Italian Journal of Educational Technology
ISSN 2532-4632 (print) – ISSN 2532-7720 (online)
Accepted Manuscript Online
DOI: 10.17471/2499-4324/1438
https://ijet.itd.cnr.it

NAO and emotional learning: A systematic review of applications in primary schools

NAO e apprendimento emotivo: una revisione sistematica delle applicazioni nella scuola primaria

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HOW TO CITE Musicco, A- T., & Traetta, L. (2026). NAO and emotional learning: a systematic review of applications in primary schools. *Italian Journal of Educational Technology*. Accepted Manuscript Online. https://doi.org/10.17471/2499-4324/1438

ABSTRACT Emotional competence is crucial for academic success and mental well-being, helping address challenges like anxiety, stress, bullying, and depression in school-aged children. Despite its importance, Social Emotional Learning (SEL) programs remain under integrated in primary education. Social robots, such as NAO, offer innovative opportunities to bridge this gap by fostering emotional competence through interactive and engaging approaches. This systematic review investigates NAO's potential in primary school contexts, emphasizing its dual role in promoting emotional skills and enhancing learning outcomes. Guided by PRISMA methodology, searches in Scopus, Web of Science, and EBSCO identified studies categorized into two groups: (a) those focusing on improving emotional skills, such as empathy and emotional regulation, and (b) those using NAO's emotional feedback to enhance academic performance, particularly in vocabulary and reading. The findings demonstrate NAO's effectiveness in creating interactive environments that advance cognitive and emotional development, underscoring its value in primary education.

KEYWORDS NAO; Social Robotics; Emotions; Primary School; Child-Robot Interaction.

SOMMARIO La competenza emotiva è sempre più riconosciuta come un elemento fondamentale per il successo accademico e il benessere mentale, oltre a essere un fattore chiave per affrontare sfide come ansia, stress, bullismo e depressione durante gli anni scolastici. Tuttavia, l'integrazione di programmi per promuovere l'apprendimento il Social Emotional Learning (SEL) nell'istruzione primaria rimane limitata. I robot sociali, come NAO, offrono soluzioni innovative a questa sfida, fornendo modalità interattive e coinvolgenti per

sviluppare la competenza emotiva nei bambini. Questa revisione sistematica esamina il potenziale del robot umanoide NAO nel contesto scolastico primario, concentrandosi sul suo doppio ruolo nel promuovere la competenza emotiva e migliorare gli esiti dell'apprendimento. Seguendo le linee guida PRISMA, è stata condotta una ricerca su Scopus, Web of Science ed EBSCO. Gli studi inclusi sono stati suddivisi in due gruppi: (a) quelli che utilizzano NAO per migliorare le competenze emotive dei bambini, come empatia, regolazione emotiva e problem-solving sociale, e (b) quelli che sfruttano il feedback emotivo di NAO per migliorare le prestazioni accademiche, in particolare nell'acquisizione del vocabolario e nella lettura. I risultati evidenziano l'efficacia di NAO nel creare ambienti interattivi e coinvolgenti che supportano lo sviluppo sia cognitivo che emotivo.

PAROLE CHIAVE NAO; Robotica Sociale; Emozioni; Scuola Primaria; Interazione Bambino-Robot.

1. Introduction

In an era of rapid technological advancements, digital innovations are reshaping every facet of society, including education. These technologies enable novel and more effective ways of integrating communication tools, fostering engagement, and enhancing learning experiences. As Ciotti and Roncaglia (2010) argue, ignoring the potential of digital tools in education risks alienating schools from the communicative and cognitive practices that are now integral to social and cultural contexts, particularly for younger generations.

One emerging field that exemplifies this shift is Human-Robot Interaction (HRI), which integrates interdisciplinary domains such as human-machine interaction, machine learning, psychology, and education. Within HRI, Child-Robot Interaction (CRI) has garnered increasing attention, focusing on how social robots can assist and interact with children. Among the diverse social robots, NAO, developed by engineers at the French company Aldebaran Robotics[1], is one of the most popular and widely used humanoid robots in CRI research. Its affordability, programmability, and adaptability have made NAO a preferred tool for applications in education, healthcare, and social development (Amirova et al., 2021). The NAO robot has a plastic body, is 58 centimetres tall, and can be programmed to move in 25 different directions similar to those of a human being. Furthermore, NAO, equipped with software that simulates basic social and affective skills and operates on the NAOqi system, can utilize its sensors to perceive its surroundings and act proactively. It is capable of storing received information through a conversational engine and recognizing basic human emotions via an emotional system, enabling it to interact appropriately in various contexts (David et al., 2018). NAO can be programmed with *Choreographe* software to perform movements, converse, recognise visual and auditory stimuli, and react interactively to people and its surroundings.

NAO's versatility is particularly evident in its applications as an educational companion and therapeutic aid. Previous reviews have documented its use in domains such as autism therapy (Saleh et al., 2021) and robot-assisted education (Belpaeme et al., 2018). However, while numerous studies have explored the use of NAO in the field of education, few have focused on integrating emotional education into primary school settings. Most studies

[1] https://aldebaran.com/en/

Accepted Manuscript Online. DOI: 10.17471/2499-4324/1438

addressing emotions involve NAO in the context of autism therapy. For example, Rudovic et al. (2017) employed NAO in robot-assisted autism therapy, where children were tasked with recognizing different robot emotions presented through emotion cards. Similarly, Saleh et al. (2021) documented the use of NAO to enhance emotional recognition skills in children with autism spectrum disorders. These studies highlight that NAO is predominantly used for therapeutic purposes rather than directly promoting emotional education within primary school environments.

