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A survey on the use of humanoid robots in primary education: Prospects, research challenges and future research directions

Gurkan Tuna*, Vocational School of Technical Sciences, Trakya University, 22020 Edirne, Turkey

Ayse Tuna, School of Foreign Languages, Trakya University, 22020 Edirne, Turkey

Emine Ahmetoglu, Faculty of Education, Trakya University, 22020 Edirne, Turkey

Hilmi Kuscu, Faculty of Engineering, Trakya University, 22020 Edirne, Turkey

Abstract

In parallel with the significant and exciting advancements in robot technologies, the use of humanoid robots to support teaching strategies and learning goals has become a popular topic. Different from the traditional instructional or learning tools, humanoid robots can exhibit mobile behaviours and numerous repetitions and are very helpful to the students in developing problem-solving and collaboration abilities. Presently, the roles of humanoid robots in classrooms fall into four main categories: learning materials, learning companions, teaching assistants and communication mediators to support group learning, respectively. With the humanoid appearance, anthropomorphism, interaction, flexibility, repeatability and digital data representation, humanoid robots have great potential to be useful especially in preschool and primary school education. In this paper, limitations and challenges of the use of humanoid robots as teaching assistants are presented in addition to exploring the relationship between humanoid robots and performance in learning.

Keywords: Humanoid robot, teaching, social interaction, learning tool, assisted learning.

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* ADDRESS FOR CORRESPONDENCE: **Gurkan Tuna,** Vocational School of Technical Sciences, Trakya University, 22020 Edirne, Turkey. *E-mail address*: gurkantuna@trakya.edu.tr / Tel.: +90 284 2240283

1. Introduction

Currently, many types of robots are being used for learning goals and they range from simple robots to humanoid robots. The choice of the robot is generally dictated by the area of study and the age group of the student (Sharkey, 2016). While simple robots are particularly used to teach robotics, electronics or computer science, humanoid robots are easier to interact with, and often used to teach a wide range of subjects in mathematics, science and language. Therefore, in recent years, humanoid robots have been started to be used as teaching assistants or even teachers in the classroom for some subjects across language, mathematics and science (Chin, Wu & Hong, 2011). However, as shown in many studies, while students like interacting and learning with humanoid robots, the teachers who are a bit reluctant to use the humanoid robots in the classroom prefer the humanoid robots to take on restricted roles instead of full autonomy in the classroom (Reich-Stiebert & Eyssel, 2016). This is mostly because of the fact that the teachers are in general unaware of the common technical capabilities of humanoid robots and are uncertain about how best to incorporate the humanoid robots in the classroom.

Humanoid robots, an example given in Figure 1, are able to provide real-time feedback, and due to their physical shape resembling a human, their engagement with humans is easier and better. They have enhanced social skills, and they are programmed to emote through facial expressions, gestures and intonations and respond with appropriate body language (Lin, Abney & Bekey, 2011). They can also show emotions such as surprise, fear, anger and disgust.
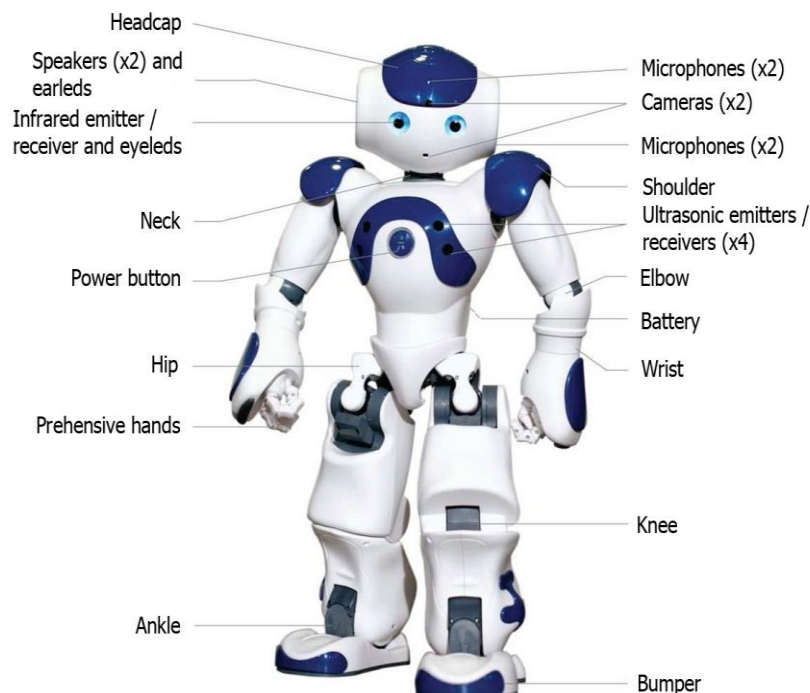

