Ethical Considerations in Designing and Testing Robots for Children in Educational Settings

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Abstract The integration of social robots into children's lives, whether for educational, rehabilitation, therapeutic, or entertainment purposes, has progressed in recent years, requiring addressing ethical concerns that extend beyond the standard ethical requirements applied to human research. This chapter discussed ethical issues surrounding developing and investigating social robots intended for children in educational settings to ensure their safety, positive development, and well-being. First, we reviewed current approaches to using social robots in educational settings. We discussed the benefits and potential concerns in child-robot interaction (CRI), including issues of attachment and dependency, obedience, reduction of human interaction, and accountability. Secondly, we reviewed the main ethical principles and guidelines, professional codes of conduct, and regulations relevant to CRI. Third, we review and discuss the methodological research aspects implemented for the design of robots and assessing their impact on children by outlining some ethical practices for conducting research. Finally, we explored the implications of integrating social robots into educational settings, focusing on their deployment and long-term use in classrooms, along with crucial aspects of sustainable research practices aiming to help shape future directions in this field.

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G. Lampropoulos and S. Papadakis (eds.), *Social Robots in Education*, Studies in Computational Intelligence 1194, https://doi.org/10.1007/978-3-031-82915-4_8

Keywords Child-Robot Interaction (CRI) · Education · Ethics · Social robots

1 Introduction

Social robots are increasingly being introduced into educational settings, offering innovative ways to engage and support children. Current approaches to using social robots in education usually involve their use as tutors, peer learners, and classroom assistants (Belpaeme et al., 2018). These robots are currently being used to support several educational activities (Anwar et al., 2019; Özgür et al., 2017), such as language learning (Asselborn et al., 2018; Huang & Moore, 2023), science, technology, engineering, and mathematics (STEM) education (Rocha et al., 2023), physical activities (Costa et al., 2015; Litoiu & Scassellati, 2015), social skills development (Neto et al., 2023), and inclusive education (Berrezueta-Guzman et al., 2021; Neto et al., 2020; Rocha et al., 2023). One innovative approach within the field of language education is Robot-Assisted Language Learning (RALL), which incorporates Artificial Intelligence (AI) to facilitate and improve language learning, offering practice opportunities, real-time feedback, and tailored instructions to meet student's needs (Huang & Moore, 2023; Konijn et al., 2022; H. Lee & Lee, 2022).

Some commercial robots have also been developed to support children's learning and play activities. Often designed to enhance STEM and language skills, these robots vary in complexity and target different age groups. Notable examples include Dash and Dot (Workshop, 2024), LEGO Mindstorms (Lego, 2024), Go and IQ (Robotics, 2024), (Sphero, 2024), Ari and Evo (Ozobot, 2024), (KUBO, 2024), Cubelets Robot Blocks (Modrobotics, 2024), Cozmo and Vector (Anki Cozmo Robot, 2024), (Thymio, 2024), and (EMYS, 2024).

Additionally, extensive literature from the research community presents a variety of early-stage prototypes developed to explore and evaluate the broader impact of these robots on children. Researchers working in Child-Robot Interaction (CRI) have also investigated the effects of different robotic social capabilities, including humanoid embodiments, to explore their social abilities and affordances, specifically how children perceive them and how they affect their behavior. For instance, a robot that listens to children's stories and exhibits backchanneling behaviors based on its understanding of the children's engagement can effectively demonstrate attention (Lee et al., 2019). Similarly, researchers have shown that when robots use memory-based personalization, such as referring to previously mentioned preferences of the children, these behaviors facilitate sustainable long-term interactions with children (Ligthart et al., 2022), even after long breaks (Ligthart et al., 2024).

However, there is a lack of systematic evaluations aiming at understanding the long-term effects of CRI in school environments and its potential impact on children's socio-emotional development (Langer et al., 2023). For example, in the context of school inclusion, it remains unclear whether the positive effects observed during a single interaction with a robot, where the robot facilitated balanced interactions between children with and without impairments, persist beyond the session (Neto et al., 2023). Additionally, the potential negative effect of fostering children's dependency on the robot's instructions raises ethical concerns. Other concerns are the difficulties in replicating studies (Spitale et al., 2023), often due to the lack of pre-registration, insufficient details about the design, and the failure to share coding and study data. Furthermore, the lack of standardized outcome measurement protocols makes it challenging to ensure consistency and reliability across different research contexts (Bethel & Murphy, 2010).

This chapter discusses the ethical challenges and concerns related to the design, development, and evaluation of social robots intended to interact with children in educational settings, focusing on ensuring their well-being, socioemotional development, and safety. It is structured as follows: Sect. 2 reviews the potential benefits of integrating social robots into educational settings, but with a primary focus on the ethical concerns related to CRI. To understand how these concerns have been addressed, Sect. 3 reviews the ethical principles, guidelines, professional codes of conduct, policies, and current regulations governing the responsible use of social robots. Section 4 examines the challenges of conducting ethical research in CRI, providing recommendations for best practices in ethical compliance, highlighting the importance of designing robotics tailored to children's needs with a focus on co-design and other methods for assessing the impact of CRI. Section 5 explores the roles and responsibilities of robot developers and Sect. 6 addresses the broader challenges and implications associated with deploying social robots in educational settings, as well as considerations for long-term sustainability. Finally, Sect. 7 provides concluding remarks, summarizing some of the key ethical concerns and challenges discussed in the chapter and suggestions for future research.

2 Main Benefits and Ethical Concerns in Child-Robot Interaction

Recent systematic reviews and meta-analyses have shown the positive effects of educational and social robots on child development, each identifying distinct types of intervention and contextual factors. Overall, social and educational robots seem to affect knowledge, skills, and attitudes positively (Sapounidis et al., 2024), including specific cognitive outcomes, such as creativity and problem-solving (Mukhasheva et al., 2023; Zhang & Zhu, 2022), several learning outcomes (Wang & Cheung, 2024; Wang et al., 2023), and trust (Stower et al., 2021). The format of these interactions, especially one-on-one versus group settings, seems to be more efficient in some learning outcomes (Lee & Lee, 2022). Although the overall effectiveness of social and educational robots is positive, their impacts also vary depending on several factors, some related to the child's characteristics (e.g., age, developmental level, gender), others related to the robotic systems, emphasizing the need for careful instructional design (Su et al., 2023; Wang et al., 2023).

Several authors underscore that one key factor behind the success of robots in facilitating learning is their embodiment and physical presence because they may capture and maintain students' attention more effectively, in contrast to traditional digital learning tools (Kennedy et al., 2015). However, the human-like behaviors of robots do not consistently seem to enhance trust or liking, which challenges the assumption that these characteristics are inherently more beneficial for all outcomes (Stower et al., 2021). Nevertheless, many of these robots are designed to interact with humans socially and are often equipped with capabilities to engage students through interactive and personal learning experiences. Sometimes, they also integrate Artificial Intelligence (AI) to adapt to users' personal preferences or needs (Huang & Moore, 2023; Konijn et al., 2022).

Beyond the classrooms, schools offer children a rich environment for group playing activities. Social play is fundamental for children's interpersonal skills and to form friendships (Whitebread et al., 2019). As a result, the potential impact of using robots in places such as the playground has been studied, including as a toy for role-play to foster children's creativity (Alves-Oliveira, Arriaga, et al., 2021a, 2021b; Zhang & Zhu, 2022), a mediator of group conversations to reduce imbalance participation (Gillet et al., 2020), a companion to encourage children's collaborative behaviors (Belpaeme et al., 2018; Strohkorb et al., 2016), or a mediator to facilitate child-adult relationship (Di Dio et al., 2020). Systematic and meta-analysis reviews have also shown that robot-assisted interventions have been effective in enhancing social functioning in children with particular conditions, such as those with autism spectrum disorder, with age being an important factor in explaining the variance of outcomes (Damianidou et al., 2020; Kouroupa et al., 2022).

Collectively, prior research and recent meta-analytic findings demonstrate the benefits of educational robots and CRI, although their deployment must consider their developmental stage, age, specific needs, and contexts (e.g., Anwar et al., 2019; Kouroupa et al., 2022; Lee & Lee, 2022; Mukhasheva et al., 2023; Papakostas et al., 2021; Sapounidis et al., 2024; Wang & Cheung, 2024; Wang et al., 2023; Zhang & Zhu, 2022).