1.1. Theoretical framework: Social and Emotional Learning and Social Robotics

European discussions, including those at the World Economic Forum (2020), have often emphasized the importance of integrating Social Emotional Learning (SEL) programs into schools.

In recent years, Social and Emotional Learning (SEL) has gained increasing recognition as a fundamental framework for promoting students' psychological well-being, academic achievement, and overall development (Cavioni & Grazzani, 2023; Corcoran et al., 2018; Lawson et al., 2019). The acronym SEL first appeared in 1994, when the Fetzer Institute brought together educators and researchers to identify strategies aimed at helping children become socially responsible citizens (Collaborative for Academic, Social, and Emotional Learning [CASEL], 2018). Within that context, CASEL was established as the leading organization promoting social and emotional learning worldwide. CASEL defines SEL as the process through which individuals acquire and apply the knowledge, skills, and attitudes necessary to develop healthy identities, manage emotions, demonstrate empathy toward others, establish and maintain supportive relationships, and make responsible and caring decisions (CASEL, 2020).

The framework proposed by CASEL identifies five interrelated areas of competence—self-awareness, self-management, social awareness, relationship skills, and responsible decision-making—which together form the foundation for socio-emotional development. Building on this theoretical model, several alternative frameworks have emerged, such as the GROP (*Grup de Recerca en Orientació Psicopedagógica*) model developed at the University of Barcelona (Bisquerra & Pérez, 2007; Bisquerra, 2009; Bisquerra & Mateo, 2019). This model emphasizes five complementary dimensions: emotional awareness, emotional regulation, emotional autonomy, social competence, and life skills for well-being.

The conceptual foundations of SEL trace back to the late twentieth century, when increasing attention was devoted to personal and social dimensions that had previously been underrepresented in traditional school curricula, despite being essential for the well-being of students, teachers, families, and society as a whole. With the publication of *Emotional Intelligence* by Daniel Goleman (1996), scientific and public interest in this topic expanded rapidly, leading to a significant growth in studies and scholarly contributions (Pérez-González, 2010). Authors such as Goleman (2000), Mayer and Salovey (1997), Bar-On and Parker (2000), and Bisquerra (2002) have highlighted the crucial role of emotional intelligence as an indispensable foundation for individual and collective well-being, emphasizing the need for every person to develop adequate emotional competencies.

Today, the importance of integrating SEL into educational contexts has become even more evident in the aftermath of the COVID-19 pandemic, which underscored the necessity for education systems to address students' mental health and emotional resilience (Grazzani et al., 2022a, 2022b; Martinsone et al., 2022). SEL programs are therefore increasingly regarded not

Accepted Manuscript Online. DOI: 10.17471/2499-4324/1438

only as instruments for personal growth but also as essential means to foster inclusion, empathy, and cooperation within classrooms (Zins et al., 2004).

However, many educational systems, including Italy's, have yet to fully incorporate these competencies into their curricula.

Internationally, Denmark stands out with its *Klassens tid* program, introduced in the 1960s, which focuses on fostering empathy and promoting a positive classroom environment (Solborg Pedersen, 2015). Similarly, Spain's *Programa Emozioak* has demonstrated the effectiveness of interventions rooted in emotional intelligence (Cubero & Romero Perez, 2013). In contrast, Italy addresses SEL only in general terms within its national guidelines and lacks a structured program. A bill introduced in November 2020, aimed at piloting emotional intelligence education in schools, has yet to be enacted (Italian Parliament, 2020). Research highlights the importance of emotional intelligence in improving mental health and supporting academic achievement. Positive peer relationships and decision-making skills have also been shown to predict academic success (Schutte et al., 2007).

Within this theoretical framework, social robotics offers promising avenues for the practical implementation of Social and Emotional Learning (SEL) principles. NAO, one of the most widely used humanoid robots in educational contexts, combines interactive, multimodal, and affective features that can support both socio-emotional and cognitive learning. Through the mechanisms of affective computing (Picard, 2000; Salazar et al., 2021), NAO is able to simulate empathy, provide adaptive emotional feedback, and create safe, non-judgmental environments that foster engagement and emotional expression. Affective Computing, which encompasses the recognition, interpretation, and processing of human emotions, holds significant potential to transform educational practices. Social robotics is increasingly recognized as a valuable tool for fostering socio-emotional skills through interactive, personalized, and engaging approaches. Social robots provide a safe, non-judgmental environment that encourages active learning and the exploration of emotional and social strategies. These robots can recognize emotions through facial expressions or vocal tones and respond appropriately, helping children reflect on and understand their emotions.

