ROBOTS IN EDUCATION

IMPLEMENTING ROBOT TUTORS IN A MORALLY JUSTIFIED WAY

Matthijs Smakman

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Printing: Ridderprint, www.ridderprint.nl
Layout and design: Birgit Vredenburg, persoonlijkproefschrift.nl
http://doi.org/10.5463/thesis.133

VRIJE UNIVERSITEIT

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ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad Doctor aan
de Vrije Universiteit Amsterdam,
op gezag van de rector magnificus
prof.dr. J.J.G. Geurts,
in het openbaar te verdedigen
ten overstaan van de promotiecommissie
van de Faculteit der Sociale Wetenschappen
op woensdag 31 mei 2023 om 13.45 uur
in een bijeenkomst van de universiteit,
De Boelelaan 1105

door

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geboren te Alphen aan den Rijn

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This work was funded by the Dutch Research Council (NWO), project number 023.010.066, and supported by the HU University of Applied Sciences Utrecht

CONTENTS

AUTHOR CONTRIBUTIONS

Chapter 1. This chapter has not been submitted for publication. Smakman wrote the first version of this chapter. Vogt and Konijn both acted as supervisor by providing feedback on earlier versions of this chapter. Smakman incorporated this feedback and revised the chapter into its final form.

Chapter 2. This chapter is published (in part) as: Smakman, M.H.J., Konijn, E.A. (2020). Robot Tutors: Welcome or Ethically Questionable?. In: Merdan, M., Lepuschitz, W., Koppensteiner, G., Balogh, R., Obdržálek, D. (eds) Robotics in Education. RiE 2019. *Advances in Intelligent Systems and Computing*, vol 1023. Springer, Cham., and as Smakman, M.H.J. & Konijn, E.A. (2022) *Harms and Benefits of Robot Tutors: A Systematic Literature Review*. Manuscript submitted for publication. Together with Konijn, Smakman formulated the research question and set up the methodology. Smakman was the principal investigator of this study responsible for the data collection, data analysis and writing the first version of this chapter. Konijn acted as supervisor, providing feedback on earlier versions of this chapter. Smakman incorporated this feedback and revised the chapter into its final form.

Chapter 3. This chapter is published as: Smakman, M.H.J., Vogt, P.A., & Konijn, E.A. (2021). Moral considerations on social robots in education: A multi-stakeholder perspective. *Computers & Education*, 174, 104317. Smakman was the principal investigator of this study responsible for the data collection, data analysis and writing the first version of this chapter. Konijn and Vogt acted as supervisor, providing feedback on earlier versions of this chapter. Smakman incorporated this feedback and revised the chapter into its final form.

Chapter 4. This chapter is published as: Smakman, M.H.J., Konijn, E.A., Vogt, P.A., & Pankowska, P. (2021). Attitudes towards social robots in education: Enthusiast, practical, troubled, sceptic, and mindfully positive. *Robotics*, 10(1), 24. Smakman was the principal investigator of this study responsible for the data collection, data analysis and writing the first version of this chapter. Pankowska supervised the data analysis. Konijn and Vogt acted as supervisors, providing feedback on earlier versions of this chapter. Smakman incorporated this feedback and revised the chapter into its final form.

Chapter 5. This chapter is published as: Smakman M.H.J., Konijn E.A., & Vogt P.A. (2022) Do Robotic Tutors Compromise the Social-Emotional Development of Children? *Frontiers in Robotics and AI.*; 9:734955. doi: 10.3389/frobt.2022.734955. Smakman was the principal investigator of this study responsible for the data collection, data analysis and writing the first version of this chapter. Konijn and Vogt acted as supervisors, providing feedback on earlier versions of this chapter. Smakman incorporated this feedback and revised the chapter into its final form.

Chapter 6. This chapter has not been submitted for publication elsewhere. Smakman wrote the first version of this chapter. Vogt and Konijn both acted as supervisor by providing feedback on earlier versions of this chapter. Smakman incorporated this feedback and revised the chapter into its final form.

CHAPTER 1

GENERAL INTRODUCTION

Primary education is fundamental to children's development and a basic human right according to Article 26 of the Universal Declaration of Human Rights (United Nations, 1948). However, providing each child with the primary education they need is no easy task, even in a developed country such as the Netherlands. The question is, to what extent new technologies, in particular the newest communication technology social robots, might be of support to primary education. This dissertation aims to provide an answer to that question.

The challenges currently faced in (Dutch) primary education are diverse, they include growing shortages of primary school teachers (Arbeidsplatform PO, 2021), relatively high administrative loads that contribute to work-related stress (OECD, 2020) and a more diverse population in classrooms, differing in educational ability levels, special needs, and cultural backgrounds (Berlet et al., 2008). What adds to these challenges is that significant learning hiatuses were caused by the multiple COVID-19-related lockdowns in 2020 and 2021. These lockdowns did not only create greater work pressure for teachers but also resulted in increasing inequality of opportunities between children (Inspectie van het onderwijs, 2021). The combination of these challenges makes it difficult for teachers to provide children with the attention they need. However, new opportunities may arise with the introduction of innovative educational technologies. These new technologies could support teachers and children to cope with the challenges faced in primary education.

A promising new technology that could help support teachers and children in facing these challenges is social robots. Especially for kindergarten, primary school, and special education, social robots seem to be of added value. For example, robots are used to act as an assistant to engage kindergarten children (Conti et al., 2020), to assist primary school children in second language learning (Konijn et al., 2022) and to reduce anxiety for children with Autism Spectrum Disorder (ASD) (Papakostas et al., 2021). In primary school settings, social robots are being introduced in the role of tutors, peers or novices (Belpaeme, Kennedy, et al., 2018; Lehmann & Rossi, 2019). In these roles, social robots can support children in a wide range of subjects, such as mathematics (Liles et al., 2017), second language learning (Vogt et al., 2019) and geography (Serholt et al., 2013). Next to being explored for teaching knowledge-based (cognitive) outcomes, robots are also being studied for affective outcomes (Belpaeme, Kennedy, et al., 2018), such as stress and fear reduction (Moerman et al., 2019) and motivational outcomes (Tanaka et al., 2015). Although social robots can be viewed as a promising new educational technology, their introduction could also have negative, undesired outcomes.

The introduction of social robots in education requires caution, especially because (young) children are considered a vulnerable group. In the past, however, robots aimed at child-robot interaction (CRI) have been introduced, seemingly, without proper consideration. These robots have resulted in undesirable situations where children were (at risk of) being harmed. For example, a robotic toy - My Friend Cayla - was banned from being sold because it failed to safeguard basic consumer rights, children's security and privacy. According to the German Federal Network Agency (Bundesnetzagentur) this robot could "be used by anyone in the vicinity to listen in on conversations undetected" (Bundesnetzagentur, 2017, p. 1). Another example is CloudPets, a robot toy sold by Amazon, Target and Walmart, that allowed children to send and receive audio messages from their parents. Due to a data breach, over two million private voice recordings of children and parents were exposed (Seals, 2018). The cases of CloudPets and My Friend Cayla, unfortunately, do not stand alone. In multiple other cases, robots have been shown vulnerable to hacking, resulting in strangers being able to talk to children (Smithers, 2017). In these situations, it is clear that the introduction of robots has led to undesirable situations. However, the balance between what is desirable (good) and undesirable (wrong) is not always this straightforward. Hence, it is important to carefully analyse the desirability and potential impact of new technology, especially when it is targeted at vulnerable groups.

Scholars and stakeholders have voiced the need for moral reflection on why and how to use social robots in (primary) education (Belpaeme, Kennedy, et al., 2018; Pandey & Gelin, 2017; Serholt et al., 2017; Sharkey, 2016; Tolksdorf et al., 2020; Woo et al., 2021). These scholars report that social robots can undermine values upheld in education, such as privacy, friendship, human contact, and equal access. The value of friendship, for example, could be undermined when children start preferring robots over their human friends. Likewise, the introduction of robots could lead to human teachers being replaced by robots, negatively impacting the value of human contact and creating fear of losing jobs. Following these concerns and the understudied topic of moral values related to the implementation of social robots in education, the current dissertation aims to identify the relevant values and moral considerations of stakeholders related to social robots in primary education. In so doing, the results of the studies presented in this dissertation provide a first step toward guidelines on how social robots can be designed and used in such a way that robots do not undermine these values and moral considerations.

In the following of this introductory chapter, we will first elaborate on what social robots are and what sets them apart from other educational technologies. Second, we will introduce the moral concerns related to social robots and elaborate on the relationship between morality and technology. Thereafter, we will present the methodological approach and the research questions that guided the studies presented in this dissertation. Finally, the overview of the studies conducted and an outline of the dissertation are provided.

1.1 SOCIAL ROBOTS IN EDUCATION

Robots in general are not a new phenomenon in classrooms. As early as the 1970s, robots were introduced in primary education, such as the Turtle robot developed by Papert and Solomon (1972). These early robots were mainly used for teaching children how to build and program robots, or as technical tools that did not need construction or programming. More recently, powered by new developments in hardware and software, social robots have emerged in classrooms. Whereas the earlier robots were mainly considered a tool for learning about robots and programming, social robots for education are applied to teach children or assist the teacher. They can be defined by three characteristics: (1) having a physical (often humanoid or zoomorphic) embodiment; (2) having social interaction with humans; and (3) having some form of autonomy, meaning that they can respond to their surroundings without being (completely) teleoperated by humans (Bartneck & Forlizzi, 2004). Examples of social robots are NAO (SoftBank Robotics, 2020), Pepper (SoftBank Robotics, 2021), Tega (Westlund et al., 2016) and Paro (PARO Robotics, 2014), see Figure 1.1. However, many more social robots, ranging in size and appearance, have been explored, see overview of Henschel et al., (2021).

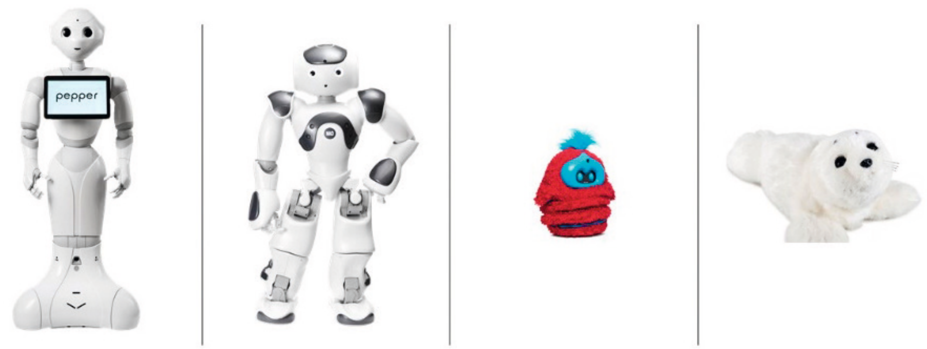

Figure 1.1. Examples of social robots (Pepper, NAO, Tega & Paro).

Social robots can be viewed as just another new educational technology, such as previously introduced tablets or online adaptive learning applications like Squla (Smeets et al., 2019) or 'Rekentuin' (Straatemeier, 2010). However, the (potential) capabilities of social robots and the way children perceive and interact with robots radically differ from other educational technologies. The first feature that sets apart social robots from other educational technologies is their physical embodiment. The physical embodiment of the robot enables the robot to be present in the same physical space as humans. This results in people perceiving robots differently than other (screen-based) technologies. For example, physical robots are reported to be perceived as more enjoyable by children when playing chess, compared to virtually embodied agents (Pereira et al., 2008). Also, physical robots are reported to be perceived as more trustworthy compared to a tablet (Mann et al., 2015). In an educational setting, the physical presence of a robot is reported to result in higher motivation and increased behaviour that is conducive to learning, compared to traditional computer-based platforms (Belpaeme & Tanaka, 2021). Social robots have also been shown to outperform tablets in increasing children's growth mindset (D. P. Davison et al., 2021), in stimulating preschool children's motor task performance (Fridin & Belokopytov, 2014b) and in second language acquisition among primary (migrant) school children (Konijn et al., 2022). Some scholars (e.g., Gordon et al., 2016) have argued for an integrated system combining tablet-based education and social robots, which could hold great potential. Such a combination of screen-based applications and psychically embodied robots has been the subject of multiple studies (e.g., Van den Berghe et al., 2019; Vogt et al., 2019). These studies show that combining the two technologies does not automatically result in increased benefits. The mediating role of the tablet may even undermine the benefits of the physical presence of the robot (Konijn et al., 2020). This might be explained by the tablet distracting from the child-robot interaction, or the robot distracting from the learning task displayed on the tablet. This area of research shows that it is still difficult to combine tablet-based education and social robots; and that it can even undermine the unique benefits of child-robot interaction.

