The use of social robots as teaching assistants in education: literature review

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Abstract. *This literature review examines the impact of social robots as teaching assistants on student engagement in learning activities. The study identified and analysed 16 studies that investigate the use of social robots mostly in preschool or primary education. The results reveal that social robots, such as NAO, Pepper, and Skusie, have been used in various educational contexts, including language learning, STEM education, special education, and collaborative learning. The findings highlight the positive effects of social robots on student motivation and engagement, leading to improved learning outcomes. The review emphasizes the importance of taking ethical considerations into account, data privacy, and the role of human educators when integrating social robots into educational settings.*

Keywords. social robot, education, motivation, engagement

1 Introduction

Robotics is one of the expressions of technology and takes place in various contexts of life (Kalaitzidou & Pachidis, 2023). The use of advanced technologies that include robotics and artificial intelligence in education motivates students to learn at different educational levels. These technologies encourage active learning in an innovative, effective, motivating, and individualized way. Active learning equals active engagement of students in discussions, problem solving, case studies, role plays, and other methods with a higher degree of learners' responsibility. Many studies show that the integration of advanced technologies has a positive impact on learning about various topics.

A social robot in education refers to the use of robotic systems designed to interact with students, improve engagement, and support their learning experiences (Belpaeme et al. (2018); Kubilinskiene et al. (2017)). These robots are equipped with artificial intelligence (AI) and various sensors to perceive and respond to their environment and engage with students in a social and educational manner.

The impact and influence of social robots in teaching/learning process has been researched in different educational contexts, accentuating their great potential in supporting learners and teachers (Donnermann et al. (2020)). We describe some cases found in the literature according to the areas in which social robots assisted.

Personalized Learning: Social robots can adapt their interactions based on individual student's needs. They can assess student's abilities, tailor content and feedback, as well as provide personalized teaching and support (Chen et al. (2020)).

Language Learning: Robots can help with language acquisition by engaging students in conversation, pronunciation practice, and vocabulary building. They can provide real-time feedback, correct pronunciation errors, and simulate immersive language scenarios, creating interactive and engaging learning experiences in which children participate with high motivation (Sisman et al. (2018)).

STEM Education: Social robots can facilitate hands-on learning experiences in science, technology, engineering, and mathematics (STEM) subjects. They can guide students through experiments, help them understand complex concepts, and foster problem-solving skills (Konijn & Hoorn (2020)).

Special Education: Robots can provide valuable support to students with special needs. They can assist in communication, development of social skills, and emotional regulation (Lopez-Caudana et al. (2021)). Robots can create a non-threatening environment that promotes engagement and learning for children with autism spectrum disorder, for example.

Collaborative Learning: Robots can act as collaborative partners for group activities and projects. They can encourage teamwork, facilitate discussions, and provide prompts or challenges to foster critical thinking and creativity. The robot as a collaborative learning companion could also contribute to the child's social development (Ekström & Pareto, 2022).

Emotional Support: According to Escobar-Planas et al. (2022), social robots can offer emotional support

to students by acting as empathetic companions. They can engage in conversations, listen attentively, and provide encouragement. This can be particularly beneficial for students experiencing stress, anxiety, or loneliness.

Virtual Field Trips: Robots equipped with cameras and remote operation capabilities can allow students to explore remote locations or otherwise inaccessible environments. This enables virtual field trips, enhancing students' understanding of geography, history, or scientific phenomena (Oh et al. (2018)).

Coding and Robotics Education: Robots can serve as tools for teaching coding and robotics concepts. Students can program robots to perform specific tasks, solve problems and learn computational thinking skills along the way (Konijn & Hoorn (2020)).

The integration of social robots in education aims to enhance student engagement, provide personalized support, and foster the development of various skills. However, it is essential to take ethical considerations into account, followed by data privacy, and the role of human educators in the learning process when implementing social robots in educational settings.

Therefore, this study explores empirical findings on the use of social robots as assistants in education with a special interest in the impact of social robots on student engagement in learning activities across the educational sector.

2 General objective and research questions

The most important factor for active participation in the learning process and achieving success is learner motivation (Leitão et al. (2021)). Motivation can be described as a stimulus to action that defines intrinsic and varied extrinsic layers of motivation. Intrinsic motivation is determined by autonomy, competences, and socialisation, while extrinsic motivation is determined by external regulation: introjection, identification, and integration.