According to Pennazio (2019), it is considerably easier for a child with Autism Spectrum Disorder (ASD) to interact with a robot rather than with a human interlocutor, as the latter tends to provide unpredictable responses, whereas the robot's reactions can be programmed based on the child's specific needs. In this way, a comfort zone is created for children, since the robot establishes predictable and reassuring relational situations (Pennazio, 2019). Campitiello et al. (2021) also highlight several positive aspects of child–robot interaction, including *social acceptability*—that is, the child's willingness to engage first with the robot rather than with a human partner—*motor communication through imitation*, referring to the child's tendency to reproduce some of the robot's behaviors, and the *maintenance of shared attention*. As stated on the official website of the Aldebaran Robotics.

NAO is a humanoid robot designed to capture attention, foster communication, and support learning for children with Autism Spectrum Disorder (ASD). NAO is an emotional robot that helps children reduce their timidity, reluctance, frustration, and build self-confidence, social skills and self-esteem. NAO encourages the acceptance of special education in an ordinary classroom, developing positive attitudes and perceptions towards special education[2].

[2] https://aldebaran.com/en/education/

Accepted Manuscript Online. DOI: 10.17471/2499-4324/1438

The robot, thanks to its engaging appearance and its ability to interact in an encouraging and patient manner, can repeat instructions and provide support without judgment, thereby creating a reassuring relational context. This form of interaction helps to build the child's confidence, allowing them to persist in their efforts even in situations where human interaction might pose challenges. The humanoid, friendly, and recognizable appearance of NAO further contributes to capturing and maintaining students' attention, facilitating emotional engagement and the learning process.

Consequently, NAO can be considered an embodied pedagogical partner, capable of helping children recognize, understand, and manage their emotions through interactive and experiential learning. Its ability to mediate social interactions and to model empathy and self-regulation aligns closely with the core objectives of Social and Emotional Learning (SEL), suggesting that humanoid robotics represents an innovative approach to supporting emotional education in primary school settings.

Despite a growing body of research on educational robotics, few studies have systematically examined how humanoid robots such as NAO contribute to Social Emotional Learning (SEL) in mainstream primary education. This review aims to fill this gap by synthesizing evidence on NAO's role in fostering emotional competencies and related learning outcomes.

In this context, we addressed two research questions:

- RQ1. What are the applications of the NAO robot in enhancing the emotional competencies of children in primary school?
- RQ2. How does the NAO robot contribute to improving learning outcomes through emotional support?

Answering the research questions posed in this systematic literature review aims to contribute to the academic discourse by providing insights that can serve as a foundation for advancing educational practices and informing public and educational policies in the field.

The following section outlines the steps undertaken to identify and include the studies reviewed.

2. Methodology

A systematic review was conducted to identify articles on the use of the NAO robot to develop emotional competence in primary school pupils. The focus on primary school pupils was chosen because this developmental stage is critical for fostering emotional and social skills, which can have lasting impacts on academic success and personal well-being. Moreover, primary school-aged children are particularly receptive to interactive and engaging tools like social robots, making this a promising area for intervention.

The review followed the PRISMA 2020 guidelines to ensure methodological transparency and quality. Three databases were used to search the studies for the current review (Table 1).

Table 1. Databases used in the systematic review.

Databases	Web sites
Web of Science (WoS)	https://www.webofscience.com/wos/woscc/basicsearch
Scopus	https://www.scopus.com/
EBSCO	https://research.ebsco.com/c/jb7ptv/search/advanced/

The search string was structured around three main components. The first referred to the robot under investigation, namely NAO; the second focused on the competence intended to be

Accepted Manuscript Online. DOI: 10.17471/2499-4324/1438

developed through robotic intervention, specifically emotional competence; and the third restricted the results to studies conducted in primary school settings.

The keywords ("NAO" OR "NAO robot*") AND ("emotion*" OR "emotional competence*") AND ("primary school*" OR "elementary school*" OR "primary education" OR "elementary education" OR "k-6") were used both on their own and in Boolean combinations.

The following inclusion and exclusion criteria were adopted.

Inclusion criteria:

- articles published between 2014 and 2024;
- studies published in English language;
- type of robot (NAO);
- primary school setting;
- empirical studies (qualitative or quantitative) that used the NAO robot for the development of emotional competence in educational processes.

Exclusion criteria:

- we excluded non-empirical studies;
- studies that do not use NAO;
- studies not published in English.

The search targeted articles published over the past ten years to ensure the inclusion of up-to-date contributions and to accurately represent the current state of research in educational and socio-emotional robotics. The use of multiple filtering criteria resulted in a relatively limited number of relevant studies retrieved across the main databases; however, this allowed the review to maintain a focused, coherent, and methodologically rigorous scope.

The studies were double-checked and filtered by the two authors. The initial search provided 21 papers. During the first phase, after removing duplicates (n=10), two authors independently reviewed the titles and abstracts of all retrieved studies (n=11). Of these, three were excluded: one because it was a literature review rather than an empirical study; another because it did not concern the NAO robot (the term “NAO” appeared only as part of an author’s name); and a third because it was written in Spanish instead of English. In the second phase, the same reviewers independently read the full texts of the 8 selected studies to assess their eligibility. Each reviewer coded 4 articles (randomly assigned) and then jointly reviewed the data extracted from these 8 articles. Discrepancies were resolved through discussion. Inter-rater reliability between the two coders was assessed using Cohen’s kappa coefficient, which indicated substantial agreement ($\kappa = 0.78$, $p < .001$) according to Landis and Koch’s (1977) criteria. After this preliminary phase, the two authors divided the remaining articles and coded them individually. Figure 1 illustrates the different stages of the review process.