A second feature that set robots apart from other educational technologies is gaze. Eye gaze is an important part of nonverbal communication in human-human interaction; gaze can support verbal communication and convey mental states (Admoni & Scassellati, 2017). Although there are many gaze strategies for human-robot interaction (e.g. Gillet et al., 2021; Ham et al., 2015; Lathuilière et al., 2019), in general, gaze can be divided into two types, *mutual gaze* (Rogers, 2013) and *averted gaze* (Belkaid et al., 2021). With mutual gaze, two persons (or a person and a robot) make eye contact. This type of gaze is an important part of social communication and is one of the crucial abilities needed in creating joint attention (Morales et al., 2005). In a situation of averted gaze, a person (or robot) does not, or no longer, make eye contact. Changes in gaze can shift attention to the location a person looks at (Friesen & Kingstone, 1998), also known as *gaze cueing* (Admoni & Scassellati, 2017). Given the importance of eye gaze in human-human interaction, it is unsurprising that it is a key research topic in human-robot interaction (Chesher & Andreallo, 2021; Damm et al., 2013; Meltzoff et al., 2010; Oliveira et al., 2018; Wiese et al., 2018). Robot eye gaze has been shown to have a significant effect on human-robot interaction. For example, in turn-taking processes, eye gaze can simplify the communication between humans and robots (Mutlu et al., 2012) and lead to participants following the gaze cues provided by robots (Weldon et al., 2021; Wiese et al., 2018). For educational purposes, robotic gaze cues have been used to help children in matching tasks and have been shown to make matching tasks significantly easier for children (Mwangi et al., 2018). Also, some studies, such as Mutlu et al., (2006), have found that increased mutual gaze can result in significantly better learning outcomes. They found that participants performed significantly better in recalling the story told by a robot when the robot looked at them more (mutual gaze). These results illustrate the potential benefits of utilising eye gaze of social robots in educational settings, not only to enhance interaction but also for improving learning outcomes.

A third feature that sets apart social robots from other educational technologies is that robots are often equipped with multiple sensors, which provide them with more capabilities compared to other educational technologies. One of the most frequently used social robots in educational studies is the NAO robot (Belpaeme, Kennedy, et al., 2018). This robot has seven touch sensors, four microphones, two 2D cameras and is equipped with speech recognition software (SoftBank Robotics, 2020). These tools allow the robot to register contextual data that can be used to personalise the interaction with children. Such personalised child-robot interaction (CRI) has been shown to result in increased learning gains and higher acceptance compared to non-personalised child-robot interaction (Baxter et al., 2017). Personalisation strategies in CRI do not necessarily have to be complex; even with relatively simple personalisation strategies, the performance of children can be increased (Leyzberg et al., 2014; Kory Westlund & Breazeal, 2015). However, for currently used robots to be able to personalise their interaction with children on a higher, more complex level, the robots need more sophisticated capabilities, such as improved autonomy, self-learning capabilities and complex facial and speech recognition systems, according to a recent systematic review (I. Papadopoulos et al., 2020). The autonomous behaviour and the artificial intelligence (AI) of social robots in education used in the extant literature thus far are still rudimentary. Most child-robot interactions in educational studies are still (partly) scripted, with limited autonomous behaviour of the robot (Van Straten et al., 2020). Although the current technological developments limit personalisation capabilities, robots are already able to react to multimodal input (e.g., using touch, sound, and video). In contrast, other educational technology, such as screen-based apps, often only use touchscreen-based, singular input. Therefore, even though robots are often not yet capable of autonomously reacting to sensory input in a real-life educational setting, their opportunities seem to exceed other, currently existing screen-based educational technologies.

A fourth and final feature that sets apart social robots from other educational technologies is that robots can take on new roles that most screen-based apps cannot, such as that of a novice or a peer (Hood et al., 2015). Robots that follow social norms are even reported to be perceived by children as their friends (Leite et al., 2013). These new roles can boost a child's self-confidence on a topic (Ghosh & Tanaka, 2011), relief loneliness (E. Z.-F. Liu, 2010) and enhance learning performances (Zaga et al., 2015). For example, letting a child teach a topic to a robot is argued to boost a child's self-confidence and also reinforce the existing knowledge of the child (Ghosh & Tanaka, 2011). Social robots taking on these roles could support children in classrooms in new ways, where other educational technologies may not. However, there are still significant technical challenges to overcome before robots can optimally utilise the features that set them apart from other educational technologies effectively. Therefore, it is important to mention the technical limitations of currently studied social robots in education.

Although social robots are increasingly explored to support children and teachers in primary schools, there are still technical issues that limit their use. To adequately support children and teachers, social robots would need to be able to interact with children and adapt to their needs without being completely controlled by a teacher. However, current robots are not yet able to function autonomously in a real-life classroom. The technological capabilities limit the use of social robots to often scripted dialogues and Wizard-of-Oz-like interactions where the robots are being teleoperated by a human (Chang et al., 2010; Kwok, 2015). One of the major technical issues is the current state of the robot's speech recognition capabilities. The current state is not adequately developed to allow for a stable spoken dialogue between a robot and a young learner, which challenges the effectiveness of social robots (Belpaeme, Vogt, et al., 2018; S. Lee et al., 2011; Papakostas et al., 2021; Woo et al., 2021). Other technical limitations include the limited ability to display socially acceptable behaviour in natural interaction with children (Castellano, Pereira, et al., 2009) and the robots being inadequate for complex social tasks (Serholt, 2018; Shiomi et al., 2015). It seems that, for now, robots are only able to assist teachers in simple (rehearsal) teaching tasks in real-life situations (Konijn et al., 2020). However, as pointed out by Van den Berghe et al., (2019), it is still hard to assess how effective social robots are for learning, even for relatively simple teaching tasks. This is mainly due to most studies still being relatively short-term and based on a limited number of interactions. Scholars such as Baxter et al. (2015), Lee and Lee (2021) and Van den Berghe et al. (2019) have voiced concerns that the initial positive response may be due to children's curiosity about this new technology and that the benefits may not persist over time. This is known as the novelty effect (Sung et al., 2009). This effect can be defined as: "the first responses to a new technology, not the patterns of usage that will persist over time as the product ceases to be new" (Sung et al., 2009). There are multiple ways scholars have tried to maintain children's overall enthusiastic first response to social robots, such as by focusing on engagement (e.g., Björling et al., 2020; Donnermann et al., 2021) or personalisation (Schadenberg et al., 2017). However, how robots could be used effectively over longer periods of time remains a subject for further research. Potentially many issues can be solved by just improving the technological capabilities of the robots, such as improved speech recognition and multimodal capabilities. However, the challenges related to social robots in education are not limited to just technical issues. Throughout the literature, moral concerns are also voiced related to the use of social robots in education (e.g. Serholt et al., 2017; Sharkey, 2016). These concerns require scholarly attention if robots are to be introduced into primary schools in a responsible manner.

1.2 MORAL CONCERNS RELATED TO SOCIAL ROBOTS IN EDUCATION

The introduction of social robots in (pre)primary education has led to scholars voicing moral concerns (Belpaeme, Kennedy, et al., 2018; Pandey & Gelin, 2017; Serholt et al., 2017; Sharkey, 2016; Tolksdorf et al., 2020; Woo et al., 2021). One of the first scholars reporting on the moral concerns related to social robots in education is Sharkey (2016). In her analysis, Sharkey (2016) highlights three main themes (1) privacy, (2) attachment, deception and loss of human contact and (3) control and accountability. Sharkey first points out that, due to children perceiving the robots as a social entity such as a friend or peer, the children could be more inclined to tell personal information to the robot. This could even include delicate secrets that children have told the robot in confidence. The robots' ability to record sensitive personal data such as secrets and options for emotion detection contribute to privacy concerns, such as: who should be allowed access to children's sensory data? Sharkey's (2016) second concern is related to the potential loss of human contact in classrooms that could result from the introduction of social robots. This loss could be triggered by the lifelike appearance of robots which, according to Sharkey, "could lead people to form attachments to them or to imagine that they were capable of or worthy of attachment" (Sharkey, 2016, p.288). Other studies have also reported on this issue and reported on concerns related to children potentially becoming socially isolated as a result of children bonding with a robot and preferring a robot over their human peers (Kennedy, Lemaignan, et al., 2016), which could even have a dehumanising effect on children (Serholt et al., 2017). Sharkey's (2016) final concern focuses on the issue of transferring decision-making from the teacher to the robot. The robot can autonomously adjust its interaction and learning material might lead to issues on who is accountable for potential negative outcomes. When considering a fully autonomous robot, this could even lead to ambiguity as to who should decide about what to teach, the human teacher or the robot (Sharkey, 2016). The moral concerns raised by Sharkey (2016) and the call from other scholars to view the introduction of social robots in education with caution, highlight the potentially harmful impact of social robots in education. According to Woo et al. (2021), these moral issues have rarely been addressed in (empirical) studies. Therefore, Woo et al. highlight "the need for future 'in the wild' studies to address the legal, social, and moral impact that social robots can have on children, teachers, parents, and other stakeholders" (Woo et al., 2021, p.9). In recent years, some scholars (e.g., Ahmad et al., 2016; Lutz et al., 2019; Serholt et al., 2017) have started to address these issues from a stakeholder perspective, thereby providing insights into stakeholder views on moral issues related to social robots in education.

Thus far, only a few studies have focused on stakeholder perceptions related to the moral concerns reported in conceptual studies such as Sharkey's (2016), and these studies sometimes present conflicting stakeholder views. For example, some parents consider robots as potential friends for their children while others would consider educational robots much more negative or accept social robots merely as mechanical tools (Choi et al., 2008). Results on the perspective of teachers show that (some) primary school teachers have moral concerns related to the use of social robots in education (Kennedy, Lemaignan, et al., 2016; Serholt et al., 2017), which seems to be in line with Sharkey's (2016) theoretical analyses. These results give a first insight into stakeholder views, however, an in-depth understanding of these views is still missing. In recent years, an increasing number of scholars (e.g., Belpaeme et al., 2018; Pandey & Gelin, 2017; Serholt et al., 2017; Tolksdorf et al., 2020; Woo et al., 2021) have argued for the need for (empirically based) guidelines on how to implement robots in education in a morally responsible way, to make sure that robots pose no threat to children and that values are not undermined by their introduction. Given the limited number of studies on the various stakeholder perspectives related to social robots in primary education and the probably conflicting views of different stakeholders, it is still largely unclear how social robots could be used in primary education in such a way that their implementation could be considered morally responsible.

1.3 MORALITY AND TECHNOLOGY

Morality can be defined as the perception of what is right and wrong (Rawls, 1974; Wernaart, 2022). The function of morality is to regulate behaviour so that it complies with the interests of a community (Malle & Schreutz, 2018). In the literature focusing on morality and technology (e.g., Friedman & Kahn, 2003; Van den Hoven, 2013; Van Wynsberghe, 2013), it is common to express the interests of communities in terms of values. People strive towards these values, which can be defined as "what a person or group of people consider important in life" (Friedman et al., 2013, p. 56), by following norms and evaluating their behaviour in light of these norms (Bicchieri, 2005). The introduction of new technology can have an impact on concepts that people consider important in life; technology, therefore, can impact values. It is not uncommon that the introduction of one specific technology impacts some values positively and others negatively (e.g., Mudliar, 2020; Mueller & Heger, 2018). Especially when introducing technology in a social context, conflicts between values can arise (Ligtvoet et al., 2015). For example, body scanners at airports can contribute to the value of safety, but can also harm the value of privacy of the passengers (Spiekermann, 2015). In such situations, *moral challenges* arise.

Moral challenges (also known as moral problems) are situations that "require a value judgement in which more than one, mutually excluding, value judgement can be right" (Wernaart, 2022). Some argue that such situations do not exist. For example, when considering classic top-down moral theories, such as deontology (Kant, 2009) or utilitarianism (Bentham & Mill, 2003), moral challenges can always be solved by following certain universal rules. For example, Utilitarianism (Bentham & Mill, 2003), argues for actions that result in the greatest pleasure (or welfare) for the greatest number. This theory allows a person to make moral decisions based on a single universal rule. By following this rule, conflicts, such as the privacy versus safety conflict described above, could be solved by solely considering the outcome: the greatest pleasure (or welfare) for the greatest number. However, universal moral theories such as Utilitarianism have been critiqued for being impractical. Anderson et al. (2004), for example, have argued that it is simply impossible to know exactly what the outcomes of an action will be, and Allen et al., (2000) argue that it is very hard to calculate all the outcomes of any actions for all parties involved for all time. Even in an ideal situation, where all the outcomes are known, universal moral theories such as Utilitarianism or Deontology often provide outcomes that people consider immoral (see Thomson, 1976). Therefore, it is generally accepted that, in practice, these classical theories do not provide sufficient guidance to ensure that values are not undermined (P. Lin et al., 2012; Wallach, 2010). Hence, we take the viewpoint that moral challenges do exist. When considering the potential benefits of social robots and the reported moral concerns, we foresee that implementing social robots in primary education will lead to moral challenges.