Engagement can affect learners' intrinsic or extrinsic motivation, and gamification as a strategy with the purpose of generating commitment can lead to changes in behaviour (Rojas-López et al. (2019)). It is defined as the passion to participate in and perform the assigned learning activities (Rojas-López et al. (2019)). It is encouraged through the use of active teaching methods. Learner engagement can be categorized into three categories: behavioural, cognitive, and emotional (Rojas-López et al. (2019)). The positive attitude of the learner towards participating in the teaching process is called behavioural participation. Cognitive engagement implies the disposition to think and comprehend one topic or concept, which involves self-regulation. The reactions and feelings of the students during the learning process are known as emotional engagement. Many studies show that the use of advanced technologies as a teaching strategy increases the engagement of the learners.

Therefore, the general objective of this study is to investigate the connection between the use of social robots as a teaching assistant and the teaching-learning processes. The following research questions are at the center of interest:

RQ1: What are the major fields of research in the context of social robots in education?

RQ2: How does the use of social robots as teaching assistants affect student engagement and motivation in learning activities?

3 Material and method

The literature review process was divided into four stages: identification, screening, eligibility, and inclusion, according to Boland et al. (2017) and the complete process is illustrated on Figure 1.

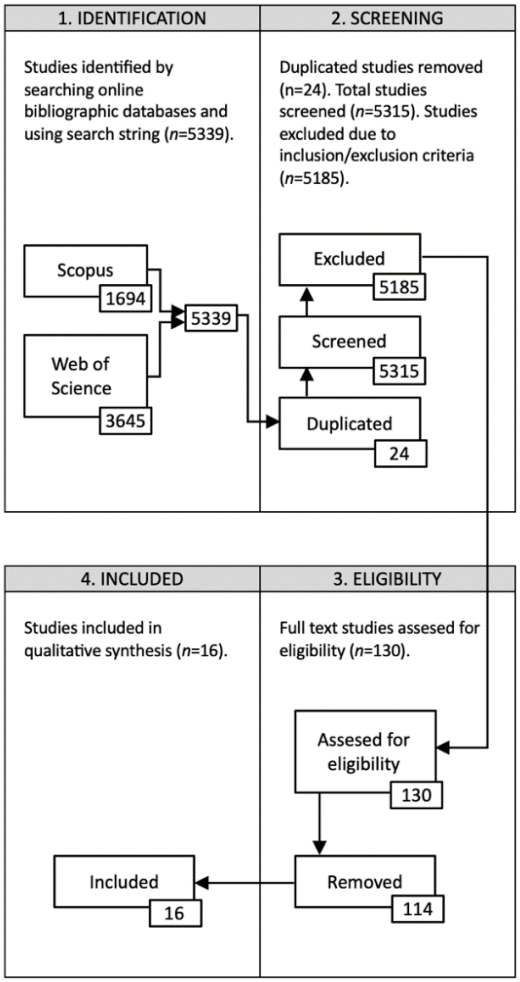

Figure 1: PRISMA flow diagram of the literature review process

In the first identification stage, a structured search strategy was created for use on the scientific databases Scopus and Web of Science. A search string: *social* and *robot* and *education*, was used for database search.

For the second stage, screening, 3,645 results from Web of Science and 1,694 results from Scopus were identified. The following additional selection criteria were used:

1. Published in English,
2. Published within the time frame 2019-2023,
3. Document type was article,
4. Full text was available,
5. The subject areas were Computer and Social Science (Scopus) and Educational Research in Education (Web of Science).

As a result, 45 studies were obtained from Scopus and 109 from Web of Science. 24 duplicates were detected and excluded, and 130 studies were reviewed by titles and abstracts.

Other means of availability, such as the author's contacts, were also used for the acquisition of studies. In this way, 5 studies were acquired, while 6 studies could not be acquired.

In the next stage, the final eligibility criterion was applied – studies should have included empirical findings on the use of social robots as assistants in education. From the focus are excluded all those studies that research robots in education that are not social robots, and studies that explore social robots, but these robots are not in the function of teaching assistants. 114 studies were removed because they did not meet the required criteria. A total of 16 studies were included in the fourth stage of the literature review.

4 Results

The results of the research are presented in Table 1 and they show the type of robot used, the number of participants and their age, the educational field (languages, STEM, other) and the duration of the educational activity.