Various authors also emphasize ethical concerns related to the design and integration of robots in children's lives, which should involve a wide range of stakeholders, including educators, parents, psychologists, robot designers, and policymakers.

One main concern is the need for a delicate balance in CRI. Although robots should be engaging to maintain the children's interest and keep them motivated in their learning activities (Neumann et al., 2023), it can also become a distraction if a robot is overly social or interactive, pulling the children's focus away from their educational tasks. Additionally, it may make them feel uncomfortable or overwhelmed by the robot's presence (Belpaeme et al., 2018; van den Berghe et al., 2019). Therefore, designers and educators must carefully calibrate robots' social behaviors to ensure they effectively engage without being distracting or intimidating.

Another concern is children's over-reliance on robotic guidance, which might inhibit the development of essential skills such as autonomous learning, critical thinking, and decision-making (Boada et al., 2021). On the other hand, if the robot does not meet children's expectations, it can cause frustration (Belpaeme et al., 2013).

Additionally, children's emotional bond to a robot might evolve into emotional dependence, where users become overly reliant on the robot for emotional or social support (Boada et al., 2021), which in turn may affect their social interactions with peers and teachers (Neto et al., 2023). It is also possible for social robots to disrupt the traditional teacher-student dynamic, where teachers are viewed as experts and leaders (Serholt et al., 2017). To minimize these risks, it is essential to set boundaries for their use in educational settings. Robots should complement, rather than diminish or replace, interactions among students, teachers, and other people. Since robots do not experience emotions, are incapable of relating in a genuine way, and lack real-life experiences (Boada et al., 2021), their role should also primarily support the development of cognitive skills and, to a lesser extent, social skills to prevent the dehumanization of education (Tarrés-Puertas et al., 2023), and ensuring that education remains focused on human-centric values and meets the developmental needs of students (Boada et al., 2021). Recently, Contro and Brandão (2024) proposed the "Interaction Minimalism" design philosophy to guide the ethically responsible development of social robots. This philosophy seeks to ensure that robots are employed in a functional and non-intrusive way, advocating for the use of robots as tools to maintain their functional benefits without becoming central to emotional fulfillment or social interaction. In educational settings, this would mean the use of robots to facilitate students' activities and promote collaborative learning among students rather than allowing technology to dominate the learning and social experiences, which might compromise children's socioemotional development.

The design of social robots that can subtly affect human behavior, a concept known as "nudging," is also controversial (Mehenni et al., 2021). This controversy arises from the need to ensure that users are fully informed about how robots might influence their decisions or behaviors and that they are given control over these interactions, respecting their autonomy and preventing manipulation (Torras, 2024). This approach underscores the need for ethical design in robotics, emphasizing transparency, user consent, and agency as fundamental components (Ali Mehenni et al., 2021; Torras, 2024; van Straten et al., 2023). For instance, one study explored the impact on children of observing robots that excluded another child during a ball-tossing game, similar to the "Cyberball paradigm" (Correia et al., 2024). This classic paradigm has also been employed in developmental science to study the effects of ostracism on children (Scheithauer et al., 2013). The results by Correia et al. (2024) revealed that children were able to recognize the robots as excluders and that this exposure had a negative impact on their basic needs of belonging and control. However, these children were also more prosocial in a follow-up task. Based on these results, the authors discussed two important concerns. First, the finding that children expressed a desire to interact with the same robots they had considered excluders suggests that robots can maintain children's engagement even after negative experiences, highlighting the need for careful robotic design. Secondly, they discussed how interactions with robots might trigger carryover effects on children's subsequent social interactions with other children, underscoring the importance of monitoring and supervising CRI to prevent any negative influence on their social behaviors.

Research has also shown that robots can exacerbate inequality of access among children, posing challenges at multiple levels of accessibility which may lead to increased stigma and exclusion (Su et al., 2023). The high costs associated with robotic technologies may prevent economically disadvantaged children from accessing them, amplifying social exclusion across age, educational, economic, and geographical levels. This disparity may occur in affluent countries, where peers might have access to robots, and in less economically developed nations, where such technology might be unavailable. Furthermore, situations where individuals have more access to services through robots than human interaction can also create exclusion (Torras, 2024). One example includes automated teaching, where schools might consider using robots as instructors for several activities, potentially depriving them of personalized human teaching. For example, in the case of children with disabilities, there is a risk of entrusting care activities to robots, which may further isolate them from human interactions. Therefore, it is crucial to consider how these social and economic factors might raise ethical concerns (López-Sintas et al., 2012; Tarrés-Puertas et al., 2023). To mitigate some of these disparities, Tarrés-Puertas et al. (2023) developed activities in which robots were confined to school settings to ensure equal access. To address the possible lack of competencies related to the use of technological tools, students also received training about the materials used by the robots. Moreover, teachers tried to ensure all students were adequately trained in programming the robots, striving to ensure equitable educational experiences.

Other researchers have highlighted the possible negative effect on social equality regarding the quality of assistance, which depends on how they are implemented. For instance, if social robots do not have information in their database about specific characteristics of children, it will be challenging to provide similar assistance to all users (Boada et al., 2021). In this way, if vulnerable minorities do not have sufficient data representation, they may not benefit equally from the services that robots offer, such as expressive or facial recognition tailored to cultural minorities (Torras, 2024). Although the use of social robots designed to assist vulnerable groups could combat prejudice and exclusion, they might also inadvertently impact their well-being if they reinforce stereotypes associated with certain disabilities for which the robot provides assistance. Thus, the design of a social robot can also be a source of stigmatization, individual or collective, by reflecting the stereotypes that developers hold about end users (Boada et al., 2021). Sexist, ableist, or racist programming and design must not exist in robots.

To overcome these concerns, some researchers emphasize the need to actively challenge stereotypes in technology (Su et al., 2023; Tarrés-Puertas et al., 2023). Based on a systematic review of the role of socioeconomic status and gender on children's use of robotics in early childhood education, Su et al. (2023) underscored the need to develop inclusive robotics education programs to mitigate educational inequalities. Key recommendations include more effective engagement of girls and children from less advantaged backgrounds in robotics activities, the pivotal role of female teachers as role models in robotics education, and the need to develop, implement, and evaluate age-appropriate robotics activities to reduce these gaps and foster interest and skills among all children. Similarly, Tarrés-Puertas et al.

(2023) advocated challenging the perception of technology as a male-dominated field through class discussions about stereotypes in programming and AI. Additionally, they highlighted the need for teaching algorithmic awareness, which involves educating students on how algorithms can unintentionally perpetuate biases.

In addition to lacking genuine human feelings, robots typically lack several assistive tools, limiting interaction opportunities for children with impairments, whether visible or not. However, research addressing whether robots distribute classroom resources in a biased or unfair manner has not been fully investigated, nor have the broader, long-term consequences of such systematic disparities, resulting in a critical need to also investigate these ethical concerns (Neto et al., 2023).

Another concern is related to the issues of responsibility, which are relevant when a robot fails to assist children adequately. It is critical to make sure that children and educators are safe during interactions (Tolksdorf et al., 2021). These may include situations where the robot may fall, scare, or even harm a child. Given the highly unstructured nature of many activities (e.g., free play), programming a robot to account for all possible scenarios might be extremely challenging. Additionally, educators often lack detailed knowledge about the robot's functions and movements, making it difficult to intervene if something goes wrong. Since robots cannot legally bear responsibility, it is crucial to determine who is responsible—developers, manufacturers, owners, researchers, or users—for its actions, and there is a need for clear guidelines on roles and responsibilities concerning robot use in educational settings (Serholt et al., 2017). Currently, social robots lack reflective abilities to assess the correctness and success of their actions. Therefore, robots should only be used in these settings under the supervision of human experts (Tolksdorf et al., 2021). Moreover, robots operate autonomously only in very restricted contexts, and achieving full autonomous behavior in unstructured environments is still beyond current technological capabilities. However, robots are expected to act more autonomously in the future, which could lead to accidents or violations of privacy and autonomy (Boada et al., 2021). Therefore, a robot's decision-making process must always align with human values and ethical considerations, addressing dilemmas such as balancing security and privacy. To manage these complexities, robots need to be equipped with skills to handle ethically sensitive situations effectively (Torras, 2024). To ensure that the integration of social robots into educational and other settings is beneficial and aligns with educational goals and ethical standards, it will be important to establish clear protocols based on transparency, traceability, and accountability (Boada et al., 2021; van Straten et al., 2023).