Figure 1. Humanoid robot NAO (Courtesy of SoftBank Robotics)

Compared to a human teacher, humanoid robots can help resolve issues related to shyness, frustration, reluctance and confidence better, and are being commonly used in many countries, especially for special education. Table 1 lists the main operational requirements of humanoid robots

and Table 2 lists the relation between the common attributes of humanoid robots and desired instructional goals. One of the reasons for humanoid robots' success for learning goals is that a humanoid robot does not get tired no matter how many mistakes a student makes. Some humanoid robots allow telepresence, which allows teachers to connect to the classroom through the display mechanisms remotely, usually embedded in the robots' torsos.

Table 1. Main operational requirements of humanoid robots

Requirement	Functions
Human–robot interaction	Sensor-motor interaction, vision and speech recognition
Learning and memory	Incremental learning and memorisation, cognition and imagination
Homeostasis	Control internal systems and maintain overall system stability (Alnajjar, Hafiz & Murase, 2010)

Table 2. The common attributes of humanoid robots and desired instructional goals

Robot attribute	Desired instructional goal
Body movement	Elicit student response, gain attention, support visual examples
Existence with human-like	Recall prerequisites, elicit student response, gain attention, present goals, present new content and support visual examples (Chang, Lee, Chao, Wang & Chen, 2010)
Interaction	Provide feedback, recall prerequisites, elicit student response
Suspension humanity	Elicit student response, provide feedback
Repeatable	Gain attention, recall prerequisites, enhance retention and transfer

Although in parallel with the advances in robot technologies, researchers and academicians have focused on using humanoid robots for various educational goals in the last couple of years and have proven that humanoid robots can help students learn subjects in mathematics and science and develop problem-solving abilities, few of which have been discussed whether humanoid robots are appropriate for all children and what challenges must be overcome to successfully integrate humanoid robots. Accordingly, in this paper, we review state-of-the-art humanoid robots that can be used as teaching assistants, investigate research challenges and state future research directions.

2. Related work

The use of technology for learning has become more and more popular in the last couple of decades. In recent years, the use of robots as a teaching assistant or teacher has replaced the popular technology-based learning paradigm and opened the possibility of robot-based learning systems (Han & Kim, 2009). Especially, the use of humanoid robots has drawn such attention that several companies have started to focus on humanoid robot development. As children enjoy interacting with humanoid robots (Fior, Ramirez-Serrano, Beran, Nugent & Kuzyk, 2010), humanoid robots help teachers manage the lesson as a teaching assistant. Humanoid robots easily motivate children to learn by praising and cheering up or calling the roll, and enhance the relationship between the children and learning goals. Since humanoid robots can provide immediate feedback, they provide a unique experience for the students.

Since the use of robots to support teaching strategies and learning goals has drawn the attention of research communities in recent years and become an increasingly popular topic (Klassner, 2002; Klassner & Anderson, 2003; Ryu, Kwak & Kim, 2007), its suitability and efficiency at different educational stages have been investigated. In fact, the use of robots for educational goals started to be investigated before 2000. For instance, Papert (1993) proposed that students learn while they

design and assemble their own robots. Robots can easily capture the imagination of children and teenagers; hence, the use of robots as aids for the teaching of physics and mathematics has been validated (Cooper, Keating, Harwin & Dautenhahn, 1999). Moreover, robots can be used for arts and science courses and are not limited to engineering departments (Hendler, 2000).

Weinberg and Yu (2003) pointed out three main factors, namely, cost, plug-and-play feel and unique learning experience, respectively, to demonstrate that robots will be successfully used for educational goals. Over the past decade, the cost of microcontrollers and microprocessors has decreased significantly, and cost-effective robot controllers have been developed and marketed (Marin, Mikhak, Resnick, Silverman & Berg, 2000).