Table 1: Presentation of the research results

Authors	Robot	Participants		Subject	Duration
		No	Level		
Sisman et al. (2018)	NAO	232	secondary	language	4 months
Escobar-Planas et al. (2022)	Haru	84	primary	problem-solving	1 session
Tolksdorf et al. (2021)	NAO	21	preschool	language	4 sessions
Connolly et al. (2022)	NAO	13	adults	health	-
Demir-Lira et al. (2020)	NAO	38	preschool	language	30 mins
Arar et al. (2021)	Emys	54	primary	language	8 weeks
Guggemos et al. (2020)	Pepper	462	high school	academic writing	45 mins
Yueh et al. (2020)	Julia	36	primary	literacy	60-80 min
van den Berghe et al. (2020)	NAO	104	preschool	language	7 sessions
Chen et al. (2020)	Tega	59	primary	language	48 sessions
Konijn & Hoorn (2020)	NAO	86	primary	mathematic	3 x 5 min
Velentza et al. (2021)	NAO	138	university	engineering	1 session
Chalmers et al. (2022)	NAO	29	teachers	-	8 weeks -9 months
Kim & Tscholl (2021)	Skusie	24	preschool	language	49 sessions
Kim et al. (2021)	Skusie	11	preschool	STEM	30 sessions
Ekström & Pareto (2022)	Pepper	92	teachers	mathematics	2 years

The results show that NAO is one of the most popular social robots in education, used in as many as 8 out of 16 studies. The robots Pepper and Skusie were used in two studies each, and the robots Haru, Emys, Julia and Tega were used in one study each.

The number of participants who actively participated in the research ranges from 11 to as many as 462. Studies are most often conducted among children of preschool and primary school age, with five studies conducted for each age category. Only one study was conducted among secondary school students, one among high school and one among university students. Two studies were conducted among teachers and one among adult participants (patients).

The use of social robots is most common in teaching foreign languages, as many as seven studies have been conducted in this area. The next field of education in terms of the popularity of use of social robots is the STEM field (mathematics, engineering). Four studies were conducted in the STEM field. One study per field was conducted in the areas of literacy, academic writing, health education and problem solving, while the field was not specified for one study.

Considering the duration of teaching/learning and the use of social robots in the educational process, both short-term and long-term studies were carried out. Eight studies conducted educational activities for a period of two months to two years. Seven studies conducted educational activities as a one-time activity, while for one study the duration of the educational activity was not specified.

Considering RQ1, major fields of research were identified by taking into account the main findings and focus of the studies analysed: 1) Changes in learning; 2) Gains in knowledge; 3) Student-robot interaction; 4) Student engagement and enjoyment. In the next sections we briefly describe each of them along with the key findings.

4.1 Changes in learning

Konijn & Hoorn (2020) investigated the impact of the social robot on learning and the contribution of the robot's more social behaviour to the learning effect. They found that social robots are capable of creating a positive learning effect, but robot's more social behaviour did not add to learning. They were not teasing out a relationship, they tested if increasing the number of social cues was helpful in remembering.

Ekström & Pareto (2022) explored teachers' perceptions of a learning activity based on learning-by-teaching where the robot is designed to act as a didactic tool and a social actor. They found that robot-based learning activities can contribute to learning, develop skills, increase children's metacognitive awareness, and especially can increase children's interest, motivation, and participation. Robot as a didactic tool achieves relatively short-term goals with increased knowledge in a defined area. From the other perspective, the robot as a social actor has a rather long-term goal to support the general development of children.

Kim & Tscholl (2021) researched the advantages of an embodied social robot to engage children in play and learning from the perspective of embodied cognition. They found three embodied phenomena: the embodiment of early mathematics and scientific knowledge and reasoning, the appropriation of physical space, and the embodied collaboration. Embodiment occurs not only in thinking but also in social and emotional experiences. We can conclude that social robots have the potential to enable embodied learning experiences.

4.2 Gains in knowledge

Demir-Lira et al. (2020) showed in their research that children successfully learnt a foreign language from a social robot as an assistant, as well as they learnt from a human teacher. The observers expressed great excitement and enjoyment due to the social robot acting as an assistant, which is associated with the novelty and the anthropomorphic tendencies of the robot.

The use of social robots is most common in educational institutions, but examples show successful use in other areas of adult education as well. Connolly et al. (2022) researched using social robots in digital health for patient education. They observed significant improvements in patient knowledge, meaning the social robot provides health education effectively. Users (patients) reported high levels of acceptance and engagement with this method of intervention and reported low or slight levels of associated diabetes distress.