Moral challenges related to robotics are the main focus of an intradisciplinary research field called *Robot Ethics* (P. Lin et al., 2011). Robot Ethics is located at the boundaries of applied ethics[1] and robotics and aims to understand the moral implications and consequences of robotic technology, and to suggest means for achieving improved results for the integration of robots in our everyday world (Sullins, 2011). The research field can be roughly divided into two subdomains (Malle & Schreutz, 2018). The first focuses on the moral considerations of people designing, developing and interacting with robots. Moral considerations are deliberations on the moral desirability of new technologies, balancing right and wrong (Boenink et al., 2010). These considerations can be derived from values and should be studied to the point that designers and users can make more informed decisions on how to responsibly design and use technologies (Van den Hoven, 2017). Exemplar studies for this subdomain are: Draper and Sorell (2017), who studied the values that should underlie the development and integration of social robots into the homes of elderly people; Salem et al. (2015), who focused on the moral challenges related to trust and safety concerning social robots for everyday tasks in home and healthcare settings; and Van Wynsberghe (2013), who created an ethical framework for the design and implementation of care robots.

The second subdomain is concerned with questions related to the moral capacities of robots, also known as *Machine Ethics* (Moor, 2017; Van Rysewyk & Pontier, 2015) or *Machine Morality* (Wallach et al., 2008). This subdomain focuses on how robots can be programmed in such a way that they have sufficient capabilities to make moral decisions in social environments. It is overall accepted that for robots to have sufficient moral competence for complex social situations, like in education, they should follow a hybrid approach in which both pre-programmed moral rules, as well as self-learned rules (based on interactions) should guide the robot's behaviour (T. W. Kim et al., 2021; P. Lin et al., 2012; Wallach et al., 2017). However, how and if robots will ever be capable of making moral decisions is still part of an ongoing scientific debate. What makes it even more complex, is that norms that guide moral judgements are highly context-specific (Malle & Schreutz, 2018), that is, what is considered good in context A, can be wrong in context B. For example, whereas Korean and Japanese parents are reported to view robots as potential friends for their

1 Although the field of applied ethics is broad and difficult to define, an overall accepted view is that "applied ethics refers to any use of philosophical methods to treat moral problems, and policies in the professions, technology, government and the like" (Frey & Wellman, 2005, p. 3).

children (Choi et al., 2008), European studies report on cautious attitudes and concerns about the so-called "friendship" between children and robots (Reich-Stiebert & Eyssel, 2016; Serholt et al., 2017). The state-of-the-art social robots used in education, however, still lack the capabilities of correctly interpreting complex social environments, such as a primary school classroom. These robots are still largely based on scripted dialogues and their AI capabilities are still limited. It might therefore take several decades before social robots in education can adequately make moral decisions on their own. For this reason, our focus will be on the first domain of robot ethics: the moral considerations of people designing, developing and interacting with social robots. By focusing on this domain, we aim to provide new insights into how social robots in education can be used in a morally responsible way, allowing designers and users to make informed decisions on how robots can be designed and used in such a way that they do not violate values now, nor in the near future.

Over the last decades, numerous guidelines on the responsible (moral) design and use of artificial intelligence (AI) and robots have already been presented, such as the Ethics Guidelines for Trustworthy AI by the High-Level Expert Group On Artificial Intelligence set up by the European Commission (AI HLEG, 2018), the OECD[2] Principles on AI (OECD, 2021), the Guide to the Ethical Design and Application of Robots and Robotic Systems by the British Standards Institute (BSI, 2016) and the Principles of Robotics developed by roboticists and AI experts (Prescott et al., 2016). Although these guidelines are relevant and very much needed, scholars argue that they provide limited guidance for the actual development of AI/robotic systems in specific contexts (e.g., Hagendorff, 2020; Mittelstadt, 2019), such as in primary education. For example, the Principles of Robotics (Prescott et al., 2016) provide five high-level principles aimed at regulating robots in the real world. However, using the principles in "real world" environments, such as education, is still a challenge. Illustrative of the high level of these principles is, for example, the third principle *"Robots are products. They should be designed using processes which assure their safety and security"* (Prescott et al., 2016). Another example is the fourth principle *"Robots are manufactured artefacts. They should not be designed in a deceptive way to exploit vulnerable users; instead their machine nature should be transparent"* (Prescott et al., 2016). These principles give some guidance but they do not state what should be considered safe and secure in the context of education or how to address the often-voiced concern of, for example, children's 'artificial bonding' with a robot. In line, some scholars argue that social robots are deceptive because they pretend to be peers or friends (e.g., A. Sharkey & Sharkey, 2021; Sparrow & Sparrow, 2006). To what extent robots are allowed to

2 Organisation for Economic Co-operation and Development

"deceive" children (who can be considered vulnerable users) in a way that could be beneficial to them is hard to evaluate based on these high-level principles. Next to being difficult to interpret in specific contexts, the above-mentioned guidelines have been criticised for being vague, too high level, and intended to delay governmental regulations (Mittelstadt, 2019). Because the outcomes of robot use can differ per stakeholder and stakeholder feedback is needed to refine and contextualise guidelines, a substantial proportion of the current guidelines emphasise the need to take into account stakeholders' perspectives when developing and implementing (AI) robots. (e.g., AI HLEG, 2018; BSI, 2016). However, how different stakeholders view the use of social robots in education and how the stakeholder values might be impacted by the introduction of social robots is hard to determine based on the current literature, as argued in the section *Moral concerns related to social robots in education*, above.

1.4 INCLUDING STAKEHOLDER VALUES WHEN DESIGNING AND IMPLEMENTING SOCIAL ROBOTS

The current guidelines on the responsible (moral) design and use of AI and robots seem to offer limited guidance for specific social contexts, such as social robots in education. Given this limitation and the moral concerns related to social robots in education reported in the literature, this dissertation aims to serve as a basis for developing guidelines on how to design and use social robots in education in such a way that it respects the values of relevant stakeholders, and thereby allowing for the use of social robots in primary education in a morally justified way.

To create guidelines that take into account the social context, it is important to identify the potential impact of social robots on stakeholder values (what they consider important in life), and the moral considerations of different stakeholders involved. An accepted methodology to systematically include stakeholder values when designing and implementing new technologies, such as social robots, is Value Sensitive Design (VSD) (e.g., Umbrello et al., 2021; van Wynsberghe, 2013). The methodology has not only been used when studying social robots but has already been applied to numerous complex technological innovations, such as AI (Umbrello, 2019), parental control applications (Badillo-Urquiola et al., 2020) and self-driving vehicles (Mladenović et al., 2014).

At the core of the VSD methodology is the principle that to design and implement new technology in a morally responsible manner, three types of research are needed: 1) conceptual, 2) empirical, and 3) technical (Spiekermann, 2015). The first is concerned with the analytical, theoretical analysis of the central moral challenges related to the new technology under scrutiny. The second type of research needed aims to analyse the empirical human/ social context in which the technology will be implemented, in our case primary education. The third type of research focuses on how technology can support the values upheld in the specific context. This so-called tripartite approach can be applied through four phases: 1) value discovery, 2) value conceptualisation, 3) empirical value investigation, and 4) technical values investigation (Spiekermann, 2015), illustrated in Figure 1.2. Each phase will be described below.

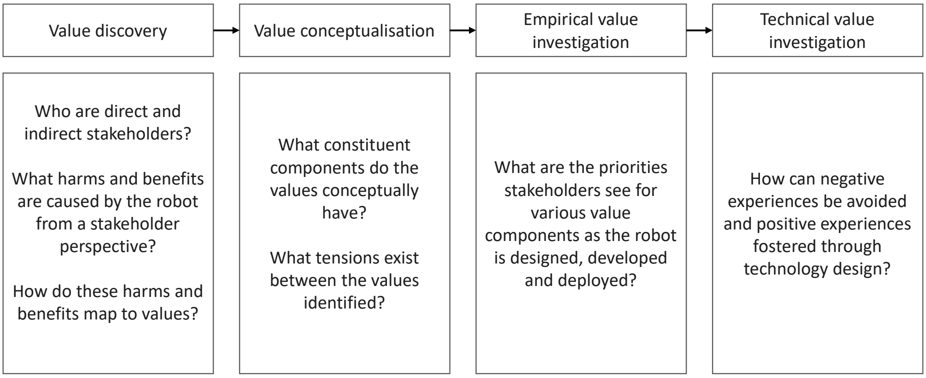

Figure 1.2. Values Sensitive Design Phases (Spiekermann, 2015).

1.4.1 Value Discovery

The first step of the value discovery phase is to identify the direct and indirect stakeholders. Direct stakeholders are those who are in direct contact with the robot or directly experience the result of the robot's use. Indirect stakeholders, however, are not in direct contact with the robot but are impacted by the robots indirectly (Friedman et al., 2008). For example, the parents of primary school children are considered indirect stakeholders related to robot tutors. They are not in direct contact with the robots but do potentially experience the effect that robots have on their children. For Dutch schools, key stakeholders are the government (e.g., policymakers), parents, staff, students, supervisory board, business (e.g., robot builders), supplying schools (e.g., Kindergarten), recipient schools (e.g., secondary schools), and other educational institutions (e.g., sector associations) (Konermann et al., 2010).

The second step of the value discovery phase is, for each stakeholder group, to identify the (potential) harms (e.g., concerns, disadvantages, downsides, drawbacks and risks) and benefits (e.g., positive effects, opportunities) caused by implementing social robots in education. When the perceived harms and benefits are identified, these can then be used to recognise corresponding values (Friedman & Hendry, 2019). These harms and benefits can be identified using both conceptual and empirical research, according to Friedman and Hendry (2019). The extant literature that is focused on moral challenges related to social robots in education is often conceptual, such as the studies conducted by Sharkey (2016) and Tanaka and Kimura (2009). These studies provide important input towards identifying the potential harms and benefits from a stakeholder perspective. However, without empirical grounding, it is hard to evaluate these conceptual studies for each stakeholder perspective. The limited studies that do focus on empirical insights into stakeholder perspectives, such as Kennedy et al. (2016) and Serholt et al. (2017), often focus on a single stakeholder perspective only. Therefore, in the current dissertation (i.e., in Chapter 2), we start by identifying the potential harms and benefits of social robots in education and link them to the relevant stakeholders, such as children, parents, teachers, governmental policymakers, and the robot industry. This provides a broad and comprehensive overview of the potential (both positive and negative) impact of social robots on the values upheld in primary education. Therefore, we follow the steps of the Value Discovery phase, as shown in Figure 1.2, to answer the first research question of this dissertation:

RQ1: What are the moral values in terms of potential harms and benefits of the implementation of social robots in education that are currently reported in the scientific literature?

1.4.2 Value Conceptualisation

When the harms and benefits of social robots in education are explored for all relevant stakeholders and used to identify the relevant values, each value needs to be broken down into constituent parts (Spiekermann, 2015). This is done in the value conceptualisation phase. The constituent parts of values can be referred to as norms (Van de Poel, 2013). Although there are many definitions of norms, a common definition is that they describe properties, attributes or capabilities that the designed artefact (i.e., the robot) should possess (Van de Poel, 2013). These norms provide guidance and break down the often general, high-level values, into more concrete elements. For example, breaking down the value of human autonomy in the case of care robots, Umbrello et al. (2021) showed that the constituent parts of this value are receiver-contextualised intervention, privacy protection, and data subject consent. Using the potential harms and benefits identified during the value discovery phase, the considerations of not just direct stakeholders such as children and teachers, but also indirect stakeholders (i.e., parents, educational policymakers, and robot industry representatives) will be presented in Chapter 3 of this dissertation. This results in insights into similar as well as conflicting moral considerations of various stakeholder perspectives. These insights allow for identifying the constituent parts (the norms) belonging to the relevant values. Thereby completing the second phase of the VSD methodology, the value conceptualisation phase (see Figure 1.2). Hence, the second research question of this dissertation reads as follows:

RQ2: What are the moral considerations of relevant stakeholder groups on implementing social robots in education, and how do they compare?

1.4.3 Empirical values investigation

When the relevant values and their constituent parts (the norms) are identified, further insight into the considerations of stakeholder groups is required to establish which values and norms stakeholders conder most important (Spiekermann, 2015). A common approach to studying the perceptions of stakeholders is to cluster them into stakeholder groups based on their roles (Friedman & Hendry, 2019), such as being a parent or a teacher. However, similar or conflicting values and norms can exist within stakeholder groups as well as between these groups (Ligtvoet et al., 2015). Therefore, to provide in-depth quantitative insights into the moral considerations of stakeholders, we not only focus on similarities and conflicts between stakeholder groups (RQ2) but also within stakeholder groups. This leads to distinct attitude profiles, insights into the priorities of stakeholders, and the identification of characteristics that affect the probability of belonging to a specific profile. We thereby answer the third research question of this dissertation, for which the empirical value investigation phase (see Figure 1.2) is the focus:

RQ3: How do individual educational stakeholders compare in their moral considerations of the implementation of social robots in primary education?