Liles and Beer (2016) showed that the use of humanoid robots as individualised mathematics tutors in rural, elementary classrooms is feasible. Humanoid robots are a cost-effective way of providing individualised or differential supplemental mathematics instruction in the classroom without diverting the attention of the teacher away from the rest of the class. The authors programmed humanoid robots to ask and explain fifth-grade mathematics questions and carried out a user study with fifth graders from an area in rural South Carolina. It was shown that the fifth-grade students preferred working with the humanoid robots to teachers, peers and computer programs. Similarly, Hashimoto, Kobayashi, Polishuk and Verner (2013) showed that humanoid robots were able to deliver elementary science lessons successfully.

The study conducted by Chang et al. (2010) reviewed previous studies on using humanoid robots as an instructional tool in teaching a second language. They also used a robot partner for classroom teachers to determine the effectiveness of humanoid robots in teaching and learning the second language in primary school. To achieve this, the design and application of five instruction scenarios including an oral reading mode, a storytelling mode, a cheerleader mode, a question-and-answer mode and an action command mode were implemented to teach the second language. According to the results, the students showed great participation with high motivation while practicing listening and speaking skills with the humanoid robot. In short, the children's eagerness to interact with the humanoid robot and the teachers' opinions showed that humanoid robots might be a supportive and enjoyable partner in language learning.

Karahoca, Karahoca & Uzunboylu (2011) explored the effectiveness of the robot education in science and technology courses given to the primary school students. It was carried out as a case study to provide the student's knowledge on robot construction. Besides this, it was aimed to create an opportunity in order to help the students get proficiency in their skills and ability in this respect. The results of the study show that robotics education increased students' proficiency in science and created a classroom atmosphere in which the students could develop positive relationships.

Meghdari et al. (2013) utilised a humanoid robot to support language teaching and learning in their case study. The robot was in the role of a teaching assistant in English as a Foreign Language (EFL) classes at Iranian middle schools. It was aimed to find out the effectiveness of human–robot cooperation in English language teaching and learning. The applied method called Robotics Assisted Language Learning (RALL) technology aimed to support students who are young learners of English Language in Iran by providing individual help, motivation and native-like production and interaction. It has been suggested that as the humanoid robots have the features of mobility, intelligence, sensing, interaction, adaptability and repeatability; the application of RALL technology in English language classes can result in effective interaction with the children and lead to increase their motivation, interest and cooperation in the activities and exercises.

The study conducted by Fridin (2014) examined how a humanoid robot which took the role of a teacher assistant in telling stories that were uploaded beforehand can convey to the young children learners of a foreign language while performing a song and motor activities together in the process of teaching. The aim was to find out how the robot could engage the children in constructive learning. It was suggested that a humanoid robot could be an assistant to the teacher in supporting the

constructive learning process of young learners by telling stories and teaching new things and motor skills with the combination of songs and motor activities. It was shown that the storytelling ability of the humanoid robot fostered the children's interest in involving the activities more eagerly. In short, the result of the study indicates that the children attending a kindergarten demonstrated more enjoyment while interacting with the humanoid robot and regarded the humanoid robot as an authority during the learning process.

Keren and Fridin (2014) carried out a pilot study in which they used Kindergarten Socially Assistive Robot (KindSAR). Their aim was to show how a robot could support teachers while teaching geometric thinking and also help the students improve their metacognitive development through interactive play activities (Four season procedure and learning process of geometric thinking). It was argued that a robot could be an assistant to the teacher in teaching geometric thinking skill by using educational activities in the game form. The results proved that the students showed increase in their performances in learning these skills while playing with the robot.

Haas, Vogt & Krahmer. (2016) carried out a study in which a robot was used in teaching English to the children aged between 3 and 4 years and whose native language is Dutch. They also examined the reactions of the children to the different types of feedback given by the robot. In the study, they did an experiment to find out how the children dealt with the robot after getting feedback in a tutoring session. During these sessions, the robot displayed three scenarios in which it gave peer-like, adult-like feedback and did not give feedback. The aim was to find out the possibilities of peer interaction between a robot and child for future studies.