4.3 Student – robot interaction

It is usual for social robots to assist in the learning process in a variety of different ways, but there is a research on social reference in the context of a child–robot interaction. According to Tolksdorf et al. (2021) interaction with a social robot led to more social referencing in children compared to an interaction with a human partner and instances of social referencing of children did not decrease over the course of a long-term interaction.

Kim et al. (2021) investigated the use of a social robot to moderate interactions among culturally and linguistically diverse children, with a focus on design challenges and solutions to facilitate positive peer interactions. They proved that children could benefit from their design principles of using social robots for flexible children's exploration, friend-like communication, tasks relying on familiar experiences while stimulating imagination, and use of children's native languages.

The degree to which children anthropomorphise a robot as an assistant and whether this anthropomorphism relates to their learning of a foreign language were investigated by van den Berghe et al. (2020). Their results show the importance of taking children's anthropomorphism into consideration when designing robot - assisted learning sessions. van den Berghe et al. found that children generally anthropomorphised the robot and a weak but significant correlation was established between children's increased anthropomorphism and their word knowledge. Children who came to perceive the robot more as a human knew more words after the tutoring sessions.

Social robots need to be designed in a way that they are child-centred and collaborative because robot behaviours and collaboration paradigms affect children's perception about the robot. Escobar-Planas et al. (2022) prove in their research that the cognitive reliability of the robot shapes the helping relationship between the children and the robot, while the robot's expressivity impacts the perception of the robot's support ability and friendship. Children's perceptions about the robot remain individual, even if they interact with it in pairs, although a good collective task-performance seems to empower children's perception of the robot in terms of friendship and reliability.

Guggemos et al. (2020) investigate the acceptance of social robots by higher education students in the field of social sciences. The perceived characteristics of the social robot: trustworthiness, adaptiveness, social presence and appearance, indirectly predict the intention to use a social robot for learning purposes. The most important characteristic for predicting students' behavioural intention to use a social robot is its adaptiveness. An anxiety about making mistakes in handling the robot and privacy issues are not significant predictors.

The social robot as a reading companion to facilitate children's reading participation, as

alternatives to group storytelling activities in libraries, was investigated by Yueh et al. (2020). Their results showed that the children perceived the robot companion as more favourable and desirable to read with than a human co-reader. According to the results of the comparison, cognitively, it was found that human and robot companions facilitated the comprehension of the children's language in different ways and that the children performed similarly well with both types of companions. Affectively, the robot co-reader induced more social interaction during the reading sessions.

4.4 Student's engagement and enjoyment

Arar et al. (2021) researched the use of social robots in foreign language teaching and found that the use of social robots enhances the effectiveness of the educational process and significantly improves learning outcomes. Furthermore, given the facilities offered by the social robot through its support for foreign language learning to children, the authors recommend the use of social robots for improving the quality of learning outcomes and comfort in the schooling conditions.

According to Sisman et al. (2018) engagement is the most influential construct among all sources of attitude towards the integration of robots into the lesson. They have determined a high rate of correlation between engagement and intention as well as between enjoyment and intention. Furthermore, Sisman et al. (2018) highlighted that enjoyment is of particular significance to transform a teaching practise into a personalised experience of 'education', which, in turn, might influence the level of students' engagement in the lesson.

In the teaching process, a social robot can assume the role of an assistant and the role of a peer. The impact of peer learning with a social robot on children's learning and emotional engagement was investigated by Chen et al. (2020). They found that children who interact with the robot in the role of an assistant learnt more target vocabulary words than children who interact with the robot. Children interacting with the peer robot were more expressive in their facial affect display and more engaged than children interacting with the assistant robot, they learnt the most target words and showed the highest enjoyment.

Velentza et al. (2021) found that the social robot in the role of assistant increases the student's enjoyment. In their research, students had statistically significant higher scores in the enjoyment questionnaire in comparison with the human - teacher condition. It can be concluded that the presence of the robot played a key role in student motivation. The scores during the final exam confirmed that the presence of the robot motivated the students, as shown by the statistically significant higher scores in comparison to students who did not have any course with the robot as assistant.

Teachers' perceptions of the benefits and challenges, pedagogical practises that helped with student engagement, and where the social robots fit in the curriculum were investigated by Chalmers et al. (2022). Their findings show that the robot could be used to enhance the curriculum, from introducing robotics, coding and computational thinking to using the robot to engage students with foreign language and mathematics. Most teachers adopted a constructivist social approach to teaching with the social robot and reported that students were highly engaged with their learning when programming and working with the robot.

