizumi, Children learning with a social robot, in *Proceedings of the Seventh Annual ACM/IEEE International Conference on Human-Robot Interaction (HRI*

'12) (ACM, New York, 2012), pp. 351–358. https://doi.org/10.1145/2157689.2157809
7. M. Alemi, A. Meghdari, M. Ghazisaedy, The impact of social robotics on L2 learners' anxiety and attitude in english vocabulary acquisition. Int. J. Soc. Robot. **7**(4), 523–535 (2015)
8. C.-W. Chang, J.-H. Lee, P.-Y. Chao, C.-Y. Wang, G.-D. Chen, Exploring the possibility of using humanoid robots as instructional tools for teaching a second language in primary school. Educ. Technol. Soc. **13**(2), 13–24 (2010)
9. H. Köse et al., The effect of embodiment in sign language tutoring with assistive humanoid robots. Int. J. Soc. Robot. **7**(4), 537–548 (2015)
10. S. Carpin et al., USARSim: a robot simulator for research and education, in *Proceedings 2007 IEEE International Conference on Robotics and Automation*, Roma, 2007, pp. 1400–1405
11. F. Tanaka, S. Matsuzoe, Children teach a care-receiving robot to promote their learning: field experiments in a classroom for vocabulary learning. J. Hum.-Robot Interact. **1**, 1 (2012)
12. D. Hood, S. Lemaignan, P. Dillenbourg, When children teach a robot to write: an autonomous teachable humanoid which uses simulated handwriting, in *2015 Human-Robot Interaction Conference*, Portand, 2015
13. W. Johal, A. D. Jacq, A. Paiva, P. Dillenbourg, Child-robot spatial arrangement in a learning by teaching activity, in *25th IEEE International Symposium on Robot and Human Interactive Communication*, New York, 2016
14. T. Kanda, T. Hirano, D. Eaton, H. Ishiguro, Interactive robots as social partners and peer tutors for children: a field trial. Hum.-Comput Interact. **19**(1), 61–84 (2004)
15. T. Kanda, H. Ishiguro, Communication robots for elementary schools, in *Proceedings of AISB'05 Symposium Robot Companions: Hard Problems and Open Challenges in Robot-Human Interaction*, 12 Apr, 2005
16. A.A. Deshmukh, A. Jones, S. Janarthanam et al., Empathic robotic tutors: map guide. *HRI (Extended Abstracts*), 2 Mar, 2015
17. N. Tazhigaliyeva et al., Learning with or from the robot: exploring robot roles in educational context with children, in *International Conference on Social Robotics*, 2016.
18. J.R. Abildgaard, H. Scharfe, A geminoid as lecturer, in *International Conference on Social Robotics* (Springer, Berlin/Heidelberg, 2012)
19. E. Pot, J. Monceaux, R. Gelin, B. Maisonnier, Choregraphe: a graphical tool for humanoid robot programming, in *RO-MAN 2009 – The 18th IEEE International Symposium on Robot and Human Interactive Communication*, Toyama, 2009, pp. 46–51
20. C. Chase, D.B. Chin, M. Oppezzo, D.L. Schwartz, Teachable agents and the protégé effect: increasing the effort towards learning. J. Sci. Educ. Technol. **18**(4), 334–352 (2009)
21. Alves-Oliveira, Patrícia, Tiago Ribeiro, Sofia Petisca, et al.. An empathic robotic tutor for school classrooms: considering expectation and satisfaction of children as end-users, in *Social Robotics: 7th International Conference, ICSR 2015*, Paris, October 26–30, 2015, Proceedings (Springer Publishing, 2015), pp. 21–30
22. J. Han, *Robot-Aided Learning and r-learning Services* (INTECH Open Access Publisher, Croatia, 2010), p. 288. https://doi.org/10.5772/8143. ISBN:978-953-307-051-3
23. L. A. Williams, et al., PEBBLES: providing education by bringing learning environments to students. Adv. Hum, Factors/Ergon. 115-118 (1997).