1.4.4 Technical value investigation

The goal of the technical value investigation phase is to translate the refined understanding of the relevant values and stakeholder considerations into specific goals and requirements for the social robots used in education (Spiekermann, 2015). By taking into account the results of the value discovery, value conceptualisation, and empirical value investigation phases, the goals and requirements detailed in the *technical value* investigation should lead to the robot being designed and used in such a way that it upholds, and does not undermine, the values of the stakeholders (Van de Poel, 2013). One of the key concerns reported in the literature is the fear that social robots would have a negative impact on children's social-emotional development (e.g., Pashevich, 2021; Peter et al., 2021). Stakeholders, such as teachers (Serholt et al., 2017), are also reported to be concerned about this potential harm. However, the participants in these stakeholder studies often lack experience in using robots, which makes it hard to evaluate the potential risks for children's social-emotional development. Furthermore, current CRI studies on education are often short-term and based on controlled case studies and not real-life classroom experiences (Woo et al., 2021), which makes statements on potentially long-term effects problematic.

Among the most important stakeholders in primary education are the teachers; not only are they responsible for the learning process of children, but they are also responsible for their social-emotional development and mental health. According to a large-scale survey among primary school teachers and school management, teachers have a great training need related to the cooperation between students and ICT, in addition to new applications such as Virtual Reality and robotics (E. Smeets, 2020). Teachers feel that they are not yet sufficiently able and knowledgeable to use such technologies in their classrooms. CRI researchers (e.g., Serholt et al., 2014) have argued that prior experience with technology can influence individual stakeholder perceptions. Hence, teachers without experience with social robots may be more negative about the use of social robots in their classrooms or have unrealistic fears (cf. 'moral panics' when new (media) technology is introduced; Carlson, 2020; Markey & Ferguson, 2017; Walsh, 2020). This could explain the reported concerns of teachers in the literature. Therefore, our fourth and final research question aims to assess the impact of social robots in primary education on the social-emotional development of children and to identify best practices based on the experiences of teachers who have applied social robots in their day-to-day classrooms:

RQ4: Do currently used social robots in education compromise the social-emotional development of children according to teachers who have experience in using social robots in their day-to-day education?

By answering this question, we provide more insights into the impact that social robots can have on children. Furthermore, these insights result in design and implementation requirements, which are the focus of the technical value investigation phase, the last phase of the VSD methodology (see Figure 1.2).

From the integrated results of the four phases, concrete requirements will follow on how to responsibly design and implement new technologies in a specific context. This is much needed because generally, high-level principles would not be sufficient for safeguarding values upheld in primary education. Following the overall methodology of VSD, this dissertation will focus on all four phases, thereby adding to the empirically-based knowledge about the values and perceptions of stakeholders in primary education, and finally providing guidance for the responsible design and use of social robots in primary education. We thereby answer the main research question (MRQ) that guides the research project presented in this dissertation:

MRQ: How can social robots be implemented in primary education in a morally justified way by balancing the related values and moral considerations of various educational stakeholders?

By answering this main research question, we aim to provide new insights into the relevant values and moral considerations of stakeholders related to social robots in education and contribute to the first conceptualisation of an empirically grounded code of conduct for the design and use of social robots in primary education.

1.5 METHODOLOGICAL APPROACH

By following the phases of the VSD methodology, this research project utilises a mixed-method approach of conceptual, empirical, and technical research. To systematically examine the potential harms and benefits (as indicators of moral values) of social robots in education (RQ1), we conducted a systematic literature review covering various scientific fields, such as Communication Science, Psychology, Robotics and Philosophy. We systematically searched relevant databases (e.g., *IEEE Digital Library* and *Scopus)* and refined the best possible search string consisting of the relevant keywords, such that most references would be found that were relevant for our purposes and such that irrelevant references would be excluded (see Chapter 2). Because social robots for educational and learning purposes can still be considered a novice technology, we did not only focus on the empirically reported harms and benefits, but also on the fears and potential harms reported in the identified studies. This resulted in a broad overview of the potential harms and benefits per stakeholder group and also identified current gaps in the literature on the perspective of some stakeholders.

To fill the gaps in stakeholder perceptions identified by the systematic review (RQ1) and to get a more in-depth, qualitative understanding of the perspectives of stakeholders, we conducted focus group sessions with the main stakeholder groups. Selecting which stakeholders to include can be a complex and daunting challenge, as there are multiple methods (e.g., Freeman, 1998; Friedman & Hendry, 2019; Phillips, 2011). For this study, we selected stakeholders based on the impact social robots could have on them, which is an accepted selection method in ethics of technology studies (Friedman et al., 2017; Miller et al., 2007), rather than based on the experience they had with the technology. Therefore, we included teachers, parents, governmental policymakers, robotic industry representatives and primary school children in the focus group sessions (RQ2). Each focus group consisted of a homogeneous group of participants based on their role (e.g., being a parent, a teacher, or a policymaker). To familiarise participants with social robots in education, we used video footage of social robots as an introduction to the focus group session, which is a commonly used method in social robotics studies (e.g., Ahmad et al., 2016; Rosanda & Istenič Starčič, 2019) and has some benefits over using real robots, for example, they do not break down during experiments and do no need programming (Belpaeme, 2020). Next to video footage, we let participants interact with a physically present social robot at the start of the session, to ensure that the participants had a sufficient understanding of the topic of the focus group session. After getting acquainted with the social robots, stakeholders discussed potential harms, downsides, risks and fears of social robots in education from their perspective, as well as potential benefits, opportunities and upsides if social robots would be implemented in education. This allowed for new insights to emerge on the differences and similarities among stakeholder groups related to their moral considerations of social robots in primary education.

Based on the results of the focus group sessions (RQ2), we have set up a large-scale questionnaire to examine and compare the attitudes of individual stakeholders on the use of social robots in primary education (RQ3). This quantitative study further provided important insights into (comparing) the considerations of stakeholders, which could not be identified during the preceding qualitative focus group study. Using a quantitative method allowed for investigating the priorities of values among the different stakeholders and is therefore advocated in the VSD literature (Spiekermann, 2015). Using these results, we could identify distinct attitude profiles per stakeholder group and show that the probability of belonging to a specific profile is affected by characteristics such as stakeholder type, age, education, and income. These insights, combined with the insights of the review and the focus group sessions, contributed to the design of our final study.

In our final study (RQ4), we conducted semi-structured interviews with experienced teachers who have used social robots in their classrooms to examine the impact of social robots in primary education on the social-emotional development of children (RQ4), which was shown to be one of the main concerns of stakeholders in earlier studies (e.g., Serholt et al., 2014; Sharkey, 2016) and in Chapter 2, 3 and 4. This resulted not only in an evaluation of the impact on children's social-emotional development but also provided a list of best practices on how social robots can best be used in primary education according to experienced teachers.

1.6 OUTLINE OF THE DISSERTATION

This dissertation consists of four research papers (to be) published in multidisciplinary journals (e.g., *Computers & Education*, *Robotics,* and *Frontiers in Robotics and AI*), that reflect the four research questions mentioned in the sections above. The overall aim of these studies was to use the results as a basis to develop guidelines on how to design and use social robots in education. Developing such guidelines would fill a gap in the current literature on stakeholder perspectives regarding the use of social robots in primary education. By doing so, we open up the field for developers and other stakeholders to include the perspectives of various relevant stakeholders and their values in the moral design and implementation of social robots in primary education from a Dutch perspective. As argued in this introductory Chapter 1, we thereby apply the Value Sensitive Design methodology to systematically identify the relevant values, and study the moral considerations of stakeholders related to social robots in education.

In Chapter 2, we present a broad systematic literature review on moral considerations related to social robots in education, operationalised as the potential harms and benefits as reported in the relevant literature. Thereby, we categorise the types of studies that have been conducted in relation to the specific harms and benefits reported. Furthermore, the analysis reveals which stakeholder perspectives are currently understudied.

In Chapter 3, we present a focus group study to get a more in-depth, qualitative understanding of the perspectives of different stakeholder groups, in particular also from the understudied stakeholders (cf. Chapter 2). We present the similarities and differences in perspective of each stakeholder group and report on unresolved issues where stakeholders could not agree.

Chapter 4 describes a large-scale quantitative study (N = 515) into the attitudes of stakeholders on the moral considerations related to social robots in education to get more insight into the priorities of various stakeholder groups. Based on the results of Chapter 3, we created a questionnaire to identify the different attitudes related to moral considerations. The results reveal not only different attitude profiles per stakeholder group but also what socio-demographic characteristics influence the attitudes of stakeholders on their moral considerations related to social robots in primary education.

In Chapter 5, we present an interview study with primary school teachers who do have prior experience in using social robots in their day-to-day education to provide deeper insights into one of the main concerns of stakeholders reported in the earlier studies (e.g., Serholt et al., 2014; Sharkey, 2016) and in Chapter 2, 3 and 4: the potential harm to children's social-emotional development. We interviewed nine teachers who, in total, oversaw the child-robot interactions of more than 2,600 unique primary school children. The results provided important input to develop a first draft on how to implement social robots in primary education in a morally justified way, according to these experienced teachers.

Finally, in Chapter 6, this dissertation concludes with a general discussion, where we summarise and reflect on the findings of the four studies and the future of social robots in primary education. We present the theoretical implications and discuss the methodological strengths and limitations of the studies in this dissertation. This discussion concludes with the practical implications based on the theoretical and empirical findings, resulting in a code of conduct for designing and using social robots in primary education in a morally justified way.

CHAPTER 2

HARMS AND BENEFITS OF ROBOT TUTORS: A SYSTEMATIC LITERATURE REVIEW

This chapter is (in part) published as:
Smakman, M.H.J., Konijn, E.A. (2020). Robot Tutors: Welcome or Ethically Questionable?. In: Merdan, M., Lepuschitz, W., Koppensteiner, G., Balogh, R., Obdržálek, D. (eds) Robotics in Education. RiE 2019. *Advances in Intelligent Systems and Computing*, vol 1023. Springer, Cham. https://doi.org/10.1007/978-3-030-26945-6_34, and Smakman, M.H.J., Konijn, E.A. (2022) *Harms and Benefits of Robot Tutors: A Systematic Literature Review*. Manuscript submitted for publication.

Abstract. To relieve pressure in education due to shrinking resources and increasing demands, new technology may be helpful. Hence, robot tutors are tested for their potential to support regular and special education purposes. However, they come with moral challenges. The current systematic review examines these challenges through the harms and benefits of robot tutors as identified in the literature, covering various scientific fields and categorised per study design. Results revealed more potential harms than benefits reported for children and teachers. The benefits found in our review are: increased motivation and enjoyment, reduced anxiety, new opportunities for education such as beyond the classroom learning, personalised learning and reduced administrative work. The types of reported harms associated with robot tutors are more spread out compared to the benefits. By analysing the relationship between the hams and the benefits we identified four key issues, being: privacy and security, control and accountability, social implications, and loss of human contact. However, relevant stakeholders (e.g., parents, policymakers) are currently overlooked in the literature. This review concludes with suggestions for future research on the guidelines for implementing robot tutors in education.

2.1 INTRODUCTION

Nowadays, robots are being explored in several social domains; one such domain is education. The use of robots in education can be seen as occurring through three categories, 1) build robots, 2) use robots, and 3) social robots (Catlin et al., 2018). With build robots, children learn to build and program robots, whereas use robots refer to tools that do not need construction or programming. Social robots for education are aimed to teach or assist the teacher and often have a humanoid appearance. Key elements of social robots are a physical embodiment, the robot following social norms and having some form of autonomy (Bartneck & Forlizzi, 2004). Social robots in education can also be described as learning collaborators and can serve in the role of a tutor or peer, thereby improving cognitive (e.g., knowledge, comprehension, application, analysis, synthesis, and evaluation) and affective (e.g., the learner being attentive, receptive, responsive, reflective, or inquisitive) outcomes (Belpaeme, Kennedy, et al., 2018). These robots are explored both in regular primary education and in special education, such as education for children with an Autism Spectrum Disorder (ASD) (Huijnen, Lexis, & de Witte, 2016; Palestra et al., 2014). Children perceive social robots as a social entity rather than a tool and - according to the children - the children even seem to establish a kind of friendship-relation with them (Leite et al., 2013). This paper defines a "robot tutor" as a social robot in the role of a learning collaborator, which is a definition commonly used in the existing literature (Belpaeme, Kennedy, et al., 2018).

Although robot tutors hold great potential (Belpaeme, Kennedy, et al., 2018), they also introduce moral challenges. Various studies report on moral values that are at risk of being undermined by the introduction of robot tutors for education, such as privacy, accountability, and human contact, and address the need for moral considerations and guidelines for introducing and designing robot tutors (Belpaeme, Kennedy, et al., 2018; Pandey & Gelin, 2017; Serholt et al., 2017; Sharkey, 2016). This study will provide a first step towards these guidelines. As robot tutors are increasingly being explored in education, the need for such guidelines becomes more urgent. Without the proper guidelines on how to build and implement robot tutors, the values upheld in education are at risk when robot tutors are introduced. Furthermore, in the field of Child-Computer Interaction design ethics (which focuses on the impact of technology) is underdeveloped and should be addressed more explicitly, according to a recent systematic literature review on ethics in Child-Computer Interaction (Mechelen et al., 2020).

When studying moral considerations and values related to the introduction of a new technology it is important to focus on both direct and indirect stakeholders.