Alemi, Meghdari & Haeri. (2017) realised a study in which they tried to explore the young EFL learners' attitude towards RALL. The experiment in which a humanoid robot was used as an assistant to the teacher was conducted in a private kindergarten in Iran. They looked for the motivation, interaction and anxiety of the students while they were studying with the humanoid robot. The results showed that the positive interaction with the humanoid robot caused an increase in the students' motivation. They also displayed no signs of anxiety while interacting with the humanoid robot in the learning process as it created a friendly atmosphere in the classroom. In short, this study has been an outstanding example for future studies that will use humanoid robots in second language learning and teaching situations as robots are perceived attractive and useful tools. They can also meet the students' different needs.

Fernandez-Llamas, Conde, Rodriguez-Lera, Rodriguez-Sedano & Garcia. (2018) aimed to find out students' attitudes towards robots while doing an experiment in which two groups of students whose ages differ from 6 to 16 years were taught some computational items by a robot and a human teacher. Therefore, they tried to decide on the differences in learning caused by these two different applications. Two types of questionnaires adapted for children were used in the study and the students' attitudes towards robots, gender and age differences and the previous experience with robots were taken into account. The results obtained from these questionnaires reveal that age is the core element that extremely affects how the students approach the robot and their attitudes towards the robot.

To sum up, while humanoid robots acting as teaching assistants may not be seen in all elementary schools within the coming decade, it is clear that they will possibly take education to a new level. Because they are capable of grabbing the attention of students of all ages and can help students learn various concepts in a more effective way. The common benefits of humanoid robots for educational goals can be listed as follows and based on the aforementioned studies possible uses of humanoid robots for preschool and primary school learning goals are listed in Table 3.

• Humanoid robots can be used to automate basic activities in education and change the role of teachers (Mubin, Stevens, Shahid, Al Mahmud & Dong, 2013). In parallel with the advancements in humanoid robot technologies, humanoid robots can take over some routine tasks, help students improve learning and may be adapted to many other aspects of teaching (Toh, Causo, Tzuo, Chen &

Yeo, 2016). Therefore, by delivering some routing tasks to humanoid robots, teachers can focus on supplementing lessons, assisting students who are struggling and providing human interaction and hands-on experiences for students.

- Humanoid robots can be adapted according to student needs and provide greater levels of individualised learning (Hedgecock, Standen, Beer, Brown & Steward, 2014). They can respond to the needs of each student by putting a higher emphasis on certain subjects, providing immediate helpful feedback to the student, repeating things that the student has not mastered and helping the student work at his/her own pace. In this way, humanoid robots provide custom-tailored education in order to help students at different levels work together in the same classroom while teachers facilitate the learning, and offer help and support whenever needed.
- Humanoid robots are able to make trial-and-error learning less discouraging (Bers & Ettinger, 2013). Since they are designed to help students to learn, they can offer students an alternative way of experimenting and learning in a judgment-free environment. Moreover, they can be programmed to offer solutions to the students for improvement.
- Humanoid robots can be programmed to help children with disabilities in their learning process (Desideri et al., 2017). Since they rely on artificial intelligence techniques and are built in the form of teaching assistants, children take an immediate liking to them and are eager to learn from them. However, humanoid robots should be programmed with better social skills so that they can be more beneficial in teaching children with learning disabilities.

Table 3. Possible uses of humanoid robots for preschool and primary school learning goals

Role	Description
Learning material	Humanoid robots are suitable for specific uses in primary schools such as teaching basic algorithms (Cooper et al., 1999; Tazhigaliyeva, Diyas, Brakk, Aimambetov & Sandygulova, 2016).
Learning support tool	Humanoid robots are good candidates to support some educational activities such as simulations (Chang et al., 2010).
Peer	To offer students encouragement and guidance in learning activities, teachers can use humanoid robots as peers (Diyas et al., 2016).
Assistant	Teachers can use humanoid robots in their daily tasks as assistants (Tanaka & Kimura, 2009).
Teacher	Humanoid robots can replace teachers in teaching specific subjects (Mubin et al., 2013).
Telepresence	Teachers can use displays on humanoid robots to attend classroom sessions virtually (D'Agustino, 2016).