Relatedly, social robots might also pose a threat to human privacy due to their capacity for monitoring, collecting, and processing personal data. These privacy issues in school settings apply to children, educators, and parents (Tolksdorf et al., 2021). Social robots can collect different information from users, including images, voice, location, and learning progress, which may pose risks of misuse (Ahtinen et al., 2023). Robots supporting learning activities tend to collect and analyze this data, which can be valuable to understanding children's engagement and skills development, but it may also raise privacy concerns. Moreover, children and their guardians might not be fully aware or have not consented to the storage and use of such detailed interaction data in the robot's memory. Additionally, the emotional bonds users may form with social robots can lead them to share more personal information, exacerbating privacy risks. This issue also relates to a lack of transparency in how social robots function, potentially misleading users about the robots' capabilities and the use of their data (Serholt et al., 2017; Torras, 2024; van Straten et al., 2023). Thus, it is important to detail who will evaluate this data and the pedagogical or therapeutic concepts behind it. Although such data can help educators tailor activities to a child's progress, relying too heavily on this data might lead to a narrow assessment (Tolksdorf et al., 2021).

Based on the various concerns outlined above, it becomes relevant to address how they can be managed and mitigated. Ethical guidelines, professional codes of conduct, and regulations are essential to ensure that the integration of robots into educational contexts is conducted responsibly and ethically.

3 Ethical Principles and Guidelines, Codes of Conduct, and Regulations Relevant to Child-Robot Interaction

Considering the intricate relationship between robots and AI, many of the well-established ethical principles and guidelines for AI also apply to robotics. The concept of "ethical AI" must align with fundamental human rights and adhere to professional ethics and codes of conduct (Tractenberg, 2024). Additionally, it is crucial to consider the laws and regulations on ethical issues that apply in each country or state, such as those regulating data protection and the conditions for developing and deploying AI systems that safeguard human rights.

3.1 Aligning Robots and Artificial Intelligent Technologies with Human Rights

The foundational Universal Declaration of Human Rights (United Nations. General Assembly, 1949), established by the United Nations (UN), sets a global standard for dignity and equality. Similarly, the European Convention on Human Rights (ECHR) within EU member states underscores the need for the protection of human rights and fundamental freedoms, with a strong emphasis on privacy and education rights. Building on these principles, the United Nations Guiding Principles on Business and Human Rights (UNGPs) present 31 principles designed to implement the UN's "Protect, Respect, and Remedy" framework. These principles ensure that business practices, including AI deployments, uphold human rights standards, emphasizing the responsibilities of transnational corporations and other business enterprises.

In research ethics, several key guidelines and codes have been proposed, including the Nuremberg Code (1947/1996), the National Commission for the Protection of

Human Subjects of Biomedical & Behavioral Research (1979), and the WMA Declaration of Helsinki (World Medical Association, 2013). The Nuremberg Code emphasizes voluntary consent, minimizing suffering, a favorable risk–benefit ratio, and strong protective measures. The Belmont Report develops these ideas by outlining three fundamental ethical principles for human subject research—respect for persons, beneficence, and justice—and their three main applications: informed consent, risk and benefit assessment, and participant selection, all aimed at protecting human rights and well-being. The Declaration of Helsinki builds on these principles and extends them, including outlining requirements for vulnerable groups and individuals to safeguard the welfare of participants with clinical conditions.

The commitment to fundamental human rights, ethical principles, and their implications for AI technologies is further emphasized by the Toronto Declaration (Amnesty International & Access Now, 2018), which specifically addresses the impact of machine learning on human rights (Tractenberg, 2024). Moving to AI-specific guidelines that impact the development of autonomous robots, some frameworks, such as the Montréal Declaration for a Responsible Development of Artificial Intelligence (Montréal University, 2018), set forth critical principles. These include ensuring that AI systems follow principles of well-being and autonomy, protecting privacy and intimacy, solidarity, democratic participation, equity, diversity, and inclusion. The Declaration also emphasizes prudence by anticipating the AI's potential adverse effects, underscores that only humans can be held responsible for the AI systems, and advocates for sustainable development. In Europe, the Ethical Guidelines for Trustworthy AI also reflect a commitment to ensuring that AI systems are developed and deployed in a manner that respects EU values and fundamental rights.

Additionally, it is crucial to consider specific guidelines and principles for vulnerable populations, such as children and those with special needs. Among these, the Convention on the Rights of the Child, adopted by the United Nations in 1989 (UNICEF, 2007), outlines the fundamental rights of children to ensure that children's rights and well-being are always prioritized, including in research, such as the right to express their views, protection of privacy, and safeguarding from abuse. Additionally, UNESCO's Guidelines for Policy-makers on AI and Education (Miao et al., 2021) provide several ethical considerations for using AI in educational settings, with the aim of making these technologies inclusive and equitable. These considerations include using "smart" robots to promote student learning, communication, and social skills, as well as to empower teachers.

In reviewing AI ethics policy documents with guidelines tailored explicitly to K-12 education, Adams et al. (2023) specifically selected documents from globally influential organizations, such as the Institute for Ethical AI in Education (IEAIED, 2021), which released a report and a AI framework offering guidance on how schools can responsibly acquire and use AI-based resources to enhance teaching and learning outcomes. By examining several guidelines in promoting the ethical development and implementation of AI technologies in educational settings, they identified eleven core AI ethics principles derived through content analysis. These principles included

Children's Rights, Transparency, Justice and Fairness, Non-maleficence, Responsibility, Privacy, Beneficence, Freedom and Autonomy, Pedagogical Appropriateness, AI Literacy, and Teacher Well-being.

Children's rights principles include protecting and prioritizing the needs and interests of young learners, which can be achieved by designing robots that respect and support the rights and needs of children. Transparency aims to ensure that AI systems used in education are understandable and provide clear explanations for their decisions and actions to both children and educators, which applied to robots can be achieved by clearly explaining their functions and decision-making processes. Justice and Fairness seek to guarantee that these AI systems are unbiased, treating all children equitably and avoiding discrimination, which can be integrated into robots by programming them to treat all users fairly and without bias. Non-maleficence focuses on preventing harm and ensuring the safety of children interacting with AI systems, which can be upheld by ensuring that robots do not harm users physically, emotionally, or socially. Responsibility involves holding individuals and organizations accountable for the development and use of AI systems in educational settings, reflecting the need for ethical considerations in the design and actions of robots used by children. Privacy is concerned with safeguarding personal data and information of children, ensuring compliance with data protection laws, which must be safeguarded in robots by implementing measures to protect user data and confidentiality. Beneficence is required to promote the well-being and best interests of children through the appropriate use of AI systems, which can be achieved by designing robots that enhance children's educational experiences and well-being. Freedom and Autonomy uphold children's rights to make autonomous decisions, allowing them to control their choices, which can be respected by giving children control over their interactions with robots. Pedagogical Appropriateness aims to ensure that AI applications are suitable for educational purposes, aligning with best teaching practices to support children's learning, which can be ensured by designing robots that are educationally relevant and effective. AI Literacy seeks to promote an understanding of AI technologies among children, helping them to engage with these tools responsibly and knowledgeably, which can be supported by using robots to teach children about AI in an accessible way. Lastly, Teacher Well-being highlights the importance of supporting educators in adapting to and integrating AI tools, ensuring they can effectively aid children's education while also maintaining their professional and personal well-being, which can be facilitated by designing robots that are easy for teachers to use and that enhance their teaching experience.

3.2 Professional Ethics and Codes of Conduct

Various professional organizations have also established ethical guidelines to ensure responsible practices and codes of professional conduct. Some of these are particularly relevant for children, such as the Code of Ethics for Educators proposed by the

National Education Association (NEA, 1975), and the Ethical Principles of Psychologists and Code of Conduct proposed in 1953 and revised in 2017 by the American Psychological Association (APA, 2017).