Direct stakeholders are those who are in direct contact with the technology or directly experience the result of it, whereas indirect stakeholders are those who are impacted by the technology but are not in direct contact with it (Friedman et al., 2008). Children's parents, for example, are considered indirect stakeholders related to robot tutors. The parents are not in direct contact with the robots but do potentially experience the effect that robots have on their children. Such a multi-stakeholder perspective is crucial because stakeholders' values and perceptions may differ, which may result in conflicts (Ligtvoet et al., 2015). An approach to identify and analyse moral values from a multi-stakeholder perspective is Value-Sensitive Design (VSD; Friedman, Kahn, & Borning, 2008).

VSD promotes design ethics based on moral values, when designing and integrating new technology in a social context (Friedman et al., 2013). The approach is used to design and implement socially acceptable technology in different fields, such as wind parks (Oosterlaken, 2014), smart metering (Van de Kaa et al., 2019), robotics (Cheon & Su, 2016), social robots in healthcare (Van Wynsberghe, 2013) and educational support to parents and parental control applications (Badillo-Urquiola et al., 2020). It provides an approach to discover and conceptualize values related to technology by identifying the harms and benefits related to the system from a multi-stakeholder perspective (Spiekermann, 2015).

The first step of VSD is to identify the direct and indirect stakeholders who will (potentially) be affected by the technology. Second, for each stakeholder the (potential) harms (e.g., concerns, disadvantages, downsides, drawbacks and risks) and benefits (e.g., positive effects, opportunities) caused by implementing the technology are described. These harms and benefits can then be used to identify the moral values. A common definition of a value in the VSD literature is *"a value refers to what a person or group of people consider important in life"* (Friedman et al., 2008). These moral values shape moral conceptions (Rawls, 1974). Identifying potential harms and benefits therefore underlies moral considerations in education and will be the focus of this review.

Thus, the aim of this systematic literature review is to identify the harms and benefits related to robot tutors from a multi-stakeholder perspective, thereby providing the first steps for identifying the moral considerations and the creation of guidelines for the design and implementation of robot tutors. We will therefore answer the following research question: *which harms and benefits related to the use of robot tutors are reported in the existing scientific literature?* By answering this question, we will provide the systematic base for future guidelines for the design and implementation of robot tutors in education, which is currently missing and urgently needed to prevent moral values being undermined. In the following, we present the selection procedure of the literature search and categorise the harms and benefits related to robot tutors.

2.3 METHOD

The first step of our systematic literature review was to identify relevant databases and search engines. A comprehensive search for relevant databases was conducted, resulting in databases and search engines from various academic fields, being: *IEEE Digital Library, SpringerLink, JSTOR, Science direct, ACM, NARCIS, EBSCO, Web of Science* and *Scopus*. In the initial search string, we used multiple keywords for robot tutors. This resulted in multiple search terms for tutor robots and various synonyms for harms and benefits. In several search rounds, we refined the search criteria such that most references would be found that were relevant for our purposes and such that irrelevant references would be excluded. For example, a relevant source is Fernández-Llamas et al. (2018) focusing on students' behaviour when lectured by robotic vs. human teachers, whereas an irrelevant source is Alkhaldi et al. (2016) who reviewed contemporary remote and virtual laboratory implementations in different disciplines and was therefore discarded. In all, various searches resulted in our final, most optimal search string as follows: ("robot tutor" OR "tutor robot" OR "robotic tutor" OR "teacher robot" OR "robot teacher" OR "robotic teacher" OR "education* robot") AND ("harm" OR "benefit" OR "positive effect" OR "negative effect"). No limitations were set on year of publication.

2.3.1 Selection procedure.

The first step in the selection procedure of the resulting references (shown in Figure 2.1) was to exclude duplicates. This step resulted in 909 unique studies. Second, we checked if the abstracts matched our inclusion criteria, which were: (1) the context should be educational, and (2) the abstract should include a specific mentioning of a tutor robot (or synonym). We also excluded publications that were not written in English. To identify the educational context, terms searched for included: teacher, pupil, school, education, tutor, peer, assignment, learning, course, curriculum, kindergarten, and learning topics such as chess and language. Exclusion criteria for the educational context were: revalidation in healthcare, elderly, training in industry, robots learning from (human) teachers and reinforced learning. To identify various types of the robot tutor, inclusion terms were: learning collaborator, learning companion, learning peer, teaching assistant and physical agent. Exclusion criteria regarding the topic robot tutors were: as a programming project (e.g., Lego Mindstorms), as a learning focus (use robots), virtual agent, distance education, software robots, virtual reality, augmented reality, telerobot, therapy tool, constructivism, and robotic education.

This resulted in 134 studies selected for a full-text analysis. After this phase, we conducted a backward reference search, which resulted in an additional 473 possibly relevant studies. The abstracts of these studies were also matched to the inclusion and exclusion criteria, which resulted in 152 relevant studies. Together, the initial and backward search resulted in a total of 286 studies selected for a full-text analysis. In the last step, 30 studies were excluded based on a lack of the educational context or there was no full-text available. In all, this resulted in a final list of 256 studies included in the systematic literature review.

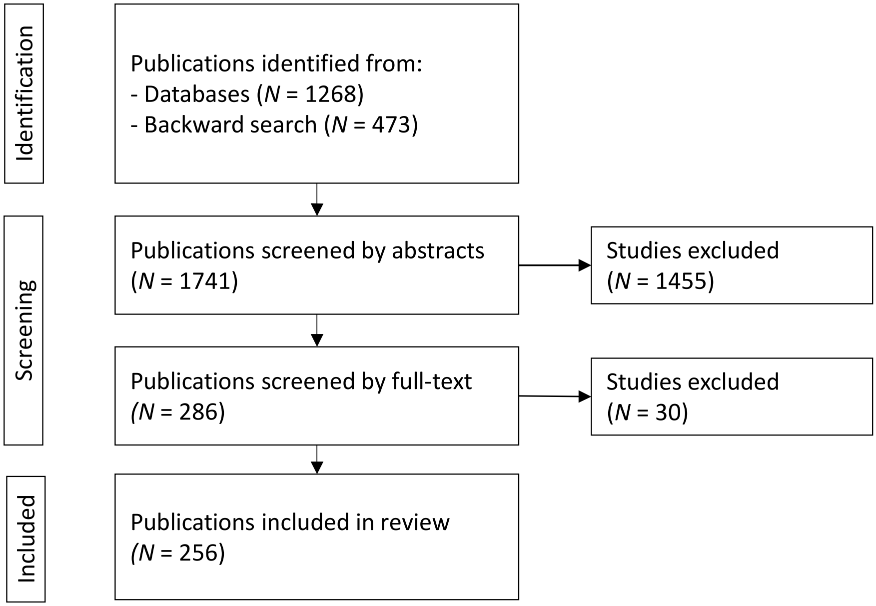

Figure 2.1. Selection procedure of studies in this review.

2.4 DATA ANALYSIS

The literature found for the current review covers various scientific fields such as *Pedagogy, Psychology, Communication Science*, *Philosophy*, *Human-Computer Interaction, Human-Robot Interaction and Child-Robot Interaction*. Therefore, the 256 publications selected for full-text coding were diverse in their goal and methodology. The full-text data analysis was conducted in three cycles of coding, following Corbin and Strauss' (1990) process of (1) open coding, (2) axial coding, and (3) selective coding. Applying these three cycles, we segmented the publications based on their main goal for comparison purposes and as such identified the categorisation of these studies. We identified five categories: (1) Conceptual studies, (2) Design studies, (3) Effect studies, (4) Exploratory cases, and (5) Perception studies, illustrated in Table 2.1.

Table 2.1. Category Description.

Category	*Description*
Conceptual studies, *N* = 39	The focus of the conceptual studies is primarily theoretical and visionary. They include short reviews, philosophical arguments, discussion papers, and published descriptions of research projects and their progress. No empirical work or applied cases are included in this category.
Exploratory cases, *N* = 87	The focus of the exploratory studies is the discovery of the broad effects of robots by applying them in an educational setting. These also include comparison studies between teachers and robot tutors, often single case studies.
Perception studies, *N* = 26	The focus of the perception studies is the identification of expectations, judgements and opinions of stakeholders, such as teachers, children and the general public.
Design studies, *N* = 31	The focus of the design studies is to inform the design of tutor robots, frameworks, approaches, principles, classifications, and technical aspects.
Effect studies, *N* = 73	The focus of the effect studies is to establish the effect of the capabilities of the robot, such as: gestures, emotions, embodiment, and personalisation.

This categorisation does not only provide a framework for comparison purposes but also allows for a systematic overview of the available studies related to tutor robots, until 2018. The 256 studies included in this review are available online at the Open Science Framework, Table S1 (https://osf.io/97uza/).

For each individual category of these studies, through our full-text data analysis, we identified the harms and benefits discussed within each paper and linked their effects to a specific or multiple key stakeholder(s) in education. To do justice to the diverse nature of the studies included in our review, ranging from philosophical papers to engineering studies, we report all (potential) harms (e.g., concerns, disadvantages, downsides, drawbacks and risks) and (potential) benefits (e.g., positive effects, opportunities) mentioned in the studies, not only those which were measured or empirically validated.

2.5 RESULTS

In the following, we present the harms and benefits related to the introduction of robot tutors from a multi-stakeholder perspective, that are discussed within the reviewed papers. All harms and benefits discussed in the reviewed studies were related to children and teachers. In the extracted literature, it appeared that potential harms of robot tutors were not discussed for other stakeholder groups.

The descriptive information for each study included in this review (e.g., method used, robot used, learning topic, and location) can be found at the Open Science Framework, Table S1 (https://osf.io/97uza/), in line with the principles of Open Science. Furthermore, for each study we recorded the harms and opportunities mentioned per specific stakeholder, see Table S1. The identified harms and benefits, and the number of studies which reported on these harms and benefits, per category, are shown in Table 2.2.

Table 2.2. Overview of the number of studies which report on the harms and benefits of robot tutors per category. (B = Benefit, H = Harm, Ch = Children, T = Teachers)

Opportunities and concerns			*Categories (see Table 2.1)*					
B/H	Ch/T	Description	Conceptual studies, *N* = 39	Exploratory cases, *N* = 87	Perception studies, *N* = 26	Design studies, *N* = 31	Effect studies, *N* = 73	Sum of H/B
B	Ch/ T	Motivation and enjoyment	10	43	5	8	24	90
B	Ch	Reduced anxiety	1	9	2	1	1	14
B	Ch	Personalized learning	12	7	7	14	6	46
B	Ch/ T	New opportunities for education, new social interactions, or beyond the classroom learning	11	21	13	6	9	60
B	T	Reduced administrative work	6	9	4	0	0	19
H	T	Cost of the robot	2	4	5	1	1	13
H	Ch	Privacy and security	2	0	3	3	0	8
H	Ch	Social implications, e.g. friendship, trust, respect, and deception	8	1	3	1	1	14
H	Ch/ T	Discomfort, e.g. Uncanny Valley effect and stress	1	6	3	1	5	16
H	T	Technology is too complicated or low technology adaptation	1	4	3	0	0	8
H	Ch	Loss of motivation	4	6	1	1	3	15
H	Ch	Loss of human contact	2	2	5	0	0	9
H	T	Control and accountability issues	3	0	2	1	0	6
H	Ch/ T	Disruption	0	2	2	1	3	8
H	T	Increase of workload	1	0	1	0	0	2

Table 2.2. Continued.

Opportunities and concerns			Categories (see Table 2.1)					
H	T	Technology is inadequate, ineffective or wrong expectations	6	18	7	4	6	41

Through our literature review, we identified five types of benefits (e.g., positive effects, opportunities) and eleven types of harms (e.g., concerns, disadvantages, downsides, drawbacks and risks) related to teachers and children. The identified five types of benefits related to robot tutors are: (1) motivation and enjoyment, (2) reduced anxiety, (3) new opportunities for education, (4) personalised learning, and (5) reduced administrative work. The harms associated with robot tutors are more spread out, consisting of eleven different types of harms and concerns, namely: (1) technology is inadequate, ineffective or raises wrong expectations, (2) discomfort (e.g., Uncanny Valley) and stress, (3) loss of motivation, (4) social implications (e.g., friendship, trust, respect) and deception, (5) cost of the robot, (6) loss of human contact, (7) privacy and security, (8) technology being too complicated or low technology adoption, (9) disruption of the classroom, (10) control and accountability issues, and (11) increase of workload. Clearly, these types of harms have the potential to challenge the benefits of robot tutors. Figure 2.2 shows which types of harms could negatively impact the types of benefits, based on the reviewed literature. In the following, we will present the main types of benefits in light of the potential harms that may undermine these benefits.

2.5.1 Benefit 1. Motivation and Enjoyment

One of the main types of benefits for children working with robot tutors is the possibility to increase the children's motivation and enjoyment; more than a third (n = 90) of all identified studies report on this opportunity (see Table 2.2). However, there are multiple harms that could undermine this benefit, which are: discomfort (reported in 16 studies), losing motivation (reported in 15 studies), and the technology being inadequate, ineffective and users having wrong expectations (reported in 41 studies).