3. Research challenges

Building humanoid robots is very hard in terms of generating human-like movements although the human-like movement is an essential component for natural human–robot interaction, collaboration and expressions and in terms of the challenges arising when a robot takes a human form (Gielniak, Liu & Thomaz, 2013). A key practice in research efforts in humanoid robotics is to include experts from multiple disciplines including robotics, computer science, electrical engineering, mechanical engineering, human factors engineering, organisational behaviour and the social sciences.

Humans have three main senses that are essential for moving through the world around, namely, balance, proprioception and kinaesthetic. Therefore, mastering the movement and awareness of the human body is highly difficult for robots to achieve and not to mention the other difficulties of mimicking humans (Kupferberg, Glasauer, S., Huber, M., Rickert, M., Knoll, A., & Brandt, 2011). Since most humanoid robot applications include mixed-initiative interaction and rich information exchanges in complex and dynamic environments, one of the key challenges is that human–robot interactions and resulting behaviours must accommodate complexity. Such a scenario is associated with a number of fundamental problems across different application domains in terms of requirements on autonomy,

information sharing and evaluation. Although proof-of-concept humanoid robot technologies are important, they should be fully supported by extensive and careful experiments with human subjects (Beer, Prakash, Mitzner & Rogers, 2011). Such experiments determine key attributes of the principles and design. Moreover, some humanoid robot applications may include multiple robots and multiple humans to interact with each other. In addition to the proximity and vulnerability of the humans in the interaction, social and emotional aspects of the interaction are the key attributes of this problem (Goodrich & Schultz, 2008). Hence, it is essential to shape multiple interactions and dynamics by establishing organisational structures with different and dynamic roles, communications protocols and support tools.

The real world is unstructured and complex, and interactions between humans and robots are also complex (Salah, Ruiz-del-Solar, Mericli & Oudeyer, 2012). For most humanoid robots, operating in such unstructured environments is rather difficult. This necessitates interactive learning, the process by which a human and a robot work together to gradually enhance perceptual ability, interaction and autonomy ('Human-Robot Interaction', 2018). In this aspect, natural language interaction is very challenging. Because, it does not only require state-of-the-art speech recognition and language understanding abilities but also incorporates cognitive modelling, mixed-initiative interaction and multi-modal interaction (Jiang & Arkin, 2015).

Similar to humans, from a humanoid robot's perspective, starting and managing effective interactions call for establishing and maintaining a common ground. This can be realised by creating cognitive models of human reasoning and behaviour selection (Goodrich & Schultz, 2008). By creating rich-enough models, the humanoid robot can be allowed to identify a human's cognitive state and in accordance with this, it can adjust information exchange (Scassellati, 2002). This approach also allows the humanoid robot's behaviour to be generated by appropriate models interpretable by a human.

To be as realistic as possible, humanoid robots are required to operate without being plugged into a power socket. Therefore, they need to have their own energy source. Although significant progress on battery technologies has been made in recent years, most humanoid robot motions are power-hungry. Larger batteries can give humanoid robots more power, but make them heavier, which then requires more energy to move the robots (Kopacek & Hersh, 2015). Hence, most humanoid robots are often docked to a charging station.

Humanoid robots may need to learn through imitation if they are going to act as a teaching assistant. In this case, as well as having a set of enhanced perceptual, cognitive and motor capabilities, the robots must locate a good model and then determine which of the model's actions are the most relevant to the task (Breazeal & Scassellati, 2002). Then, those observed actions must be mapped into behavioural responses that the robots are capable of performing. Finally, the robots must have a mechanism for recognising when it has succeeded in correcting errors when they occur.

In terms of sensing, most humanoid robots still have difficulty with recognising everyday objects. Although machine learning techniques allow humanoid robots to label images with sentences, the humanoid robots need to know what the objects are used for and how to interact with them. Different from industrial robots, humanoid robots need to infer the meaning of the scenes they exist (Johnson-Roberson et al., 2011). Hence, they need a set of sensors to use vision, touch and sound. However, whatever the learning algorithm embedded in a humanoid robot, humanoid robots' skills are still far from resembling human intelligence or understanding.