24. A. Tapus, C. Tapus, M.J. Mataric, The use of socially assistive robots in the design of intelligent cognitive therapies for people with dementia, in *2009 IEEE International Conference on Rehabilitation Robotics, Kyoto International Conference Center* (IEEE, 2009), pp. 924–929. https://doi.org/10.1109/ICORR.2009.5209501
25. B. Robins, K. Dautenhahn, R. Te Boekhorst, A. Billard, Robotic assistants in therapy and education of children with autism: can a small humanoid robot help encourage social interaction skills? Univ. Access Inf. Soc. **4**(2), 105–120 (2005)
26. E.I. Barakova, P. Bajracharya, M. Willemsen, T. Lourens, B. Huskens, Long-term LEGO therapy with humanoid robot for children with ASD. Expert. Syst. **32**(6), 698–709 (2015)
27. B. Huskens, R. Verschuur, J. Gillesen, R. Didden, E. Barakova, Promoting question-asking in school-aged children with autism spectrum disorders: effectiveness of a robot intervention compared to a human-trainer intervention. J Dev. Neurorehabil. **16**(5), 345–356 (2013)

28. A. Taheri, A. Meghdari, M. Alemi, H. Pouretemad, P. Poorgoldooz, M. Roohbakhsh, Social robots and teaching music to autistic children: myth or reality? in *Social Robotics: 8th International Conference, ICSR 2016*, Kansas City, November 1–3, 2016 Proceedings (2016), pp. 541–550
29. M. Saerbeck, T. Schut, C. Bartneck, M. D. Janse, Expressive robots in education: varying the degree of social supportive behavior of a robotic tutor, in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '10)* (ACM, New York, 2010), pp. 1613–1622. https://doi.org/10.1145/1753326.1753567
30. A. Jones, S. Bull, G. Castellano, Open learner modelling with a robotic tutor, in *Proceedings of the Tenth Annual ACM/IEEE International Conference on Human-Robot Interaction*, 2015, pp. 237–238
31. N. Reich-Stiebert, F. Eyssel, (Ir) relevance of Gender?: On the influence of gender stereotypes on learning with a robot, in *Proceedings of the 2017 ACM/IEEE International Conference on Human-Robot Interaction (HRI '17) (*ACM, New York, 2017), pp. 166–176. https://doi.org/10.1145/2909824.3020242
32. M. de Haas, A.M. Aroyo, E. Barakova, W. Haselager, I. Smeekens, The effect of a semi-autonomous robot on children, in *2016 IEEE 8th International Conference on Intelligent Systems (IS)*, Sofia, 2016, pp. 376–381
33. N. Reich-Stiebert, F. Eyssel, Learning with educational companion robots? Toward attitudes on education robots, predictors of attitudes, and application potentials for education robots. Int. J. Soc. Robot. **7**(5), 875–888 (2015)
34. EC Special Eurobarometer 382, Public Attitudes towards robots, 2012, http://ec.europa.eu/public_opinion/archives/ebs/ebs_382_sum_en.pdf
35. N. Reich-Stiebert, F. Eyssel, Robots in the classroom: what teachers think about teaching and learning with education robots, in *Social Robotics: 8th International Conference, ICSR 2016,* Kansas City, November 1–3, 2016 Proceedings (Springer International Publishing, 2016), pp. 671–680
36. P. Bihouix, K. Mauvilly, Le désastre de l'école numérique Seuil, Aug 2016, pp. 240, EAN 9782021319187
37. T. Belpaeme, J. Kennedy, P. Baxter, P. Vogt, E. J. Krahmer, S. Kopp, K. Bergmann, P. Leseman, A. C. Küntay, T. Göksun, A. K. Pandey, R. Gelin, P. Koudelkova, T. Deblieck, L2TOR – second language tutoring using social robots, in *Proceedings of 1st International Workshop on Educational Robots, ICSR 2015*, Paris (2015)
38. P.G. Esteban, P. Baxter, T. Belpaeme, E. Billing, H. Cai, H.-L. Cao, M. Coeckelbergh, C. Costescu, D. David, A. De Beir, Y. Fang, Z. Ju, J. Kennedy, H. Liu, A. Mazel, A. Pandey, K. Richardson, E. Senft, S. Thill, G. Van de Perre, B. Vanderborght, D. Vernon, H. Yu, T. Ziemke, How to build a supervised autonomous system for robot-enhanced therapy for children with autism spectrum disorder. Paladyn J. Behav. Robot. **8**(1), 18–38 (2017)
39. H. Ibrahim, M. Elhoushy, B. Zalam, O. Ottar, An interval type-2 fuzzy logic system for assessment of students' answer scripts under high levels of uncertainty, in *Proceedings of the 8th International Conference on Computer Supported Education (CSEDU 2016)*, Vol. 2 pp. 40–48. ISBN:978-989-758-179-3
40. A. Jones, D. Küster, C.A. Basedow et al., Empathic robotic tutors for personalised learning: a multidisciplinary approach, in *Social Robotics: 7th International Conference, ICSR 2015,* Paris, October 26–30, 2015, Proceedings (Springer International Publishing, 2015), pp. 285–295