Motivational gains are not simply a direct increase in motivation to complete a task. Rather, motivational gains within these studies are posited to be synonymous with the robot tutor's capacity to attract attention, increase motivation to learn a topic, encourage learners to practice, increase interaction levels, and to increase the children's perceived enjoyment of learning.

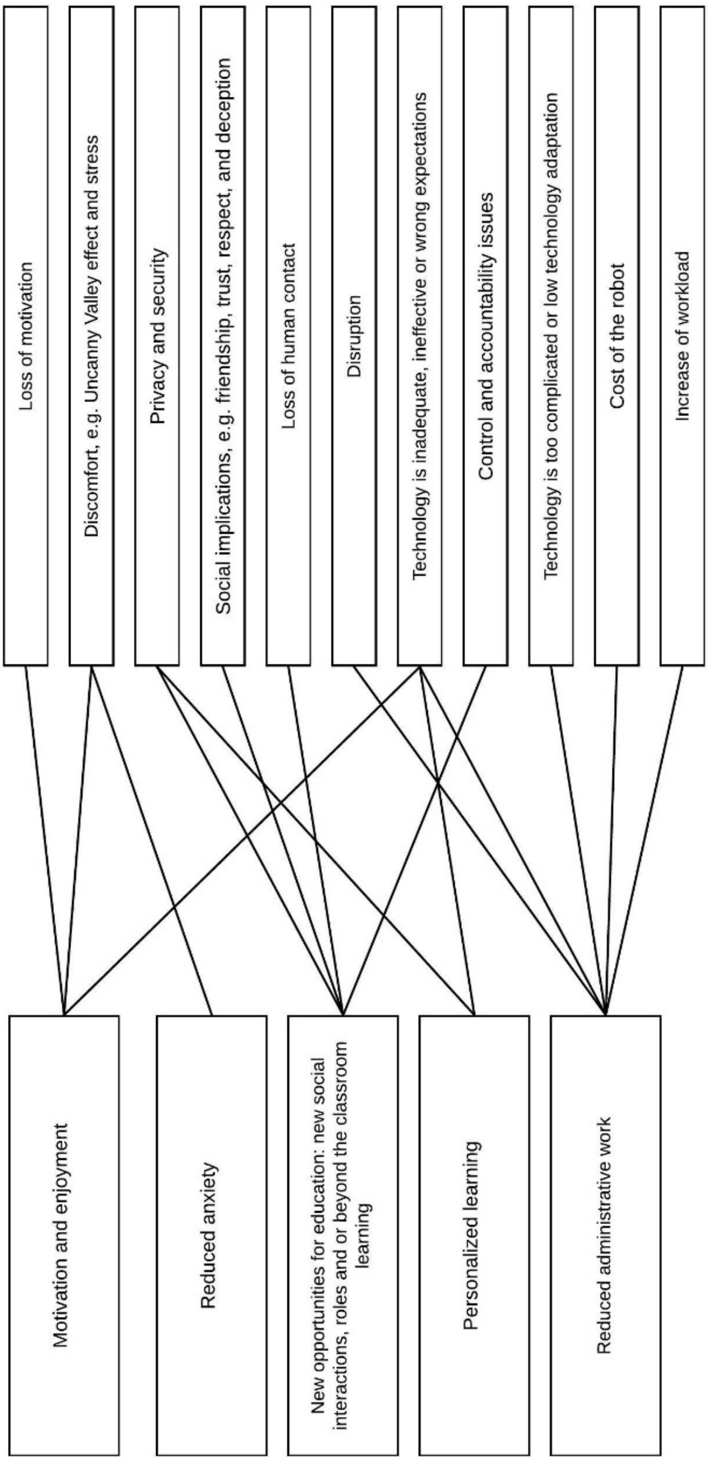

Figure 2.2. Interrelatedness between the harms and benefits related to robot tutors.

Studies report that robots have the potential to increase motivation for both regular and special needs children, such as children with hearing disabilities (Kose & Yorganci, 2011) or autistic spectrum disorder (ASD). Children with ASD could perhaps profit most from the predictable behaviour and controlled simple social interaction of a robot tutor (Aresti-Bartolome & Garcia-Zapirain, 2014). Children with ASD are recorded to show signs of enjoyment related to the robot tutor (Alemi et al., 2015), even when the children have limited verbal communication skills (Robins et al., 2005). Furthermore, interaction levels of children with ASD seem to increase when interacting with the robot (Dautenhahn & Werry, 2004). Practitioners of children with ASD and developmental disabilities are reported to have a positive attitude towards the use of robots in learning, seeing a role for the robot for objectives such as fun, rest, relaxation, and emotional well-being (Conti et al., 2017; Huijnen, Lexis, & de Witte, 2016). However, even with a human controlling the robot (i.e., a Wizard of Oz setup), the robot is not able to meet the requirements posed by professionals working with these special needs children (Huijnen, Lexis, Jansens, et al., 2016).

The reviewed studies discuss the following reasons for a robot tutor increasing children's motivation and enjoyment: physical embodiment, verbal and nonverbal cues, (personalised) social behaviour, and the role of the robot. Below we will report on the first three. The role of the robot will be presented in a later section, as it seems to refer to a broader set of benefits and social concerns.

Physical embodiment is one of the main distinctive characteristics of tutor robots, making them directly present in the physical space of the learner. Enhanced motivation is linked to the physical and visual presence of the robot tutor (Belpaeme et al., 2015; Y. Kim & Baylor, 2016). Physical embodiment is also shown to result in greater enjoyment compared to having no (humanoid) embodiment, such as in the virtual presence on a tablet (Pereira et al., 2008). Not only do children perceive embodied robots as friendlier, they are also reported to accept the robot as an authority (Fridin & Belokopytov, 2014b). Children are also reported to like the way robots move (Ros & Demiris, 2013). Related to the robot's physical presence, the illusion of a human-like life the robot tutor assumes and portrays, and the human-like acting a robot tutor performs, are reported as motivating (e.g., Pareto, 2017; Zawieska & Sprońska, 2017).

Verbal and nonverbal cues can also increase and/or maintain children's engagement. Children interacting with a robot tutor that gave verbal or both verbal and nonverbal cues expressed less boredom (Brown & Howard, 2013; Brown & Howard, 2014). Comparing a robot that helped children using gaze to a robot that didn't, children looked significantly longer at the helping robot's face using gaze and regarded the helping robot as more positive, friendly and "cool" (Mutlu et al., 2006; Mwangi et al., 2017). It is also reported that when a robot tutor displays a facial expression during a game, the child's level of engagement towards the robot increases (Castellano, Leite, et al., 2009). Nonverbal cues and gestures used in the educational process for teaching sign language are also perceived to be enjoyable (Kose et al., 2015). Verbal cues such as calling out names, praising children, and clapping on children's answers by the robot can motivate children to speak out (Alemi et al., 2014b). Just by acknowledging the beginning and end of a task, robot tutors can maintain children's attention towards that task (Brown et al., 2013).

Besides embodiment and verbal and nonverbal cues, the robot expressing social behaviour is also shown to increase motivation. Children engaged with a robot tutor with social expressiveness show a significant increase in motivation compared to children engaging with a robot tutor with neutral behaviour (Saerbeck et al., 2010). A robot with social behaviour is also reported to draw more attention, compared to a human or a solely task oriented robot without social behaviour (Vouloutsi et al., 2015). The introduction of a tutor robot can also lead to children giving their peers advice, introducing a *teaching to teach learning paradigm* which has been shown to increase motivation (Hood et al., 2015). Children showed more responsible behaviour as the children expressed more extended corrective feedback in the presence of a robot (Chandra et al., 2015). Students also seem more eager to perform well on a task in the presence of a robot compared to the presence of a human teacher (Serholt, Basedow, et al., 2014).

Social behaviour of robot tutors can be personalised to the needs of children. This personalised social behaviour within the robot is reported to improve motivation and engagement, increase the interaction with the robot tutor, and increase self-regulated learning (Jones et al., 2017; Jones & Castellano, 2018; Kanda et al., 2012; Shimada et al., 2012).

Some children report on learning with a robot tutor being more interesting than learning in a traditional classroom (Wei et al., 2011). This enjoyment could lead to a more effective learning process, thereby boosting students' motivation in the long run (Alemi et al., 2015). By attracting the attention of weaker students, a robot could motivate them to participate more in the learning process (Chang et al., 2010). The tutor robot is also reported to increase children's concentration (Hsu et al., 2007), possibly achieved by the novelty effect (Han et al., 2009).

Children's age seems to influence their perceptions of robot tutors. Younger children are reported to be more enthusiastic about learning with robots than older children, based on data from 85 Korean elementary, middle and high-school children (Shin & Kim, 2007). The motivational effect would be especially strong for children between the ages of 10-14. The robot seems to be more effective in promoting learning to these children compared to university students (Johnson & Lester, 2016). However, why robot tutors seem to have a stronger motivational effect on children within this age-range is not specified in their study.

Increasing motivation and enjoyment by robot tutors is not only reported as an opportunity for children, there are indications that teacher's motivation and enjoyment can also be positively affected in terms of job-satisfaction (Shih et al., 2007; Sumioka et al., 2017). Furthermore, teachers who find certain topics complex and tough can be motivated by the tutor robot, such as Taiwanese teachers teaching English (Shih et al., 2007). Robot tutors were also perceived as helpful and motivating by Japanese special school teachers for difficult topics such as sex education (Sumioka et al., 2017).

Discomfort, Uncanny Valley, and stress. There were 16 studies that reported on discomfort which could be caused by the robot. For teachers, one of the key concerns was the fear of being replaced by robots (Pandey & Gelin, 2017), creating feelings of discomfort. However, with the current state of technology, the robot is inadequate to serve as an autonomous tutor (Serholt et al., 2013; Sharkey, 2016). Also, most studies report on the robot tutor not as a substitute, but as a tool for the teacher to support the educational process. The current robot tutors lack the ability to determine the zone of proximal development for children, which is a capability of a good human teacher (Sharkey, 2016).

Although most children seemed to enjoy working with robot tutors, studies in our review also report that the robot tutor may cause discomfort. Some children are reported to perceive a robot tutor as scary, causing discomfort or triggering cautious behaviour (Kanda et al., 2012; Okita et al., 2009). Children can also feel rushed by the robot, finding it annoying, impatient, and nerve-racking (Brown et al., 2013). Other studies report on children's elevated fear and stress levels when interacting with a robot tutor (Fernández-Llamas et al., 2018; Jones et al., 2017; Shin & Kim, 2007). When a robot tutor responded inadequately, some children even showed signs of depression and a little bit of anger towards the robot (Wang et al., 2009).

One of the causes for discomfort could lie in the humanlike appearance of some robots, which has been discussed in view of the so called Uncanny Valley effect (Zawieska & Sprońska, 2017). The Uncanny Valley effect argues that there is a relationship between the human-likeness of a robot and humans' emotional reactions towards robots. The original hypothesis by Mori (1970) suggests that humanoid objects which imperfectly resemble actual human beings cause feelings of revulsion. Children can show signs of negative emotions towards the robot tutor, such as fear. However, it is not yet clear how factors such as age, education of parents, or familiarity with a computer affect these negative emotions (Fridin et al., 2011). Researchers have questioned the consequences of a robot breaking down, noting that this aspect should be carefully analysed (Leite et al., 2014). Early results show young children of pre-school age expressing negative emotions such as fear when a robot tutor falls down (Fridin, 2014a). A lack of a robot's social behaviour can also affect how children perceive a robot tutor. Children seem to perceive a non-social robot as an observer, which led to tension as a result (Shimada et al., 2012). The distance between the child and the robot also seems to affect how the robot tutor is perceived. Some children who actively interacted with a the robot tutor, are reported to be frightened when a robot comes (too) close (Ko et al., 2010). Other studies indicated that the distance between the child and robot could affect female participants more than male participants (Mutlu et al., 2006). The inadequacy of several technologies could explain the distraction some children exhibited when interacting with the robot tutor (Lee et al., 2011).

Losing motivation. The current robot tutors seem unable to keep children motivated over a longer period of time (Pandey & Gelin, 2017; Prentzas, 2013; Zawieska & Duffy, 2015). In the early stages of implementation, robot tutors are assumed to have a positive effect on motivation and engagement (Prentzas, 2013; Zawieska & Sprońska, 2017). However, other studies report this is due to the novelty effect - the tendency for results to improve when a new technology is introduced, not because of the technology being a good learning facilitator, but because of the elevated interest in the new technology. Thus far, the extent to which a novelty effect influences the ability of tutor robots to keep students motivated is unclear (Leite et al., 2013; Prentzas, 2013; Zawieska & Duffy, 2015). Robot tutors are reported to have difficulty maintaining children's motivation and attention over a longer period of time, which could be explained by the novelty effect (Salter et al., 2004; Serholt & Barendregt, 2016). Some studies were even prematurely terminated because all children lost interest in the technology (e.g., Salter et al., 2004). A total of 15 studies reported on the loss of motivation (see Table 2.2). However, a recent longitudinal study into the nature of breakdowns in child-robot interaction shows that technical issues, rather than boredom with the educational activity, could be traced back to breakdowns in interaction (Serholt, 2018).