Although industrial robots are highly successful at manipulating specific predefined objects in a repetitive manner, for humanoid robots, sophisticated motor control and precise planning techniques that allow interacting with everyday objects are needed. Soft robot manipulators that conform to different shapes of objects are one of the solutions for this need (Trivedi, Lotfi & Rahn, 2008). For many everyday tasks in unstructured environments, as well as safe hardware, a sophisticated sensor suite and complex algorithms, integration play a key role.

Since lack of parental support may result in confining humanoid robots acting as teaching assistants to applications only inside the classroom, in order to increase the success of humanoid robot-based teaching solutions, besides children, educators and parents have to be on-board as well (Toh et al., 2016).

In a world where human safety and customer expectation are the key factors, it is impossible to make humanoid robots a reality without building legal frameworks, developing the right standards and establishing common metrics (Leenes et al., 2017). Because, without the legal frameworks and right standards, misrepresentation in the public about what humanoid robots can do as teaching assistants may increase public concern and this may lead to the danger that policymakers may react to public opinion. Therefore, public concerns need to be discussed thoroughly.

Although humanoid robots open up teaching options and can help to improve teacher effectiveness, we need to focus on improving the quality of teaching, providing more contact between teachers and students, creating better interactions among the students themselves, enabling real-time communication and the fluid exchange of ideas and information. Looking to humanoid robot-based solutions to make teaching cheaper, ignoring teaching quality and focusing primarily on cost-efficiency may lead to a future education system relying on pre-recorded courses staffed by telecommuting humanoid robot teaching assistants and assessed by computerised scorers.

Another main shortcoming in the use of humanoid robots as teaching assistants is the lack of well-defined curriculum and learning materials for teachers. Still, the use of humanoid robots in primary education is seen as a part of informal education, which does not rely on well-defined curricula, and an extra-curricular activity. However, extensive efforts must be devoted to not only the development of humanoid robot hardware and software for educational goals but also the design and development of appropriate curriculum and learning materials.

Finally, humanoid robot studies can last up to a few years and allow finding out the reliability of tested robots. However, such long-term studies necessitate significant investment by research institutes in terms of personnel and financial resources due to different research methodologies. Therefore, for reliability-related reasons, some countries are more hesitant in acknowledging the integration of humanoid robots in classrooms.

4. Future research directions

As well as power sources, one of the main concerns for humanoid robots is energy-efficiency. For instance, human muscles are capable of impressive strength but most robot manipulators do not have the strength to carry heavy loads (Kojiyama et al., 2015). Biological muscles can be a cure for this problem. Although they are an order of magnitude lighter and smaller, they can generate the same force as robot motors (Yip & Niemeyer, 2017).

Before real-world applications, experiments that include results from simulated and physical humanoid robots should be conducted. Due to cost and reliability-related issues, it is generally difficult to carry out strictly controlled, extensive experiments with physical humanoid robots. Nevertheless, mostly it is not possible to replicate simulation-only results with physical humanoid robots since challenges and details not supported in many simulation environments existing in the physical world (Balakirsky, Carpin, Dimitoglou & Balaguer, 2009). Therefore, it is essential to develop novel methodologies and solutions that focus on the use of strictly controlled simulation platforms and replicate selected results with physical robots.

Considering that there are many vendors in humanoid robotics, there is a need for multi-vendor humanoid robot simulation environments. Similarly, there is an urgent need for a common robot operating system or middleware to make different humanoid robots work together seamlessly. Although the Robot Operating System (ROS) is a middleware designed to provide services that are designed for heterogeneous robots ('About ROS', 2007), it is not prevalent in humanoid robotics.

It is expected that humanoid robots provide user-friendly programming interfaces so that they make it easy for teachers and students to learn and play with them. Hence, they need to be equipped with a set of versatile educational kits to make their users be able to work with them without high programming complexity and experience. Although some humanoid robots are easy to be programmed, most of them fail to provide versatile programming tools (Choi, 2009).

Research studies show that a humanoid robot is a great learning tool and students are very enthusiastic about it and enjoy the human-like interaction in the classroom (Leyzberg, Spaulding, Toneva & Scassellati, 2012). Nevertheless, the students wanted the humanoid robot to adapt its behaviour to their feelings and display a broad range of emotions and expressions (Saerbeck, Schut, Bartneck & Janse, 2010; Tielman, Neerincx, Meyer & Looije, 2014). In addition, the students were not happy with the humanoid robot's unnatural voice and not being able to adapt to different situations by changing tone/pitch. Furthermore, the students prefer natural behaviour from the humanoid robot as much as possible and mostly imagine the humanoid robot in the role of their teacher (Leyzberg, Spaulding & Scassellati, 2014). Nevertheless, such kind of fully autonomous behaviours requires considerable research and development.