For technological professions, Tractenberg (2024) underscored the ACM Code of Ethics and Professional Conduct (ACM, 2018), which covers all the work of computing professionals regarding computing development, deployment, and usage, emphasizing their responsibility to contribute to society and well-being, avoid harm in their practices, ensure that technology promotes human rights and environmental sustainability, and the requirement of being honest and transparent by disclosing information of system capabilities and potential problems. The Code also stresses values of justice, equality, and fairness, urging professionals to foster tolerance and non-discrimination, and other responsibilities such as respecting privacy, honoring confidentiality, and other computing practices for the public good, such as their involvement in projects that help society. In addition, we highlight the IEEE Ethically Aligned Design guidelines introduced in 2016 (IEEE, 2016), aimed at promoting ethics in designing and deploying AI systems to guarantee that these systems are transparent, accountable, and respect users' privacy.

Professional codes of conduct are also crucial for guiding general professional behavior and ensuring integrity in research practices. While these codes provide a broad ethical framework for various professions, there are specific guidelines that focus directly on research integrity. In this context, we highlight some codes of conduct that specify research ethics. The Code of Conduct for Responsible Research by the World Health Organization (WHO, 2017) emphasizes principles of integrity, accountability, impartiality, respect, and professional commitment. It applies to all WHO staff and collaborators, ensuring adherence to research standards and promoting transparency and ethical behavior in all research activities. The European Code of Conduct for Research Integrity (ALLEA, 2023) offers a framework for good research practices within Europe by stressing the importance of reliability, honesty, respect, and accountability in scientific research. Both codes are relevant for maintaining high ethical standards and integrity in research, providing guidelines to prevent misconduct and ensure the credibility of scientific findings. Relatedly, it is also relevant to consider the codes of professionals working in the field of statistical practice (Tractenberg, 2024), such as the Ethical Guidelines for Statistical Practice developed by the American Statistical Association (ASA, 2022), which provides a framework for ethical behavior and decision-making when working with statistics and data, including data collection, analysis, interpretation, and model development.

3.3 Policies and Regulations for Ethical Use of Robots

To ensure that robotic systems are equitable, inclusive, and used ethically, we should also consider policies, regulations, and protective laws (Miao et al., 2021). Many regulatory and institutional guidelines have been developed concerning data privacy and protection, with several countries proposing their regulations. While many share common principles, such as the protection of personal data, the rights of data subjects, and the obligations of data controllers, these regulations also have unique provisions and requirements specific to their respective legal and cultural contexts. Thus, it is important to comply with the relevant data protection laws in each country or jurisdiction where they operate. For example, the United States has no general federal data privacy regulation, although a federal American Data Privacy and Protection Act (ADPPA) proposal has been introduced recently to the U.S. House of Representatives (2022). Nevertheless, several sectoral laws apply at the federal level, and among US state laws, California, Virginia, and Colorado have enacted their own data privacy laws.

In the European Union, the General Data Protection Regulation (GDPR) came into effect in 2018 and is currently applied to all EU member states (GDPR.EU, 2022). The GDPR has stringent rules, particularly emphasizing the rights of individuals, including children, in relation to their personal data. It mandates lawful, fair, and transparent processing of personal data. After the GDPR, other countries have adopted similar regulations, including Brazil with the Lei Geral de Proteção de Dados Pessoais (LGPD, 2019), which came into effect in 2020, and the Personal Information Protection Law in China, which came into force in 2021 (PILP, 2021). For an overview and updates regarding global privacy laws, see the OneTrust Data Guidance website (OneTrust, 2024).

In addressing regulations of AI technologies and managing the associated risks while promoting conditions conducive to their growth and ethical deployment across several sectors, the European Union recently introduced the European Union Artificial Intelligence Act (EU AI Act). The Regulation 2024/1689 was recently published on July 12, 2024 (European Parliament & Council of the European Union, 2024), it came into force twenty days after publication, and is set to be fully implemented by July 12, 2026.

The EU AI Act emphasizes the need for AI systems to be safe, transparent, traceable, non-discriminatory, and environmentally sustainable, advocating for human supervision over these systems. It underscores the protection of all individuals, supporting a broad spectrum of rights, including those of workers, persons with disabilities, and children, and promoting gender equality. It specifically highlights the critical importance of considering children's vulnerabilities, ensuring their protection and well-being, and the need for education, the protection of privacy, and personal data. The AI Act classifies AI risks into three categories based on a risk-based approach. The "Unacceptable Risks" will be prohibited, including AI systems that manipulate behavior, exploit vulnerabilities, perform broad social scoring, and conduct indiscriminate surveillance by engaging in biometric categorization. The "High-Risk" category, requiring rigorous pre-market assessments and continuous oversight, includes AI systems likely to impact health, safety, and fundamental rights, such as children's rights, and are those used in critical sectors like education and healthcare or involving sensitive data processing. High-risk applications affecting children, which may apply to education and vocational training, must adhere to stringent regulations and are required to be registered in an EU-wide database. These systems also fall under the EU's product safety legislation, potentially encompassing a variety of products, including toys and robots designed for children, if they are considered to impact health, safety, or fundamental rights significantly. The "Limited or Minimal Risk" category applies to AI systems that pose lesser concerns and thus require fewer regulations. These include AI applications with limited interaction with sensitive data or decision-making processes, such as AI-enhanced software tools that do not affect public safety or personal rights. Additionally, the regulation sets transparency requirements to ensure users are aware when interacting with AI to reduce risks of deception or manipulation.

This regulation may have legal implications for using robots in school settings, ensuring that any AI systems adhere to strict safety and privacy standards. While the Act specifically applies to EU member countries, its approach to AI governance might influence other countries to adopt similar regulations, which may set a precedent for the responsible use of AI, including in child-centric environments.

Overall, the aforementioned principles, guidelines, codes of conduct, and regulations have a crucial impact on the existing and future development of robots to ensure their ethical introduction in educational settings. By adhering to these requirements, educational institutions can use robotic systems that are compliant with high ethical standards, including safety and privacy, tailored to foster an environment conducive to children's learning and socioemotional development. Figure 1 depicts the central role of these standards in all different stages of research on CRI, namely the design, development, and impact evaluation of educational robotic devices for children. In the following section, we review the different stages of conducting research and their practical implications.

4 Challenges in Conducting Ethical Research in Child-Robot Interaction

When designing robots, the focus in both industry and academia does not always prioritize the benefits for children. Industry often prioritizes long-term profit, while academia tends to concentrate on available robots, aims for novelty in research, and frequently conducts short-term studies, which may limit the use of latest models, a thorough evaluation of whether previous findings are robust, and overlook their long-term effects for children. However, the design for CRI must prioritize the children's needs and ensure that designers, programmers, and researchers adhere to codes of ethics and conduct, avoid bias, and address any potential drawbacks for children.