Technology is inadequate. It seems that before a robot can be effectively integrated in education and is able to motivate children over longer periods of time, major technical challenges need to be overcome (reported in 41 studies). These challenges include difficulties with maintaining engagement and interest, the (in)ability of the robot to create trustworthy relationships and an effective learner model to personalise and adapt to the needs of individual children (Pandey & Gelin, 2017). Some robot tutors are limited in their application because of their physical embodiment and limited capabilities regarding verbal and non-verbal communications (Park et al., 2011). Technical limitations were further reported about a robot getting stuck in a corner (Salter et al., 2004), its limitations regarding location and human recognition (Han et al., 2005), and unclear utterance (Shimada et al., 2012).

Hardware limitations such as the NAO robot not having five fingers, poses a challenge for the robot teaching sign language (Kose & Yorganci, 2011). Likewise, handwriting exercises pose challenges due to the lack of fine motor capabilities, and the noise the robot makes when moving (Hood et al., 2015; Warren et al., 2015). The stability of the robot when touched by children is also a reported issue (Alemi et al., 2015).

Compared to a human teacher, the current robot tutors are limited in their ability to provide explanations and instructions. Some studies reported this as a reason why some children prefer a human teacher over a robot tutor (Kanda et al., 2012). Voice recognition is another technical challenge (Young et al., 2010). Teachers are reported to be concerned that the initial enthusiasm would disappear, leading to the loss of children's interest (Reich-Stiebert & Eyssel, 2016). Current technology seems inadequate to allow a spoken dialogue between a robot and a young learner, which challenges the effectivity of the robot tutor, as is the current state of visual sensing technologies (Belpaeme, Vogt, et al., 2018; S. Lee et al., 2011). Furthermore, the limited ability to display socially acceptable behaviour prevents robot tutors to engage in a natural interaction with children (Castellano, Pereira, et al., 2009). These limitations can not only undermine motivation and enjoyment, but also have an effect on the psychological well-being of children.

2.5.2 Benefit 2. Reduce anxiety

As stated above, robot tutors can cause discomfort, however, one of the reported goals of robot tutors is to reduce stress and anxiety of children in educational settings (Ghosh & Tanaka, 2011). This benefit is reported in 14 studies (see Table 2.2). The reduction of anxiety of making mistakes by practicing with a robot tutor is reported to be an important prospect (Alemi et al., 2015; Alemi et al., 2014b; S. Lee et al., 2010). Children report about the robot tutor to make them feel relaxed and less pressured in comparison to a human teacher, because human teachers "get tense, exert pressure and reduce enjoyment" (Kanda et al., 2012). European teachers speculate that children might be more comfortable expressing their uncertainties to a robot tutor than to a human teacher, due to the lack of fear of judgment (Serholt et al., 2017). Other teachers perceived the robot to be beneficial for reducing anxiety of low-achieving students (Chang et al., 2010). The robots' ability to reduce anxiety can be especially helpful for children who just started learning a topic (Wang et al., 2013). Social robots are also reported to increase children's confidence when learning a certain topic, such as English as a second language (Lee et al., 2011).

Taiwanese children who interacted with a social robot in a group-learning setting are also reported to feel more comfortable and relaxed with a robot present, as the robot prompted friendship with other group members, and children said it was patient and unintimidating (Young et al., 2010). Italian children seemed to humanise robot tutors, for example, by ascribing capabilities typically reserved for humans, such as emotions and behaviours (Nalin et al., 2011). They also reported on the perception that the robot could comfort them when they were sad or worried. The robot might also help the pupils to overcome their anxiety by encouraging them, or by other means that create a positive learning atmosphere, thus reducing the fear of judgment by fellow students (Shih et al., 2007). Children also reported they liked the robot because it would not punish them for misbehaving (Kwok, 2015).

Another important asset of robot tutors reported in the reviewed literature is their potential to reduce anxiety and distress in special education, such as for children with ASD (Aresti-Bartolome & Garcia-Zapirain, 2014; Boucenna et al., 2014; Prentzas, 2013). Preliminary results suggest that children with ASD may demonstrate enhanced initial performance in response to a robot tutor, compared to that of a human teacher (Warren et al., 2015).

2.5.3 Benefit 3. New Opportunities for Education

The robot tutor can provide access to resources and opportunities which were unavailable prior to its introduction, a total of 60 studies report on this potential benefit (see Table 2.2). Of these possible new opportunities, we have outlined the following: (a) new social interactions, (b) the robot taking on different roles within a school environment, and (c) beyond the classroom learning. There are multiple categories of potential harms that could undermine this benefits, which are: social implications (reported in 14 studies), loss of human contact (reported in 9 studies), privacy and security (reported in 8 studies) and control and accountability issues (reported in 6 studies).

New Social Interactions. By introducing a robot tutor, a reciprocity and closeness between child and robot comes into being (Chandra et al., 2015).

Therefore, by introducing a robot tutor in the classroom, it is not only a new technology being introduced, but also a new kind of relationship is created. The robot tutor could thereby challenge the social interactions in the learning process, and even the entire social networks of education (Zawieska & Sprońska, 2017). Social supportive behaviours of a robot tutor could have a positive effect on the learning performance of children (Saerbeck et al., 2010). It is reported that learning could be more effective through social interaction with a robot tutor, compared to a robot tutor built just for knowledge transfer (Pandey & Gelin, 2017).

For social interaction, a robot needs five behavioural dimensions: a specific role, nonverbal feedback, attention building, empathy, and communicativeness (Pandey & Gelin, 2017). This social interaction could lead to long-term relationships between the robot and child, potentially leading to a positive effect on learning outcomes (Reidsma et al., 2016). Robots with social features are perceived as more supportive and more helpful by children (Werfel, 2013), and can exceed the effectiveness of computer-based tutoring systems (Belpaeme, Baxter, de Greeff, et al., 2013). However, this effect is also contradicted by another study, where a robot tutor displaying no social behaviour lead to greater learning gains for children compared to a robot that did display social behaviour (Kennedy et al., 2015b).

The relationship between robot and child seems to enhance with a robot tutor praising and cheering up the children (Han, 2010). Children can feel supported by a robot tutor in a similar extent to what they would feel when being supported by their fellow students (Leite et al., 2014). Children are even willing to share a secret with a robot tutor (Davison et al., 2016). Children also seemed to talk naturally to a robot tutor, even if the robot is not responding to questions (Ros et al., 2014), and the social capabilities of a robot tutor seemed to have a positive effect on this verbalisation compared to other learning appliances such as a tablet (Wijnen et al., 2015). The social capabilities could also have a positive effect on children with ASD. For these children, the robot could act as a social mediator, encouraging the child to interact with a human (Boucenna et al., 2014). Furthermore, it creates new opportunities for children with ASD, such as playing the role of a helper or teacher (Bertel & Rasmussen, 2013).

The robot taking on different roles within a school environment. Robots can have multiple social roles in an educational setting, such as that of a tutor, a peer, or a servant. The robot can also take on roles that neither an adult nor peers could perform, such as that of a naïve learner (Hood et al., 2015), enabling the child to take on the social role of a teacher, which leads to boosting the child's self-confidence on a topic (Ghosh & Tanaka, 2011).

When comparing two possible roles, peer versus teacher, children interacting with the peer robot paid more attention to the robot and the task, and performed better than those interacting with the teacher robot (Zaga et al., 2015). However, a robot that's able to switch roles, in contrast to only having a static role, is shown to be a better motivator for teaching good habits than a static robot or a virtual one (Ros et al., 2016).

Children and teachers also expressed other potential roles for robots in education, such as the role of a friend (Meiirbekov et al., 2016). The social roles considered for a robot could be established by the robot having a physical embodiment as indicated by multiple studies. For example, children perceived the robot as a social, likeable agent or companion (Baxter et al., 2013; Breazeal et al., 2016; Brown et al., 2013; Davison et al., 2016; Han et al., 2009; Liles & Beer, 2015). Likewise, children are reported on that they would like the robot for personal relationships (Han & Kim, 2009). However, the perceptions of children on what role a robot tutor should have are diverse, such as: a servant or a friend (Y.-C. Lin et al., 2009), a companion for lonely children (Liu, 2010), a private tutor, or even as a possible rival (Shin & Kim, 2007). In a Swedish study, children seemed positive about using robot tutors in education, but not when the robots are granted the freedom to grade their work (Serholt & Barendregt, 2014). It is also important to note that children's perceptions of the robot tutor's role is reported to change over time (Alves-Oliveira et al., 2016). For example, after four sessions with a social robot, more children perceived the robot as a classmate and less children perceived the robots as a tutor, compared to the first session (Alves-Oliveira et al., 2016). Just as the perceptions of children, the perceptions of teachers and parents on what social role a robot tutor should have, are diverse. Spanish parents for example seemed to accept educational robots as mechanical tools, whereas Korean and Japanese parents have been reported to see robots as a potential friend for their children (Choi et al., 2008). However, there are several potential harms related to these new opportunities, related to social implication, control and accountability issues, and loss of human contact.

Social implications. These new social roles introduce social implications, such as the robots' effect on the concept of trust, friendship and respect are reported in multiple studies (n = 14). However, mainly conceptual studies (n = 8) posited concerns regarding the effect of the assumed "social" relationship that comes into play by the interaction between robot and child (Johnson & Lester, 2016; Kennedy et al., 2015a; Leite et al., 2013; Pandey & Gelin, 2017; Richards & Calvert, 2017; Salvini et al., 2016; Sharkey, 2016; Zawieska & Sprońska, 2017). On the one hand, the social bond between robot and child is considered to enhance the long-term relationship, but on the other hand, concerns are expressed that children might form social bonds with the robot tutor, because they share a similar physical space and both express social capabilities (Leite et al., 2013).

The relationship between child and robot coins new questions such as: how learners will perceive the robot tutor regarding concepts of trust and respect (Johnson & Lester, 2016; Sharkey, 2016). Furthermore, according to some scholars, the fundamentals of friendship and relationships are taking on a new meaning with the social bond created by a tutor robot (Richards & Calvert, 2017). The humanlike appearance of robots, combined with technologies such as AI, could lead to the dissolvement of the boundaries between 'artificial others' and real people (Johnson & Lester, 2016). Related possible negative social implications of the robot tutor are expressed by teachers from multiple European countries (Kennedy, Lemaignan, et al., 2016; Reich-Stiebert & Eyssel, 2016; Serholt et al., 2017). Teachers fear that children will become more socially isolated as a result of bonding with a tutor robot (Kennedy, Lemaignan, et al., 2016), or that the robot will have a dehumanising effect on children (Serholt et al., 2017). Harmful social implications are also discussed as the robot could become a bully, or the robot becoming subject to bullying (Diep et al., 2015).

The relationship between robot and child could potentially lead to the children expecting too much from the robot. Children might imagine that the robot really cares about them, which might lead to children feeling anxious when the robot is absent (Sharkey, 2016). Children having high expectations of robots, could also sort negative effects when a robot does not perform up to their standards. The expectations may go as far as Korean children being favourable of the idea that robots take over the role of the teacher completely (Shin & Kim, 2007). Results based on Swedish children, however, show very negative attitudes towards the robot replacing the human teacher (Serholt & Barendregt, 2014).

The relationship between children and robots also brings forth ethical implications regarding deception. For example, should children be made aware that the robot's concern is artificial and therefore insincere? (Leite et al., 2014). This relationship could lead to children feeling deceived or unfairly treated, possibly further resulting in aggressive behaviour (Reich-Stiebert & Eyssel, 2016; Serholt et al., 2017). Similar concerns that are expressed, such as the children believing the robot's social support is sincere, need to be carefully analysed before robots are implemented in our daily lives (Leite, Castellano, et al., 2012).

Control and accountability issues. Several studies report on accountability concerns when robot tutors are introduced in an educational context (e.g., Pandey & Gelin, 2017; Salvini et al., 2016; Sharkey, 2016). One of the issues raised is "to what extent is the robot's manufacturer responsible for unwanted consequences?" (Walker & Ogan, 2016). This question becomes more relevant as robot tutors could have stronger negative consequences compared to current educational technology, because of the social bond between robot and child. More practical issues related to control and accountability where, for example, 'who should be responsible for the robots behaviour and its maintenance?' (Walker & Ogan, 2016).

Loss of human contact. The loss of human contact is a concern reported in several studies (*n* = 9). A robot being capable to detect emotions and personalise a response, in combination with its humanlike appearance and anthropomorphic tendencies in humans, could lead children to become emotionally attached to the robot (Leite et al., 2013; Sharkey, 2016; Zawieska & Sprońska, 2017). This may result in children to prefer the companionship of such a robot over that of their human peers, which may risk the loss of human contact (Pandey & Gelin, 2017; Sharkey, 2016), or compromised social skills of children (Pandey & Gelin, 2017).