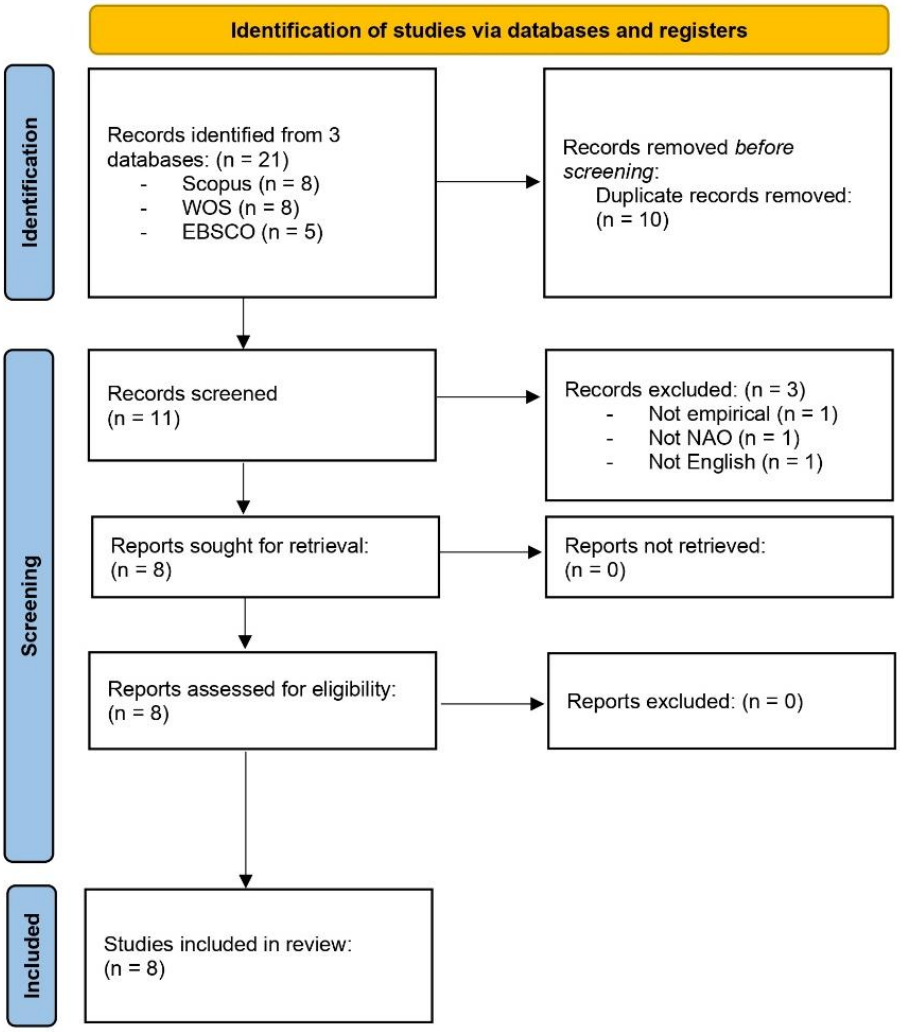

Figure 1. PRISMA 2020 flow diagram of the selection process.

3. Results

The main results of this systematic review are reported in Table 2. The articles included in this review were published between 2015 and 2023, with the majority of papers (4) published between 2017 and 2019. With regards to the sample, the analysis of data shows that the total number of participants varies from 20 to 101 children. The participants in the various studies include children aged between 6 and 13 years. The studies examine groups of children from different age ranges, with means ranging from 6.52 years (SD = 0.65) to 11.43 years (SD = 0.64), indicating variability in the participants' ages, but with a predominant focus on children aged between 6 and 11 years.

The 8 selected studies have been divided into two major categories, aligned with the research questions guiding this review: (a) studies (5) that address RQ1, focusing on the applications of NAO in enhancing children's emotional competence, and (b) studies (3) that address RQ2, exploring how NAO contributes to improving children's learning outcomes

Accepted Manuscript Online. DOI: 10.17471/2499-4324/1438

through emotional support. This categorization highlights the dual role of NAO in addressing both emotional and educational dimensions in children. However, these categories were not mutually exclusive. Several studies addressed both emotional and cognitive outcomes, revealing how socio-emotional skills and academic learning are interrelated. For instance, interventions that improved students' emotional regulation also enhanced engagement and motivation, suggesting that emotional competence contributes to better learning outcomes.

Table 2. Description of the studies included in the systematic review.