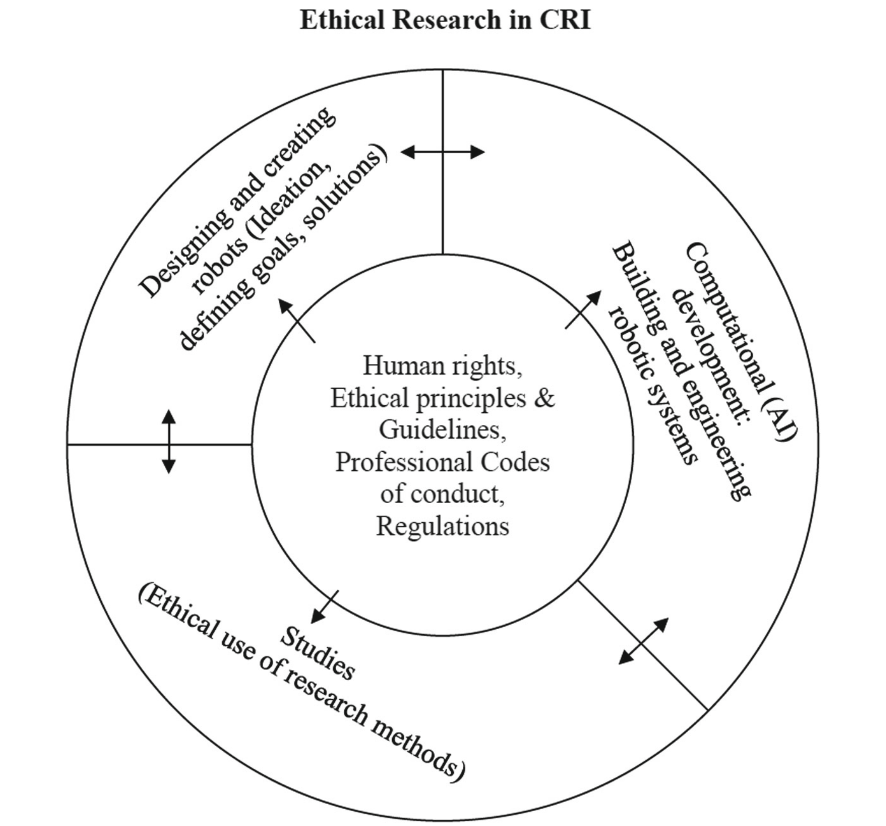

Fig. 1 Ethical research in CRI

4.1 Best Practices for Ethical and Legal Compliance in Studies Involving Children

Considering the ethical guidelines and codes of conduct in research already mentioned, obtaining informed consent is mandatory. In the case of children, this requires obtaining consent from their legal guardians or parents to ensure that they are fully informed and agree to the specific activities involving robots or other technological interventions in educational settings. The informed consent should be signed by the parents or legal guardians and the researcher. Table 1 details the essential components of informed consent for research involving CRI. It emphasizes the need to clearly explain the research's purpose, obtain ethical approval from review boards and school authorities, and maintain transparency about all procedures, including the technologies used. It should also inform about the safety measures to protect children, the benefits and risks of the research, and strategies to mitigate these risks. It underscores voluntary participation to uphold autonomy, outlines data privacy and confidentiality measures, and the participants' rights regarding their personal data. Additionally, including debriefing sessions and accessible contact information enhances transparency and accountability throughout the research process.

Different countries have specific guidelines and regulations concerning the age at which children's consent must be given by legal guardians (e.g., FRA, 2014). For example, in the US and in many European countries (e.g., Portugal, France, Germany), individuals under the age of 18 are generally considered minors, and parental consent is required, however, the specifics can vary depending on the nature of the study and the perceived ability of adolescents to make informed decisions. In the UK, children under 16 typically need parental consent, but adolescents may be capable of giving "Gillick competent" consent if they show sufficient maturity and understanding of the research. These variations reflect an understanding that older adolescents may be able to make informed decisions about their participation in research based on their comprehension of the study's implications. Researchers must ensure they fully comply with international standards and local regulations when involving children in their studies (ERIC, 2024).

Nevertheless, respecting a child's autonomy and ensuring they feel respected and heard is important. Consequently, it is common practice in many countries for children to provide assent to participate in research, even if they cannot legally give informed consent. Researchers must provide detailed information that is suitable for the age group. However, potential issues may arise when researchers are introduced to children within a school setting. Children may see researchers as authority figures similar to their actual teachers, which can lead them to feel obliged to comply with their requests, believing participation is mandatory (Davies, 2008). Thus, it is crucial that children fully understand all the procedures, including that their involvement in the research is voluntary and that they have the right to withdraw at any time. Researchers can use verbal explanations, visual aids, teach-back techniques, or hypothetical scenarios to explain and assess a child's understanding and reasoning regarding the research. According to the Community on Ethical Research Involving Children (ERIC, 2024), seeking permission from children and young people should be included in the research process as it signals respect for their dignity, capability, and rights to express their views and will. The ERIC (2024) emphasizes that all children can indicate assent or dissent if researchers try to communicate and provide information appropriate to their capabilities using verbal explanations, written materials, or visual aids. Depending on their age and cognitive development, some children may not fully understand all the complexities of the research, but they should express their willingness or unwillingness to participate. Children can show their assent using methods appropriate to their communication abilities, such as circling an emoji or ticking a box. With preschool children and children with communication difficulties, assent can be communicated through non-verbal cues such as body language, facial expressions, and gestures. Researchers must be sensitive in recognizing these forms of communication and respond appropriately in the moment. The European guidelines (European Commission & Directorate-General for Research and Innovation, 2013), for example, suggest that information for children under five should mainly use pictures. For pre-adolescents up to 16 years old, the information sheets should

Table 1 Key components of informed consent for child participation in research

Component	Explanation
Purpose of the research	Explanation of why the child is invited to participate, specifying the aims of interactions the child will have with the robots
Ethical approval and school authority	The indication that the study has been reviewed and approved by an ethical committee or institutional review board (IRB), ensuring it meets ethical standards to protect participants' rights, safety, and well-being. It should also confirm school authority approval and detail the school's role and any staff collaboration
Procedures and context	Detailed description of what will happen during the study, including when and where within the school it will be conducted, information about the robot (e.g., appearance, functions), technological features used (e.g., sensors, cameras), type of data collected (e.g., audio, video, behavioral), number of sessions, duration of each session; duration and frequency of CRI, whether teachers or school staff will be involved; how parents will be involved or informed about their child's interactions with the robots. If feasible and appropriate, the consent could also indicate opportunities for parents to observe the child's interactions with the robots
Safety measures	Information about safety measures used to protect the child during CRI and how the child's safety will be monitored and ensured
Potential benefits	Explanation of the potential benefits to the child or to others resulting from the child's participation (e.g., scientific knowledge, learning experiences)
Potential risks	Information about any potential risks or discomforts associated with participation (e.g., discomfort, attachment issues) and measures to mitigate these risks. It should include support measures or the resources available if the child experiences distress. It should also inform how the study will fit into the school day and any potential disruption to the child's regular activities. It should also ensure that participation will not negatively impact the child's grades or academic progress
Voluntary participation	Statement that participation is voluntary and that the child and parents can withdraw consent at any time without penalty or loss of benefits
Right to Inquire freely	Explanation that participants are entitled to ask questions at any stage to ensure they can seek clarifications, express concerns, and better understand the context or procedures involved
Privacy and confidentiality	Explanation of how the child's privacy will be protected, how the data will be stored, who will have access to it, how it will be used, and if any data will be used for purposes beyond the current study. Ensure that school personnel not involved in the study will not have access to identifiable data (see the additional components below on "Data Privacy Details if Personal Data is collected")

(continued)

Table 1 (continued)

Component	Explanation
Compensation	Details on any compensation for the child and their parents, type of compensation, and when and how it will be provided. Clarifies that compensation is for time and effort, not dependent on the study's risks or outcome, and should be fair and never coercive. If the study involves more than one session, provide partial compensation after each session rather than waiting until the end of the study. Types of compensation must be appropriate for the parents' socioeconomic status and the child's age. For the child, it often includes educational materials (e.g., books, educational games, school supplies), certificates or tokens of appreciation (usually for younger children), or eventually gift cards, vouchers, or modest amount of money (for adolescents). For parents, it may cover costs incurred (e.g., travel expenses, parking fees, meals) or a modest monetary compensation. ERIC (2024) advises avoiding payments if they could exert pressure, to ensure that informed consent remains entirely voluntary
Child's assent	Information about the process for obtaining the child's assent
Debriefing	Information about debriefing session(s) that will be held to explain the study's findings, the child's role, and any follow-up procedures
Contact information	Contact details about the researchers, ethical committee, and school representative for any questions or concerns about the study's ethical aspects or the school's involvement
Parental consent agreement	Inclusion of a section where parents agree to conditions through physical or digital means: a space for both the parent's and researcher's signatures and dates; for online forms, a checkbox to express parental consent, followed by an acknowledgment button to confirm their agreement. A confirmation message ensures that consent has been successfully recorded upon submission
Data privacy details if personal data is collected	
Types of personal data collected	Type of personal data that will be collected from the child (e.g., name, age, contact information, health data, behavioral data)
Purpose of data collection	Purpose of personal data collection and how it will contribute to the study goals
Data storage and security	Details on how the personal data will be stored securely (e.g., encrypted databases, secure servers), and the measures in place to protect the data from unauthorized access, breaches, or loss
Data access and sharing	Specifies who will have access to the personal data (e.g., researchers, data analysts; third parties) and under what conditions, with what protections in place
Anonymization and De-identification	Explains the steps to anonymize or de-identify the data to protect the child's identity

(continued)

Table 1 (continued)

Component	Explanation
Data retention and deletion	States how long the personal data will be retained, the process for securely deleting or destroying it once it is no longer needed
Rights regarding personal data	Information on the rights regarding the personal data, including the right to access, correct, or delete their child's data, and explanation on how these rights can be exercised and whom to contact for such requests by adding contact information about the data protection officer or authority overseeing compliance

explain the study's purpose and background and note that parents will also consent. Adolescents aged 16 to 18 who are legally adults, or "emancipated minors", must provide their written consent. Additionally, in longitudinal research, it is required to regularly update the child with age-appropriate information to ensure their ongoing agreement with using their data over time.