5 Discussion

Throughout literature review it was revealed that social robots are used mostly in preschool or primary education. The results also revealed that social robots, such as NAO, Pepper, and Skusie, have been used in various educational contexts, including language learning, STEM education, special education, and collaborative learning.

It was also noted that using social robots in education raises several ethical considerations and data privacy concerns. As technology advances and social robots become more prevalent in educational settings, it is essential to address these issues to ensure the responsible and safe use of these devices. Risks include lack of transparency, data privacy issues, dependency on robots, reduced human interaction, and potential job displacement (Boch et al. (2020)).

It is necessary to define how data will be collected and processed from social robots, to what extent this data should be stored or uploaded to the cloud, how to inform and get the users' enlightened consent to do so and how to prevent unauthorised external actors from accessing personal detailed information (Boch et al. (2020). According to the same authors, due to new technological features, allowing robots to collect more data in their environment than before, the creation of particular regulations need to be considered. All of the above issues raise the question of regulations and public policy formulations for social robots, which will be an important subject of study and research in the near future (Subramanian (2017)).

Collaboration among educators, policymakers, developers, and privacy experts is crucial to establish clear guidelines and policies that priorities students' well-being and rights (Boch et al. (2020)).

In respect to the first research question (RQ1), the research highlighted major fields of research where social robots can be used effectively in education, including personalized learning, language learning, STEM education, special education, collaborative learning, emotional support, virtual field trips, and coding and robotics education. These applications demonstrate the versatility of social robots in satisfying the diverse educational needs and contexts and further

support the claim that robots can be implemented in various contexts (Kalaitzidou & Pachidis, 2023) supporting the learning experiences of students (Belpaeme et al. (2018); Kubilinskiene et al. (2017)).

Related to the second research question (RQ2), the results show that the integration of social robots in education has the potential to enhance students' engagement, provide personalized support, and foster the development of various skills. Social robots in education contribute to the child's social development (Ekström & Pareto, 2022)" improve engagement, and support their learning experiences (Belpaeme et al. (2018); Kubilinskiene et al. (2017); (Chen et al. (2020); (Chalmers et al.(2022); (Sisman et al. (2018)). According to Escobar-Planas et al. (2022), social robots can offer emotional support to students. The robot's presence motivated the students and increased the student's enjoyment (Velentza et al. (2021)), enhanced the effectiveness and improved learning outcomes (Arar et al. (2021)) This is inline with other studies that have shown that the use of advanced technology in education has a positive effect on student motivation (Francis (2017); (Yang et al. (2021). On the other hand, research shows that students who are intrinsically motivated and those who are motivated by attaining high grades tend to engage more with learning using advanced technology (Dunn & Kennedy (2019); (Stockwell & Reinders (2019)). At the same time, the role of teachers and their attitudes can also impact technology implementation (Stockwell & Reinders (2019)).

6 Conclusion

This literature review has been focused on exploring the impact of social robots as teaching assistants on student engagement and motivation in learning activities. Following a structured methodology, a total of 16 relevant studies were included in the analysis. These studies explored various aspects of social robot implementation, such as the type of robot used, the number and age of participants, the educational fields covered, and the duration of educational activities.

The findings indicated that social robots, particularly NAO, are commonly used in educational settings, with a focus on teaching foreign languages and STEM subjects. The studies showed positive outcomes in terms of learning gains, increased engagement, and improved knowledge acquisition when social robots were employed as teaching assistants. Children's interaction with social robots was found to be beneficial, leading to enhanced social referencing, positive peer interactions, and increased word knowledge.

Furthermore, the study emphasized the importance of ethical considerations, data privacy, and the role of human educators in the learning process when implementing social robots in educational settings. It is crucial to retain a balance between the use of technology and human interaction to ensure an optimal learning experience for students.

In future research, it is recommended to explore additional aspects of social robot implementation, address ethical concerns, and investigate long-term effects on student engagement and motivation, but also to expand the research on the use of social robots in education affecting knowledge construction, self-regulation, and development of communication and cooperation skills, development of critical thinking and real problem-solving skills. By harnessing the power of advanced technologies like social robots, teachers can create dynamic and personalized learning environments that inspire and empower students.

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