Authors (Year)	Title	Country/Countries	Target sample number	Topic	Role of the NAO robot	Methods	Results
Hameed & Mahmoudi (2019)	ICPS-NAO: Nurturing Thinking Children Using a Social Robot	Norway	30 (6-9 years)	Social problem-solving for children	Teaching assistance for the ICPS program	Randomized controlled trial with pre-post tests, 17 intervention sessions	Improvement in acceptability and feasibility of the ICPS program for typical children
Ahmad et al. (2019)	Robot's adaptive emotional feedback sustains children's social engagement and promotes their vocabulary learning	Australia, Pakistan	24 10-12 years (M = 10.52, SD = 0.60)	Long-term interaction with adaptive robots	Educational tutor providing positive, neutral, and negative feedback	Long-term study with child-robot interactions through an educational game	Positive feedback enhanced social engagement and vocabulary learning compared to neutral or negative feedback
Papadopoulou et al. (2022)	Efficacy of a Robot-Assisted Intervention in Improving Learning Performance of Elementary School Children with SpLDs	Greece	40 3rd and 4th grade children (M=8.73, SD= 0.64)	Intervention for Specific Learning Disorders (SpLDs)	Support for educators in improving phonological awareness and reading	Randomized study with control group; pre- and post-tests	Comparable improvements to standard interventions; superiority in specific phonological awareness exercises
Imbernon Cuadrado et al. (2016)	ARTIE: An Integrated Environmen	Spain	20 children (10-11 years)	Affective educational robots	Affective tutor with personalizat	Development and validation of	Effectiveness of robotic tutors in

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Authors (Year)	Title	Country/Countries	Target sample number	Topic	Role of the NAO robot	Methods	Results
	t for the Development of Affective Robot Tutors				ion based on emotional state	an educational prototype for Scratch and NAO robots	educational interaction, with potential for integration into standard educational systems
Podpečan (2023)	Can You Dance? A Study of Child–Robot Interaction and Emotional Response Using the NAO Robot	Slovenia	Not specified	Child-robot interaction and emotional response	Educational entertainment via dance and games	Retrospective study with observations and qualitative data from over 8 years of robot-human interactions in various activities	Children showed high engagement, and activities helped popularize STEM concepts, especially for younger age groups and children with special needs
Peters et al. (2017)	Robots Educate in Style: The Effect of Context and Non-verbal Behaviour on Children's Perceptions	Netherlands	Study 1: 101 children S1: 10-13 years (M = 11.43, SD = 0.64) S2: 5-8 years (M = 6.52, SD = 0.65). Study 2: 72 children (52 from the Study 1) 20 new participants 8-11 years (M = 9.20, SD = 1.10)	Influence of robot behaviour on perception	Lecturer/tutor	Perception study using stylized robot behaviours (e.g., warmth and competence) during educational lectures	Subtle changes in non-verbal behaviour affected children's perception of robot competence and warmth, validating the proposed behaviour model

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Authors (Year)	Title	Country/Countries	Target sample number	Topic	Role of the NAO robot	Methods	Results
Magyar & Vircikova (2015)	Socially-Assistive Emotional Robot that Learns from the Wizard During the Interaction	Slovakia	20 children (6-8 years)	Physical therapy for back pain	Therapy assistant for exercise demonstrations	Pilot study using the Wizard of Oz method with pre-programmed exercises; sessions included a human physiotherapist for guidance	Robot-guided therapy improved exercise engagement and demonstrated potential for long-term use in paediatric rehabilitation
Ahmad et al. (2017)	Emotion and Memory Model for a Robotic Tutor in a Learning Environment	Australia, Pakistan	24 children (10-12 years)	Emotional memory model for learning	Vocabulary tutor, emotional feedback	Long-term interaction study with 4 sessions over 3 weeks, evaluating the impact of feedback types (positive, neutral, negative)	Positive feedback enhanced vocabulary learning and engagement compared to neutral or negative feedback

3.1. The use of the NAO robot to foster children's emotional competence (RQ1)

This category includes five studies that focus on the use of NAO to improve emotional competence. For instance, the study by Hameed and Mahmoudi (2019) focuses on enhancing children's problem-solving skills through the I Can Problem Solve (ICPS) program, which integrates emotional and social components into educational activities. Specifically, the program includes 17 intervention sessions, where NAO assists in role-playing scenarios to teach children how to identify emotions, try to gain perspective and evaluate actively pro-social solutions to problems. The findings provided valuable insights, particularly for children with ASD, who demonstrated an improved ability to develop social skills through interactions with the robot, which they found easier to engage with compared to a human interlocutor (McClelland et al., 2017).

Similarly, Podpečan's (2023) study highlights how the NAO robot supports emotional expression and interaction through activities such as dancing and playing. Conducted eight years, the study observed children's engagement with NAO in structured activities designed to

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promote social and emotional learning. The children exhibited greater awareness of their own emotions and those of others, facilitated by activities involving the recognition and response to NAO's emotional cues. Social interactions encouraged empathy and emotional awareness, particularly among children with special needs, who reported feeling safe, calm, and comfortable in the robot's presence. Additionally, some children experienced reduced anxiety levels during these interactions.

Magyar and Vircikova (2015) investigate the use of a socially assistive emotional robot in a primary school in Slovakia to guide children with therapeutic needs through physical exercises aimed at preventing back pain. Using the Wizard of Oz methodology, a human operator controlled the robot, determining when and how to display pre-programmed adaptive emotional expressions to facilitate emotional well-being during therapy sessions. The study demonstrated that NAO's emotional expressions motivated children and reduced their anxiety during the sessions, fostering a positive emotional atmosphere.