Research in CRI also presents unique ethical challenges, including balancing researcher interference, avoiding stigmatization, and managing adverse carry-over effects (Correia et al., 2024; Piedade et al., 2024a). Balancing researcher interference is particularly challenging. For instance, during the observation of natural peer interactions, conflicts can arise. Researchers must handle these situations carefully to avoid disrupting the research, undermining the teacher's authority, or missing opportunities to foster empathy and inclusion. Avoiding stigmatization is also a challenge, especially in mixed-ability classrooms and with minority groups. Researchers aim for seamless interaction among all children to promote inclusion, but some may require specific adaptations, such as braille for blind children, translation for non-native speakers, or additional support for those with Attention-Deficit/Hyperactivity Disorder (ADHD) (Papakostas et al., 2021). Researchers must adapt activities to support these children with sensitivity and thoughtful planning to ensure all children feel included and respected. Additionally, the carry-over effect of children's interactions cannot be ignored, as observing humans interacting with robots might affect subsequent interpersonal relations among children (Correia et al., 2024).

Balancing the privacy and confidentiality of children's data with the need to disclose data is crucial in research practices. Collecting data from CRI often involves recording sensitive information from the child (e.g., behavioral patterns, biometric data) to understand their engagement with robotic technologies. However, privacy concerns restrict data sharing, and even with techniques like data (pseudo)anonymization, risks of re-identification sometimes remain, particularly in small or specific groups. Therefore, privacy measures and security concerns may limit data sharing, posing a threat to study replication (Mott et al., 2022; Spitale et al., 2023). CRI research must balance protecting the privacy and rights of this vulnerable group and sharing data practices aiming to advance scientific knowledge which is critical for ethical integrity and maintaining public trust (Couto et al., 2022; Spitale et al., 2023; Tolksdorf et al., 2021).

4.2 Robotics Design Tailored to Children Needs

The Institute for Education Science and The National Science Foundation (2013) outlined six types of research in education, usually starting with foundational and early-stage exploratory research, followed by the design and development of strategies and interventions that typically involve pilot testing. For those deemed sufficiently promising, the research progresses to assessing their efficacy and effectiveness in improving educational outcomes for children. This usually begins with focused studies on single populations and extends to broader evaluations across diverse populations and contexts. However, research is far more complex, as these categories do not cover all valuable research, and the sequence described is often not strictly followed in practice.

Various research methods can be employed, with the choice influenced mainly by the research questions, the child's age and their cognitive development, and the practical constraints of the context. Despite the diversity of methods, it is crucial to adopt an ethical approach that centers on children's needs. We recommend initiating the process with a participatory design process, which involves collecting input from children and their surrounding communities at various stages. This approach is particularly relevant when the aim is to design and adapt robots for children. Participatory methods allow children and other stakeholders to be involved not only in the solutions, but also in the identification of existing problems/opportunities, ideation, and definition of goals.

Designers often rely on pre-existing robots and their capabilities, developing robots based on what they believe fits into a children's world. The design and its functionalities are then adapted to suit the specific context. However, even when research design methods are employed, children are often left out of the research process (Alves-Oliveira, Paiva, et al., 2021a, 2021b). In contrast, the participatory design of technology is inclusive and iterative, making children active contributors throughout the design process (Iversen et al., 2017). Techniques like cooperative inquiry allow children to collaborate with researchers and designers in the ideation, prototyping, and testing phases (Druin, 1999, 2002). Children's perspectives and creativity are harnessed through child-friendly methods (Druin, 2002), and the iterative nature of participatory design integrates continual feedback, refining the design to meet children's needs and preferences (DiSalvo et al., 2017). This approach enhances usability, acceptance, and provides insights into how children interact with technology, which may lead to more intuitive and enjoyable user experiences, fostering ownership and empowerment among children, increasing their engagement and satisfaction (Bers, 2021) and often inspiring innovative solutions, as children's creativity brings forth novel ideas that adults might overlook (Iversen et al., 2017). Therefore, it is essential to integrate children's voices in the design of technology intended for their use and involve the school community from the early stages of development for robotics technologies, ensuring ethical CRI.

Children can assume various roles in the design process, including users, evaluators, informants, or design partners. However, it is particularly important also to include them as co-designers (Alves-Oliveira et al., 2017), while the school community typically acts as informants (Druin, 2002). A multi-method approach is also recommended, which can include ethnographic observations, contextual inquiries, group and individual interviews, and participatory design activities, enabling researchers to understand the perspectives of all stakeholders (Serholt et al., 2017; Williams et al., 2021). Holistic involvement of teachers, educators, parents, and children ensures that the design process addresses real needs, leading to more effective and ethical CHI.

Formative approaches are a crucial first step in designing ethical CRI. While individual and group interviews, focus groups, and discussions are suitable for adult stakeholders, these formats can be demanding and stressful for children. Consequently, researchers often use other methods with children, such as class and playground observations, followed by participatory design techniques to gather insights and children's voices without placing unnecessary pressure (Du & Breazeal, 2022; Neto et al., 2021; Newbutt et al., 2022; Piedade et al., 2024b). Participatory design also involves a co-design process where children and researchers collaboratively design tailored robot embodiments, capabilities, roles, and interactions. This process should adopt an iterative approach to enhance children's empathy, reflection, and creativity with an ethical and inclusive mindset. This process involves the following phases: (1) exploration and familiarization with the robots, (2) ideation, (3) presentation and critique, (4) building robotic devices, and (5) enacting interaction. In the exploration and familiarization phase, children learn about robot capabilities through interaction with physical robots or watching videos. The ideation phase involves presenting a problem or activity for children to tackle, encouraging discussion and reflection on specific challenges before considering solutions. Children may interview teachers and peers, engage in group discussions (Walsh et al., 2010), and use proxy toys or narratives to describe the context and characteristics of future users and applications (Giaccardi et al., 2012; Metatla et al., 2020; Piedade et al., 2024b). Children are then prompted to think about how a robot could be used in such contexts. These activities can also foster children's interest in the problem (Barendregt et al., 2020; Neto et al., 2021; Vaajakallio et al., 2010). This phase usually ends with children preparing a presentation. During the presentation phase, children present their ideas and design decisions to researchers, teachers, and peers, receiving feedback. This reflective questioning helps them understand their design choices, during which it is crucial to ensure a supportive environment to encourage all children to share their ideas. The next phase is "Do It Yourself" (DIY) prototyping, where children materialize their ideas using various materials, bringing their concepts to life. In the final enacting phase, children use prototypes to describe robot characteristics such as function, morphology, movement, autonomy, and roles.

Additional recommendations must be addressed to create a co-design activity that will enrich the learning experience for all children. First, use age-appropriate language for the children's age group to ensure clear understanding. Second, all sharing materials must be safe, durable, accessible, and affordable physically and economically. Third, standardizing children's robot knowledge is crucial as it is often the first encounter between children and robots (Barendregt et al., 2020; Neto et al., 2021). Fourth, if children have impairments (e.g., visual, hearing, cognitive), all materials and tasks should be adapted to ensure communication. Fifth, conduct co-design activities in schools if this is the intended context for the robot's use, as this helps children explore challenges and the robot's future applications within this setting (Barendregt et al., 2020). Six, foster an atmosphere of trust and sharing to allow children to be open to each other's ideas and ensure equitable participation, making them feel comfortable to communicate, which requires understanding the established power dynamics in the classroom (Cohen & Lotan, 2014; Vaajakallio et al., 2009). Familiarize with the children and educators/teachers before the activity helps integrate into the classroom dynamics. Teachers and psychologists can also provide valuable insights and manage conflicts during the activity if needed (Neto et al., 2021). Seven, avoid a mismatch between children's expectations and the actual experience. Children typically associate robot activities with fun and playfulness, but some moments can be tedious or stressful (Piedade et al., 2024a). Finally, authenticity is important, as many CRI rely on Wizard of Oz (WoZ) techniques, where human control is used to enhance robots' capabilities. By using co-design techniques, children become aware of robots' limitations and challenges, which can give them a more genuine understanding of how social robots are built and a space for reflection (Boulicault et al., 2023).