Woods (2006) proved that although it is assumed that robots interacting with children should resemble humans as much as possible, children feel some discomfort towards the human-like images. On the other hand, the children rate human-machine like robots more positively. Hence, humanoid robots designed for children should not be designed to look completely human-like and should be brightly coloured and have a female gender, cartoon-like features and exaggerated facial features.

Although humanoid robots acting as teaching assistants can teach students fundamentals, they are not the perfect solution to help students learn high-order thinking and creativity. Therefore, human teachers are required to facilitate. However, considering the rapid rate of technological and digital advancements in the last couple of decades, we should now consider what humanoid robots will possibly be able to do in the future.

Humanoid robots can perform many tasks as teaching assistants. However, one of the key topics is that researchers should focus on observing how teachers use humanoid robots in classrooms to teach different selected subjects. To get the most benefit from humanoid robots in classrooms, it is necessary to use the motivational effects of robotics to inspire and engage students (Flot, Higashi, McKenna, Shoop & Witherspoon, 2016).

It is difficult to teach a child with special needs. Hence, special education consists of a variety of tasks to open the child's world through education and unlock his/her real potential. Unlike other special education tools, humanoid robots with their customisable applications are a great tool. For special education, humanoid robots are not only assistants to the teachers but also friends to the children. Humanoid robots may harness some wonder which causes to captivate those children, draw them in and make them want to interact and play to develop abilities such as identification, object classification and categorisation. However, humanoid robot solutions designed for special education should be created to fit the needs of special education teachers (Huijnen, Lexis, Jansens & de Witte, 2016). In addition, they should allow customisation of lessons and activities through easy-to-use interfaces in addition to providing note-taking and status tracking solutions in order to realise the smoothness in-class integration. Furthermore, the design and testing of instruction scenarios should be investigated thoroughly. Finally, feedback from teachers and an active online community can help to enhance the features of humanoid robot solutions.

5. Conclusion

Although humanoid robots are currently very far away from being autonomously situated in pre-primary and primary schools because of technological limitations such as emotion recognition and inaccurate speech, they can be used in classrooms as learning tools since they have the ability to provide real-time feedback to students. On the other hand, while humanoid robots are increasingly

being used to teach students in the classroom setting for a number of subjects across language, mathematics and science, students enjoy learning with them, but teachers are a bit reluctant at first to use them in the classroom setting because appropriate interfacing mechanisms that allow the teachers to control the humanoid robots with minimal training which is needed in order to facilitate the easy integration of the humanoid robots in the classroom setting. In fact, the intention of most researchers in the robotics field is not for robots to replace teachers. Instead, the design goals of most humanoid robots are to function as an aid in the classroom setting and to increase the benefit they can bring as a stimulating and engaging educational tool. Humanoid robots may have a great impact on the way the students learn and make the teachers' lesson plans much more motivating. Cognitive, conceptual, language and social skills are the major areas that humanoid robots can influence the development of children's skills.

While it is unlikely that humanoid robots can act as teachers within the next decade since still years of research and development are required to see them in our everyday lives, it has been shown that they can help students and teachers get more out of educational experience and can provide cost-effective means for differential or individualised supplemental learning in the classroom setting without diverting the attention of the teacher away from the rest of the class. On the other hand, although considerable advances in integration, sensing, cognition, manipulation and power are still needed for successful humanoid robots, if humanoid robots are ever to succeed as teaching assistants, they have to be easily programmable, agile, stable and have a humanoid shape to make people to be comfortable during the interaction. Finally, in this paper, we have not delved into the theoretical aspects; instead, we have focused on practical issues related to utilisation of humanoid robots in education and student–humanoid robot interaction in classrooms. Therefore, it is necessary to encourage and promote pedagogical experts all around the world to investigate further the practical aspects of the utilisation of humanoid robots as teaching assistants.

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