Peters et al. (2017) investigate how NAO's non-verbal behaviour influences children's emotional engagement and perceptions of the robot. The study involved a 2 × 2 factorial design focusing on warmth and competence as variables, examining how these attributes in NAO's behaviour affected children's emotional responses. Conducted with 101 participants aged 5 to 13, the research utilized a combination of observation and adjective-based rating scales to measure perceived warmth, competence, dominance, and affiliation. Results highlighted that children's engagement and perception of NAO's emotional qualities were significantly influenced by the non-verbal cues presented, underlining the importance of robot behaviour design in fostering emotional and social connections. Conducted with 101 children aged 5 to 13, the study found that variations in NAO's warmth and competence significantly impacted children's perceptions and emotional connection with the robot, emphasizing the importance of non-verbal cues in promoting social and emotional engagement.

Finally, Imbernon Cuadrado et al. (2016) introduced the ARTIE platform, which enables NAO to function as an affective tutor in educational settings. The study's findings indicated that the ARTIE platform, which integrates the Behavior Markup Language (BML) to produce complex and adaptive behaviours, facilitated more natural and effective interactions. The system allowed NAO to adjust its behaviours, such as movements and vocal responses, based on the emotional states detected in children, significantly enhancing their engagement during educational activities. Furthermore, the interface was used to assess the effectiveness of these interactions, demonstrating that children were more likely to sustain positive and productive interactions with NAO compared to non-customized approaches.

3.2. Improving children's learning outcomes through emotional support of NAO (RQ2)

The second category includes three studies where the primary goal is improving children's learning outcomes through emotional support of NAO, where emotions are the means and not the main objective. Ahmad et al. (2019) and Ahmad et al. (2017) describe closely related studies that share the same sample, tools, and methodologies. While the short-term 2017 study introduces an emotional memory model in NAO, exploring how feedback impacts vocabulary learning, the 2019 study expands on these findings by examining long-term interactions, including extended observations and varied feedback types (positive, neutral, and negative).

The overlap between these studies suggests a research progression that explores complementary aspects of NAO's role in educational settings, reinforcing the robustness of their shared conclusions. Both studies focus on NAO's adaptive emotional feedback mechanisms,

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which enhance vocabulary learning while supporting social engagement. These overlapping results suggest that the studies may represent different facets or extensions of the same research initiative.

The findings from Ahmad et al. (2017) demonstrated that social engagement with the robot was sustained throughout all four sessions. Regarding learning outcomes, the Bonferroni post-hoc test showed that the highest improvement in vocabulary retention occurred in the condition where the robot provided positive feedback, significantly outperforming negative feedback ($p<0.04$) and neutral feedback ($p<0.02$). These results highlight that NAO's adaptive emotional responses not only supported engagement but also facilitated long-term learning, particularly in scenarios involving positive feedback.

Similarly, the 2019 study by Ahmad and colleagues found that positive feedback provided by the robot had the most significant impact ($M=22.25$, $SD=1.03$) on vocabulary learning. It also led to a longer duration of eye contact with the robot, indicating strong emotional engagement. Children retained the highest number of words learned in the positive feedback condition, compared to the negative feedback condition ($M=20.25$, $SD=1.03$) and the neutral feedback condition ($M=20.50$, $SD=1.60$). The Bonferroni post-hoc test confirmed that the robot's positive emotional feedback had a significantly greater effect on overall learning compared to negative feedback ($p=0.016$) and neutral feedback ($p=0.039$).

Papadopoulou et al. (2022) assessed the effectiveness of NAO as a tutor within a specialized educational program for children with Specific Learning Disorders (SpLDs), comparing it to a control group where only a human educator was present. The intervention focused on decoding skills, phonological awareness, and reading comprehension, with NAO providing personalized feedback and support during the activities.

In terms of learning outcomes, both groups showed significant improvements across various reading-related skills. However, participants in the NAO group achieved higher scores in word segmentation (M: 9.47, SD: 0.77 for NAO vs. M: 6.52, SD: 2.75 for control, $p < 0.001$) and word synthesis (M: 7.58, SD: 2.01 for NAO vs. M: 5.38, SD: 2.04 for control, $p = 0.003$) compared to the control group. Social outcomes, as measured by the Strengths and Difficulties Questionnaire (SDQ), revealed a significant reduction in peer problems for the NAO group (M: 1.68, SD: 1.77), compared to the control group (M: 2.19, SD: 2.04, $p = 0.046$). These findings demonstrate NAO's potential to enhance both learning and peer relationships in children with Specific Learning Disorders.

4. Discussion

This systematic review highlights the multifaceted potential of the NAO robot in both emotional and learning domains, providing valuable insights into its possible applications in primary education. The studies reviewed fall into two distinct categories, which align with the research questions guiding this review: (a) those that employ the NAO robot to enhance emotional competencies and (b) those that aim to improve learning outcomes through NAO's emotional feedback. This dual focus underscores the versatility of NAO as a tool for fostering both cognitive and emotional development in children. The overlap between emotional competence and learning outcomes in some articles suggests that the emotional and cognitive domains in education are deeply interconnected. This interdependence reflects the holistic nature of learning, in line with affective-cognitive theories of emotional intelligence and education.