Co-designing robots with children in classrooms has been used for various goals with positive results, including facilitating children's creativity (Alves-Oliveira, Arriaga, et al., 2021a, 2021b; Alves-Oliveira, Paiva, et al., 2021a, 2021b), enhancing playful learning in classrooms (Lupetti et al., 2017), conducting anti-bullying interventions (Sanoubari et al., 2021), fostering inclusion among mixed-ability groups (Neto et al., 2021; Piedade et al., 2023), and critically reflecting on the ethical dilemmas of their relations with robots (Mott et al., 2022; Woodward et al., 2018).

Other types of research can also be adopted in the early stages, as documented in the guidelines by the Institute for Education Science and The National Science Foundation (2013). While it is not the scope of this chapter to review all, the following section will highlight some important ethical considerations relevant to studies evaluating the impact of interventions with robots to ensure that the research advances knowledge while upholding the rights of all participants involved.

4.3 *Impact Assessment in Child-Robot Interaction*

Both qualitative and quantitative methods and measures can be used to evaluate the impact of CRI. Qualitative research designs are used extensively in CRI to understand children's contextual, subjective, and behavioral experiences. These methods often include ethnographies, observational, case studies, interviews, and focus groups to gather detailed information on CRI, in natural settings such as schools. In addition to involving them in the co-design of robots, as we previously discussed, these methods can be valuable to understanding how children perceive and evaluate existing robotic devices. Quantitative research designs, on the other hand, aim to quantify variables related to CRI. This approach is suited for testing hypotheses derived from theory or prior research, often using a more systematic and controlled setup to evaluate CRI. Quantitative methods like correlational or controlled experiments in cross-sectional or longitudinal studies may provide findings that often aim to be generalized to larger populations. These studies can also use structured observations, subjective assessments, biopsychophysiological measures, and task performance, especially useful for large-scale studies assessing the impact of using robots in educational contexts across multiple outcomes, for identifying conditions that may affect the relationships between robot interventions and their outcomes, as well as the factors that contribute to explaining these relationships (see some findings from systematic and meta-analyses, Anwar et al., 2019; Kouroupa et al., 2022; Lee & Lee, 2022; Mukhasheva et al., 2023; Papakostas et al., 2021; Sapounidis et al., 2024; Wang & Cheung, 2024; Wang et al., 2023).

In general, using diverse instruments is also considered a good practice but depends on the child's age and socioemotional and cognitive development. Subjective assessments, such as interviews and surveys, are generally considered appropriate for children aged seven and older because, by this age, children typically have developed cognitive skills to understand and respond to some questions, reflect on their thoughts and feelings, and comprehend abstract concepts (Borgers et al., 2000). However, because they rely on the child's ability to introspect and articulate their experiences, these methods might still be challenging even for older children. Due to cognitive or linguistic limitations, observational methods and physiological measures are often more suitable for younger children because they do not rely on verbal communication.

Ethical considerations play a crucial role in selecting the method and measures, as researchers must ensure that the techniques do not harm the children or interfere with their normal activities. In combining various methods, researchers can triangulate their findings to enhance the robustness and depth of their conclusions. Therefore, mixed-method designs, which combine qualitative and quantitative approaches, can be useful to enhance the reliability of the findings (Bethel & Murphy, 2010).

Additionally, we emphasize specific ethical considerations in research studies utilizing experimental designs, particularly those where the study's aims cannot be initially disclosed to prevent influencing participant responses. These studies often involve some level of "deception" to maintain the integrity of data collection. Moreover, in studies with control groups where children do not interact with robots, it is considered good practice to offer these participants a chance to engage with the robots at later stages, especially if the CRI is expected to yield positive outcomes for the child. Concerns have been raised in literature about the Wizard of Oz (WoZ) methodology (van Straten et al., 2022; Westlund & Breazeal, 2016), where researchers simulate the robot's behaviors to study children's reactions, often without revealing the simulation. Many WoZ studies also simulate robots' behaviors that they cannot perform. Following van Straten et al. (2022) recommendations, we agree that CRI research should not impose unrealistic portrayals on robots to misrepresent their capabilities to ensure that children's responses are based on their genuine perceptions rather than researcher-imposed concepts. One interesting example is the study conducted by van Straten et al. (2023), who have shown that it is also possible to program robots to directly convey transparent information about their capabilities and limitations to children. In their study, children interacted with a robot that either disclosed its non-human psychological capacities and mechanical nature or did not. They found that children who received this information were less likely to anthropomorphize the robot, although they felt less close and trusted the robot less than children who did not receive transparent information from the robot. These findings show that providing transparent information about a robot's capabilities is important and affects children's responses. They also suggest that robots can directly communicate this information to children, which is particularly relevant since some CRI might not always be supervised (van Straten et al., 2023).

Nevertheless, it is important that any study involving deception include thoroughly informed consent processes and provide full debriefing to participants. Maintaining transparency post-experiment is crucial for upholding ethical standards.

5 Challenges in the Development of Robots and the Role of Technical Developers

Technical developers play a crucial role in creating educational robots for children, both in industry and academia, as they hold the responsibility to address and ensure ethical compliance. Their responsibilities include designing secure systems to protect children's personal and educational data from unauthorized access and misuse. Equally important is the safety and reliability of these robots, requiring rigorous testing to prevent physical risks and ensure consistent operation. Developers must also prevent biases in the robot's algorithms to ensure fairness and equity for all children regardless of their background (Miao et al., 2021). For data-driven AI algorithms, an adequate approach is to ensure the diversity of data or, for instance, the diversity of participants contributing to data. Transparency and accountability are also critical, requiring developers to clearly explain the robots' functions, data collection and usage, and the ethical implications of their designs (Miao et al., 2021).

Pilot testing with children is a critical part of the development stage. This iterative process involves multiple rounds of testing, feedback, and refinement to ensure that the robots meet the intended goals while addressing the diverse needs of young users. As previously highlighted, engaging children in pilot testing allows developers to observe CRI in real-world settings and gain insights into the usability and appeal of the robot. This feedback loop is necessary for identifying and fixing unforeseen issues or areas for improvement. By iteratively refining the robot based on real interactions, developers can enhance the design, functionality, and overall user experience. This approach not only improves the educational impact of the robots but also ensures that ethical considerations, such as safety, accessibility, and well-being, are addressed through direct user involvement.

6 Broader Challenges of Using Social Robots in Educational Settings

It is crucial to understand the long-term effects of child interactions with robots in school settings and their potential carry-over effects to several domains affecting their development. Therefore, more empirical research is needed to assess the real socio-emotional impact of CRI, considering that current evidence is still limited (Langer et al., 2023). Furthermore, systematic evaluations are lacking in understanding the sustained impact of social robots. Sustaining robots over extended periods introduces various challenges, including managing relationships with robots, logistics, ecological impact, financial sustainability, and human resource requirements.

As previously mentioned, one key recommendation is to ensure that robots and other technologies are never used to replace human interaction but rather to complement it (Boada et al., 2021; Contro & Brandão, 2024; Tarrés-Puertas et al., 2023). Additionally, we must respect the ethical right to choose human interaction over robots (Torras, 2024). This is particularly relevant for children, as their emotional and social development depends on meaningful human interactions. For example, while robots have been used to teach social skills, their role should primarily be as engagement and educational support tools. Children derive immense benefits from the social communication and emotional responses that only interactions with human educators and peers can provide (Boada et al., 2021; Contro & Brandão, 2024; Tarrés-Puertas et al., 2023). Therefore, a balanced approach should always be promoted to preserve the advantages of human contact while using innovative technological tools.

Robots used in educational environments must be adapted to each child's evolving interests and developmental stages to ensure they remain engaging and are relevant for their welfare. Robots are composed of hard/soft materials and software components. Integrating these elements is crucial for ensuring the robotic systems function correctly in their interactions with children. This requires regular maintenance and updates not only to maintain proper functioning but also to enhance their capabilities. Moreover, the diversity of available robotic systems and prototypes used in research makes it difficult to compare and replicate them. Limited accessibility to robots, due in part to their high commercial costs or the inaccessibility of custom-built models, further restricts the scope of research and hinders reproducibility (e.g., Gunes et al., 2022; Leichtmann et al., 2022; Strait et al., 2020; Ullman et al., 2021). Additionally, ecological concerns may impact the sustainability of robots available at schools. The use of non-recycled materials and energy by social robots, alongside waste management, poses ethical concerns regarding ecological sustainability (Boada et al., 2021). These demands may compromise the maintenance of robots in educational environments, which requires careful planning for their integration and eventual removal.