Most of the included studies implemented interventions aimed at using the NAO robot to engage children in activities that enhance their emotional competencies, such as emotional

Accepted Manuscript Online. DOI: 10.17471/2499-4324/1438

regulation, empathy, and social problem-solving (Hameed & Mahmoudi, 2019; Podpečan, 2023; Imbernon Cuadrado et al., 2016; Magyar & Vircikova, 2015; Peters et al., 2017). For instance, Hameed and Mahmoudi (2019) reported significant improvements in emotional understanding and decision-making through structured sessions using the ICPS program. Similarly, Podpečan (2023) observed long-term benefits from structured activities like dance and play, which effectively fostered emotional awareness and engagement, demonstrating NAO's ability to create interactive and emotionally enriching environments. Imbernon Cuadrado et al. (2016) further illustrated how NAO, through the ARTIE platform, could personalize interactions based on children's emotional states, significantly improving their engagement and emotional understanding. These findings highlight NAO's potential to integrate emotional feedback and dynamic responses, making it a valuable tool for emotional education.

The findings from studies utilizing NAO in educational activities are particularly noteworthy, as they demonstrate its effectiveness in enhancing children's learning outcomes through emotional feedback (Ahmad et al., 2017; Ahmad et al., 2019; Papadopoulou et al., 2022). Ahmad et al. (2017; 2019) exemplify this dual role by exploring NAO's adaptive emotional feedback in vocabulary learning. Both studies share significant methodological and outcome similarities, focusing on how positive emotional feedback enhances learning and engagement. While the 2017 study introduces an emotional memory model that impacts vocabulary retention and emotional responses, the 2019 study expands on these findings by exploring long-term interactions and comparing different feedback types (positive, neutral, negative). This overlap suggests that the two studies are complementary, providing a more comprehensive understanding of NAO's role in educational contexts. The findings revealed that NAO's positive feedback not only improved learning outcomes but also sustained social engagement and emotional connections with the robot. Similarly, Papadopoulou et al. (2022) demonstrated how NAO, assisting children with Specific Learning Disorders (SpLDs), indirectly promoted motivation and positive attitudes, further reinforcing the emotional benefits of using social robots in educational interventions.

There is also a clear overlap between the two identified categories. While these studies (Ahmad et al., 2017, 2019; Papadopoulou et al., 2022) primarily aim to improve learning outcomes, such as vocabulary acquisition or reading skills, these interventions often rely on mechanisms of emotional engagement. This suggests that emotional engagement and cognitive development are deeply interconnected, with the former frequently acting as a catalyst for the latter.

The studies by Hameed and Mahmoudi (2019), Podpečan (2023), and Papadopoulou et al. (2022) underscore NAO's effectiveness in supporting students with Special Educational Needs (SEN). Hameed and Mahmoudi demonstrated how NAO, integrated into a structured social problem-solving program, could help children with SEN improve their emotional and social skills. Podpečan (2023) highlighted NAO's ability to foster emotional engagement and empathy through activities like dance and play. Notably, children with SEN felt calm, safe, and comfortable in NAO's presence, with some showing reduced anxiety levels. Similarly, Papadopoulou et al. (2022) evaluated NAO's role as a tutor for children with SpLDs, showing not only improvements in academic skills such as phonological awareness and reading but also a reduction in peer-related problems. These findings emphasize NAO's versatility in creating an inclusive environment that supports both academic and social development for students with SEN.

The reviewed studies reveal that NAO's functionality is significantly enhanced when integrated with external tools and technologies. For example, Podpečan (2023) demonstrated how Facenao and LiveChat, two AI-driven tools, augmented NAO's ability to recognize and

Accepted Manuscript Online. DOI: 10.17471/2499-4324/1438

respond to emotional expressions, providing a richer and more personalized interaction experience. Similarly, Imbernon Cuadrado et al. (2016) showcased the use of the ARTIE platform, which enabled NAO to dynamically adapt its behaviours using the Behavior Markup Language (BML). These tools highlight the importance of combining NAO's built-in capabilities with advanced AI technologies to create more adaptive and effective educational interventions.

Pennazio and colleagues (2020) highlight that while some studies prioritize the use of fully autonomous systems, there are cases where the Wizard of Oz (WoZ) method is a more suitable choice. In this approach, the experimenter remotely controls the robot's responses while concealing their involvement (Pennazio et al., 2020), as demonstrated in the study by Magyar and Vircikova (2015). The WoZ method minimizes the risk of interruptions in the interactive process between the child and the robot caused by incorrect or irrelevant responses from the robot.

Podpečan (2023) also provided insights into how perceptions of NAO differ between adults and children. While children often perceived NAO as a dynamic and engaging companion capable of emotional interactions, adults tended to focus on the robot's technical and functional aspects. This divergence in perceptions has implications for how NAO is introduced and used in educational settings, as fostering positive perceptions among educators and caregivers may enhance its acceptance and integration.

Taken together, these findings invite a broader reflection on NAO's educational and technological significance. Overall, the results of this review underscore the importance of integrating social robotics into primary education not as a technological novelty, but as a pedagogical mediator capable of fostering both cognitive engagement and emotional awareness. Across studies, NAO has demonstrated how emotional feedback can sustain motivation, support inclusion, and promote more empathetic classroom dynamics. These outcomes align with wider educational priorities, such as the integration of Social and Emotional Learning (SEL) principles and the development of learner-centered environments that value emotional well-being alongside academic success.

From a technological perspective, the reviewed studies also indicate that NAO's effectiveness depends on how technology is contextualized within pedagogical practice. Rather than acting as an autonomous teaching agent, NAO achieves its greatest impact when guided by educators who can adapt its emotional responses to instructional objectives. This synergy between innovation and human mediation exemplifies a human-centered approach to educational technology, where affective computing and robotics are designed to complement—not replace—interpersonal interaction.

Despite the promising findings, some limitations emerged. Papadopoulou et al. (2022) identified technical challenges, such as issues with NAO's voice recognition system, which sometimes required manual intervention by educators. These disruptions could affect the fluidity of interactions and potentially limit NAO's effectiveness in certain scenarios. Addressing these technical limitations is essential to maximize the robot's impact in real-world educational environments.

Regarding the methodological characteristics of the included studies, several limitations were noted. Except for the study by Peters et al. (2017), most others involved relatively small samples (<100 participants), which may limit the generalizability of the findings. Additionally, the reliance on short-term interventions makes it challenging to assess the long-term impacts of NAO-based programs. Future research should aim to address these gaps by employing larger samples, longitudinal designs, and standardized assessment tools to comprehensively evaluate cognitive and emotional outcomes.

Accepted Manuscript Online. DOI: 10.17471/2499-4324/1438

Beyond methodological issues, the reviewed literature also raises important epistemological and ethical considerations. Although the studies highlight NAO's potential in supporting emotional and cognitive learning, the concept of emotional learning mediated by a robot involves epistemological ambiguity. While NAO can simulate empathy and affective responses, these interactions remain algorithmic rather than genuinely emotional. Nevertheless, when embedded in guided educational settings, such interactions can serve as pedagogical mediators, helping children to identify, label, and reflect on emotions in a safe and structured way.

At the same time, their use raises ethical and relational concerns, including privacy, emotional dependency, and the risk of technocentric dependence that may overshadow the human dimension of learning. In this sense, the use of NAO and similar social robots should not be conceived as a replacement for human presence, but rather as a pedagogical complement within a consciously mediated framework. The teacher's role remains essential in interpreting, contextualizing, and humanizing these interactions, ensuring that technology serves the broader goals of emotional education rather than redefining them.

5. Conclusion

The findings of this systematic review emphasize the potential of the NAO robot in both emotional and learning dimensions, yet the limited number of studies identified suggests underlying challenges that merit critical consideration. The limited number of studies included highlights the specificity of the research focus and underscores the emerging nature of this field. This specificity, combined with rigorous inclusion criteria, highlights a significant gap in the literature.

One possible explanation for the scarcity of research is the uneven adoption of emotional education programs in schools worldwide. Many countries may lack formal frameworks to incorporate emotional learning into their curricula, which limits the opportunities to explore innovative tools like NAO in this domain.

Additionally, access to robotic technology in schools remains a significant barrier. High costs, limited funding, and unequal distribution of technological resources may prevent many institutions from integrating robots into their educational settings. Even in schools that possess robots, there may be hesitation among educators to use them effectively due to a lack of training or confidence in navigating these advanced technologies. Concerns about the technical reliability of robots, as highlighted by some studies, could also contribute to reluctance in their adoption.

Another critical factor may be the gap between research and practice. While studies demonstrate NAO's potential, translating these findings into scalable and sustainable educational practices remains challenging. This disconnect might hinder the broader adoption and exploration of such technologies in schools.

Despite these challenges, the synthesis of existing results serves as a valuable foundation for future research. The categorization and analysis provided in this review highlight key areas where NAO has shown promise, offering insights that can guide subsequent studies. For example, researchers can build upon the identified strengths of NAO in promoting emotional engagement and academic learning, while addressing the barriers that limit its widespread use.

Furthermore, these findings offer practical inspiration for future experimental designs and interventions. By leveraging the insights gained from this review, researchers can refine methodologies, explore new contexts for NAO's application, and evaluate its impact over longer durations and with more diverse populations. By addressing current limitations and

Accepted Manuscript Online. DOI: 10.17471/2499-4324/1438

building on the synthesized evidence, future research can better harness the potential of NAO and similar technologies to support emotional and cognitive development in primary education.

Policymakers and educators can also use these insights to advocate for more integrated and accessible emotional education programs, fostering innovation in teaching practices. In this regard, the Italian bill introduced in 2020 to pilot emotional intelligence education in schools (Italian Parliament, 2020) represents a significant policy initiative that aligns with the objectives highlighted in this review. The evidence synthesized here could support such efforts by providing empirical grounding for the inclusion of structured socio-emotional learning (SEL) curricula that make informed and responsible use of emerging technologies such as social robotics. Integrating humanoid robots like NAO within these frameworks could offer concrete opportunities to translate policy ambitions into classroom practice, combining emotional education with technological innovation in a human-centered way.

Furthermore, teacher education programs should incorporate opportunities to develop technological and emotional literacy, enabling teachers to use social robots not as replacements for human interaction, but as tools for modeling empathy, collaboration, and self-regulation. Strengthening educators' competencies in this area would ensure that innovations such as NAO are effectively integrated into classrooms, supporting both academic and socio-emotional growth.

6. Author contributions

Anna Teresa Musicco designed the study, conducted the literature search, and contributed to data analysis. Luigi Traetta supervised the article selection process, providing critical input for the interpretation of the results. Both authors wrote and revised the final manuscript.

7. Funding

This research received no external funding.

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