In academia, another concern is the often misalignment between research activities and community needs, complicating the sustainability of initiatives and projects involving robots. Research driven by academic timelines, such as grant cycles and publication deadlines, frequently conflicts with the unpredictable schedules of educational communities. This misalignment requires careful risk mitigation, plan exit strategies, and expectation management from the outset of projects. The challenge is ensuring that research projects, designed within research time constraints, align with the ongoing and often prolonged challenges faced by the community groups and the stakeholders. The goal is to empower children, teachers, and schools with the ability to continue the initiatives without needing ongoing external support. Additionally, it is important to establish long-term connections between the education system and sustainable projects.

Also relevant is ensuring reproducibility in science, which is crucial for advancing knowledge. One primary concern is that the research process (e.g., study protocols, materials) and some of the findings (e.g., data, code) are often not shared publicly on accessible repositories. These and other concerns have driven the development of initiatives with guidelines to promote transparency, openness, and reproducibility in the scientific community (Nosek et al., 2022). Various recommendations for open science have been proposed to ensure transparency and accessibility to the community. For example, in 2016, the FAIR (Findable, Accessible, Interoperable, and Reusable) principles were introduced by the GO FAIR Initiative (Go Fair, 2024; Wilkinson et al., 2016) and are currently advocated by many organizations and research communities. By implementing practices that ensure studies can be repeated (re-run a study using the same design as the original, by the same research team, and same sample size), replicated (using new data), reproduced (repeating the original analysis on the same data), and robust (applying a different analytical approach to the same data), researchers ensure that their findings are reliable and verifiable (Gunes et al., 2022; Nosek et al., 2022). Recently, these concerns have been discussed in education research (The National Science Foundation & Institute of Education Science, 2018), in HRI (Gunes et al., 2022; Leichtmann et al., 2022) and in CRI (Spitale et al., 2023).

The systematic review by Spitale et al. (2023) examined concerns related to reproducibility in CRI research from 2020 to 2022. Among the 325 studies reviewed, they identified several issues, including inadequate reporting of ethical approval and informed consent procedures, a lack of preregistrations, insufficient demographic data, small sample sizes, and insufficient details regarding study design. This includes the deployment scenario, a description of the robotic system used, and its mode of operation. Additionally, there was a notable lack of code and data-sharing practices within CRI research.

The lack of published standardized protocols for programming interactions and measuring outcomes in HRI studies may exacerbate these problems, making it challenging to ensure consistency and reliability across different research settings (Bethel & Murphy, 2010). These factors highlight the need for a more inclusive approach to robot design and a rigorous standardized methodology to enhance reproducibility.

There are, however, some examples of good open practices. For example, to implement co-design activities in the classroom, there are several robotic toolkits available that can be adapted to allow all children, regardless of their abilities, to be engaged and participate. These toolkits can employ a combination of activities (Obaid et al., 2018, 2024), and various techniques focusing on inclusive practices, such as toolkits tailored to children with and without visual impairments (Metatla et al., 2020; Neto et al., 2021) and neurodivergent classroom (Piedade et al., 2023). There are also some examples of open-source hardware and software for robots freely available within the scientific community (e.g., Alves-Oliveira et al., 2019, 2020), allowing researchers and even educators to access and use robotic technologies without prohibitive costs. As recently reviewed by Pearce (2020), making these open-source technologies accessible might also empower worldwide communities, including those with limited resources. In addition, it has the potential to train future scientists, from K-12 to university education, by providing educational opportunities to understand the equipment and its development. Moreover, it opens the possibility for users to customize and adapt tools to their needs. However, despite these advantages, there are challenges, such as the need for specialized technical knowledge and resources to build, program, and maintain these devices. These concerns are particularly relevant when deploying robots in schools, where ongoing technical support and expertise are crucial for sustained use and effectiveness. However, this challenge can be addressed by involving teachers with specialized knowledge and by providing training to educators in this domain.

As in other fields of research, in CRI (Spitale et al., 2023) there are still concerns related to a preference for quantitative studies over other research designs, a tendency to prioritize research that is novel or yields new results over replication studies, the reliance on null hypothesis significance testing (NHST), and the concern with publication bias, which favors studies that confirm hypotheses. However, as mentioned before, the need for participatory design, which includes qualitative data, is paramount for CRI. Poderi and Dittrich (2018), for example, review the synergistic relationship between participatory design and sustainability, advocating for more interdisciplinary collaboration and the development of frameworks that explicitly connect these participatory methods with sustainable outcomes. The authors also identified key trends, methodologies, and thematic focuses, revealing that participatory design inherently supports sustainability principles due to its inclusive, collaborative, and user-centered approaches. Furthermore, the authors also call for continued research into global challenges addressing resource depletion and social inequities.

Other research biases have also been highlighted, such as those favoring participants from specific economic backgrounds or social classes, with a tendency to overrepresent participants from Western, Educated, Industrialized, Rich, and Democratic ("WEIRD") nations (Bethel & Murphy, 2010; Spitale et al., 2023). Such sampling biases result in findings that are not generalizable to broader populations because they rely on a subset that does not accurately reflect the diverse range of values and social norms in the world. Due to their ongoing developmental changes and considering atypical developments, the way children perceive and interact with robotic technologies vary significantly, even among children of the same age, and is also influenced by many other factors such as cultural contexts and educational backgrounds. This diversity and variability pose additional challenges for CRI research. Additional social concerns are related to the morphological bias of the robot's appearance or behavioral responses (Giger et al., 2019), which can affect how robots are used, the expectations about their performance, and how they interact with it (Edwards & Edwards, 2022). Cultural biases in programming and designing robots may also inadvertently reflect the values or norms of specific groups, limiting their acceptance in global contexts.

Addressing CRI within educational settings and sustainability from a multidisciplinary ethical perspective is crucial. This growing awareness of sustainability is being discussed in recent workshops (e.g., Carter et al., 2024), where diverse stakeholders come together to envision the future of embedded research, emphasizing ethical and sustainable principles to foster community autonomy and ownership of projects. Such collaborative efforts are relevant for ensuring robotic technologies' relevance, effectiveness, and sustainability, ultimately supporting communities in becoming self-sufficient. These principles could similarly inspire the sustainability of research projects on CRI, giving children, teachers, parents, and other participants in the community the needed tools to continue using the robotic technologies for their welfare. Mobilizing and integrating interdisciplinary perspectives from diverse scientific fields, such as psychology, education, robotics engineering, design, and philosophy, along with multi-stakeholders, including the insights from children and the broader community, aims to ensure that as we navigate this emerging field, we do so with an ethical commitment to promoting the well-being of children.

7 Conclusions

In conclusion, this chapter addressed the critical ethical concerns surrounding the design, development, and evaluation of social robots in educational settings, particularly in contexts where they may interact with children. We explored some benefits and the ethical challenges of CRI, focusing on key concerns such as emotional attachment, dependency, and accountability for robot actions. We also examined several ethical guidelines, professional codes of conduct, and regulations. Additionally, we review some of the best practices and methodological challenges for conducting ethical research in this field. We highlighted the responsibilities of robot developers and researchers, emphasizing the need for ongoing dialogue with educators, policymakers, and stakeholders to ensure that social robots are used ethically and effectively in educational environments, prioritizing children's needs, safeguarding their rights, and ensuring long-term safety. Furthermore, we discussed the broader implications of social robots in education, underscoring the need to balance technological advancements with the preservation of meaningful human interactions.

Several avenues for future research were also identified. As highlighted earlier, longitudinal studies are limited but essential for understanding the long-term effects of CRI on children's cognitive, emotional, and social development. In addition, more efforts are needed to adapt social robots for inclusive education, ensuring they are accessible to all, regardless of gender, background, or ability. The development of standardized protocols for assessing the impact of social robots while ensuring ethical compliance—such as safeguarding personal data—will be crucial for ensuring reproducibility and reliability across research settings. Ultimately, as we continue integrating social robots into classrooms, addressing ethical concerns and challenges must remain a priority. Sustainable and responsible approaches to prioritizing children's well-being are essential not only for today's children but also for future generations.

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