Beyond the classroom learning. Besides new opportunities related to the social interactions and roles, also practical opportunities were mentioned, such as beyond the classroom learning. Teachers were reported to be generally receptive towards robot tutors; their desire to use robot tutors was mainly influenced by their beliefs that the robot would enhance and facilitate the educational process (Fridin & Belokopytov, 2014a). One such opportunity is that the robot could connect educational experiences at school to that at home, which is valued highly by teachers and promotes beyond the classroom learning for children (Kory Westlund et al., 2016). The robot could collect data on children at home (Sharkey, 2016). Such data could provide new insights into the learning progress of children beyond what the teacher normally sees (Prentzas, 2013). Although this could lead to new privacy issues, which will be presented in the privacy section in more detail later.

2.5.4 Benefit 4. Personalised Learning.

One of the design goals for developing a robot tutor is the ability to adapt to individual children (Jones et al., 2015). This capability, to create a learning environment which is tailored to children's unique learning styles, motivations and needs, creates personalised learning (Miliband, 2004). Personalised learning with a robot tutor can be based on stored contextual features and on real-time interaction with the student, which is reported by Walker and Ogan (2016). A total of 46 studies described personalised learning as a potential benefit of robot tutors, of which multiple design studies (*n* = 14; see Table 2.2). However, there are multiple categories of potential harms that could undermine this benefit, which are: privacy and security (reported in 8 studies) and the technology being inadequate (reported in 41 studies). The potential benefit of personalised learning is summarised below in relation to the related harms reported.

The robot tutor may be able to provide tailored feedback to each individual child, ranging from personalised learning styles and learner levels, to adaptive responses based on cognitive and social development (Alemi et al., 2014a; Beer et al., 2017; Belpaeme et al., 2015; Brown et al., 2013; Fridin, 2014b; Gordon & Breazeal, 2015; Keren & Fridin, 2014; Ramachandran & Scassellati, 2015; Warren et al., 2015). Personalisation might enrich learning experiences of children both socially and cognitively (Y. Kim & Baylor, 2016).

Even with relatively straightforward personalisation, the performance of children can be increased, outperforming children who didn't get the personalised support (Leyzberg et al., 2014; Kory Westlund & Breazeal, 2015). Furthermore, an adaptive learning strategy can improve the help-seeking behaviour of children, which is indicated to impact learning outcomes (Ramachandran et al., 2016), and increase self-regulated learning behaviour (Jones & Castellano, 2018). To adapt to children's needs, the robot tutor needs to elicit measurable data about the child. The effect of this elicitation (regardless of the personalisation strategy) seems to further enhance the robot tutor being perceived as more interactive (Clabaugh, 2017).

The robots' ability to detect social cues might further enhance the personalised learning experience (Richards & Calvert, 2017). One personalisation strategy is to personalise the responses of the robot to the affective state of the learner, determined by an algorithm based on the robot's camera images and the head pose of the learner (Antonaras et al., 2017). Indicators of affective state are the identified gaze direction, body posture, and facial expressions (Schodde et al., 2017). The emotional effect, combined enactment levels, and learner's progress are considered important requirements of personalised learning (Papadopoulos et al., 2013). Empowering robots with empathic adaptive capabilities are perceived as more engaging and helpful, compared to a robot without empathic capabilities (Leite, Pereira, et al., 2012). Personalising the interaction and learning strategies combined with a robot tutor can also lead to higher self-confidence for preschool children and low confidence students (Jacq et al., 2016; Y. Kim et al., 2014).

In developing personalised learning, implementing Artificial Intelligence (AI) in a robot tutor plays an important role. Deep learning allows for the robot to learn from its own interaction with children, which could lead to the robot developing more personalised social behaviour, thus further improving the level of personalised learning (Gonzalez-Jimenez, 2018). Furthermore, the use of a personalised robot tutor might not be limited to one specific period in life. It could possibly accompany children throughout their lifetime, providing specific learning subjects when needed (Johnson & Lester, 2016). The idea of a personalised robot tutor could even go beyond purely academic welfare, and expand to a more general concern of children's well-being (Timms, 2016).

Privacy and Security. Privacy and security concerns are posited in several identified studies (n = 8). These concerns are raised by the robot tutors' ability to record the behaviour of children and move in the same physical space (Leite et al., 2013; Sharkey, 2016). Scholars coin questions such as: which data is stored?; how is the data used?; and who has access to it? (Sharkey, 2016). European teachers have expressed concerns on unauthorised or secondary use of children's data, such as by commercial organisations trying to seek new business opportunities (Serholt et al., 2017). In a study with a majority of Swedish children, they were reported to consider the storage of personal information unacceptable (Serholt & Barendregt, 2014). When, where, and who is allowed to access and monitor the sensitive data of the children are still unresolved issues. However, there are guidelines on which data should be shared with the parents as reported in a study on kindergarten assistive robots (Fridin & Yaakobi, 2011).

Safety concerns are raised by the robot sharing the physical space of a child. According to some, this is one of the most obvious risks related to robot tutors (Fridin & Yaakobi, 2011) because a robot can physically harm a child or damage the educational environment, in contrast to educational software (Sitte & Winzer, 2004). Teachers have expressed concerns about children's safety when they interact with a robot (Serholt et al., 2017). However, the risk of children hurting themselves disassembling the robot is relatively small, presuming the robot is built such that a child is not capable of disassembling it (Cook et al., 2010).

Technology is inadequate. The state of robot tutor technologies needed for adequate teaching was reported to be insufficient for real-life learning environments, that could go beyond the scripted experiments already being conducted (Chang et al., 2010; Kwok, 2015). Likewise, the current robot tutors are still inadequate for complex social tasks (Serholt, 2018; Shiomi et al., 2015). This possibly makes the robot tutor still less effective than a human teacher (Kennedy, Baxter, et al., 2016). At best, the current robot tutors seem just able to assist in simple and limited tasks.

Before a robot can be effectively integrated in education, major technical challenges need to be overcome. These challenges include the (in)ability of the robot to create trustworthy relationships and an effective learner model to personalise and adapt to the needs of individual children (Pandey & Gelin, 2017).

This, combined with the technical challenges reported in the earlier sections, illustrates the technological limitations for using social robots in education.

2.5.5 Benefit 5. Reduced administrative work

One of the key benefits of the robot tutor reported for teachers is the reduction of workload, which is mentioned by 19 studies in our review (see Table 2.2.). In total, 5 types of harms might negatively influence this benefit, which are: increase of workload (reported by 2 studies), the cost of the robot (reported by 15 studies), the technology being too complicated or low technology adoption (reported by 8 studies), the technology is inadequate, ineffective or wrong expectations (reported by 41 studies), and disruptive (reported by 8 studies).

Robot tutors have the potential to take over basic and possibly dull repetitive tasks of a teacher without getting tired or bored (Belpaeme et al., 2013; Mubin, Stevens, Shahid, Mahmud, & Dong, 2013; Alemi et al., 2014a; Chang et al., 2010). The robot could thereby free up time for the teacher to focus on social interaction with the children and to guide weaker students (Chang et al., 2010). Among the expectations of Japanese special school teachers were that the robot tutors can be used for individual, as well as simultaneous support for children (Sumioka et al., 2017). The robot also allows children to make several attempts to figure out the right answer, which is perceived useful by children and relieves workload for teachers (Wei et al., 2011).

Besides these learning activities, studies report on the robots' potential ability to support the teachers in simple administrative activities, such as attendance monitoring, getting attention, select presenters, or act as a timer (Han, 2010; Han et al., 2009; Lee & Lee, 2008). The robot tutor could support the teacher in multiple administrative activities (Pandey & Gelin, 2017; Tanaka & Kimura, 2010; Timms, 2016), such as building e-portfolios and record data during assessments (Pandey & Gelin, 2017). According to European teachers, the role of the robot should mainly be focused on reducing their workload, for example by monitoring children's progress or acting as a teaching assistant (Reich-Stiebert & Eyssel, 2015; Serholt, Barendregt, et al., 2014).

Cost of the robot. The cost of the robot is a concern expressed in 13 studies. Current robot tutors are expensive teaching tools (Pandey & Gelin, 2017; Werfel, 2013). The high costs are considered an obstacle according to the general public and teachers (Kennedy, Lemaignan et al., 2016; Reich-Stiebert & Eyssel, 2016), which is a barrier for implementing robot tutors (Han et al., 2005). The costs cause additional stress to some teachers, because they fear the children might break the robot tutor (Hyun & Yoon, 2009).

Practitioners of children with developmental disabilities also report on the current technology being limited and expensive (Conti et al., 2017). The cost-performance trade-off creates the dilemma between expensive but robust robots or cheaper but less robust robots; making cost the limiting factor for creating robots for educational purposes with children as the end-users (Cook et al., 2010).

Technology too complicated and low technology adoption. The technology being too complicated to users, and therefore low adoption of the robot is reported by several studies in this review ($n = 8$). They report on the fear of teachers that the technology is too complicated or inflexible, thereby increasing their workload (Ahmad et al., 2016; Kennedy, Lemaignan, et al., 2016; Reich-Stiebert & Eyssel, 2016). Likewise, studies report on concerns regarding the low adoption of robots in education (Pandey & Gelin, 2017). A Canadian study, focused on special education, reported that teachers mainly see robots as mechanical tools to help with repetitive tasks, thereby revealing a deep scepticism towards social robots being used in special education (Diep et al., 2015).

Disruption. Another concern reported by 8 studies, is disruption. The robot is reported to have a potential disruptive effect on the educational process, thereby negatively affecting the teacher, as reported by educational professionals (Kennedy, Lemaignan et al., 2016). Another possibly disruptive effect is that children could pay more attention to the robot than to the actual task (Kennedy et al., 2015b). There are also reports of teachers being ignored by children after being taught by a robot tutor, because the children preferred the robot tutor over a human teacher (Han et al., 2009). It could also disrupt the educational process due to unfair access to the technology (Reich-Stiebert & Eyssel, 2016; Serholt, Barendregt, et al., 2014). Furthermore, children were observed to express bullying behaviour when interacting with the robot tutor, such as blocking its path and putting a cap on its head, which could also disrupt the educational process (Kanda et al., 2012).

Inadequate technology and the increase of workload. A main concern posited, concerning teachers, is the current robot technology being inadequate ($n = 41$). This could, in the end, result in extra workload for teachers, as reported by two of the identified studies. Other possible harms expressed in the papers are the extra workload regarding the maintenance of the robot (Huijnen, Lexis, Jansens, et al., 2016).

The state of robot tutor technologies needed for adequate teaching was reported to be insufficient for real-life learning environments, that could go beyond the scripted experiments already being conducted (Chang et al., 2010; Kwok, 2015).

Likewise, the current robot tutors are still inadequate for complex social tasks (Serholt, 2018; Shiomi et al., 2015). This possibly makes the robot tutor still less effective than a human teacher (Kennedy, Baxter, et al., 2016).

2.6 DISCUSSION AND CONCLUSION

The goal of this systematic literature review was to identify and categorise potential harms and benefits reported in the thus far published literature for robot tutors in education. Some studies tended to mainly focus on the negative sides whereas other studies tended to emphasise the potential benefits of robots in education. Furthermore, potential harms and benefits of robot tutors were reported from quite different angles, as some studies reported the effects of experiments, whereas others reported observations of design studies or philosophical reflections. Through our systematic review, we aimed to balance the various views and perspectives and thereby, establish a first step towards the creation of guidelines for future implementation of robot tutors. In our study, we followed the steps of the Value Sensitive Design approach and described the identified harms and benefits in perspective of the stakeholders affected.

The studies reviewed in this systematic literature review revealed that the harms and benefits were primarily reported for children and teachers as stakeholders, who are directly affected if robots are implemented in education. However, they are not the only stakeholders in this domain. Other relevant stakeholders are parents, educational policymakers, and organisations offering educational robots, but these are currently overlooked in the literature reviewed. It is important that their perspective is also included when designing and implementing robot tutors since they will be (in)directly affected by this new technology.

Robot tutors in the reviewed studies were used for teaching children multiple topics (see Table S1; online). The learning topics discussed in the identified studies were broad, ranging from handwriting (Hood et al., 2015; Salvini et al., 2016), first and second language acquisition (Alemi et al., 2015; Chang et al., 2010; Eimler et al., 2010; Gordon et al., 2015; Kwok, 2015; Shih et al., 2007; Wang et al., 2013), sign language (Kose & Yorganci, 2011; Uluer et al., 2015), improving imitation-specific tasks for children with autism spectrum disorder (ASD) (Aresti-Bartolome & Garcia-Zapirain, 2014), dance (Ros et al., 2014; Ros & Demiris, 2013), to building a LEGO house with the assistance of a robot tutor (Serholt, Basedow, et al., 2014). Please note that our review did not evaluate the effectiveness of the robot tutor for these specific learning topics, but focused on (potential) harms and benefits that would come with implementing robot tutors in education, according to the reviewed studies.

Through our literature review, we identified five types of benefits (e.g., positive effects, opportunities) and eleven types of harms (e.g., concerns, disadvantages, downsides, drawbacks and risks) related to teachers and children. Although some types were small in the number of studies reported, they all pose a negative influence on the benefits reported. Our results show that the current state of technology has the potential to undermine more benefits compared to other types of harms (see Figure 2.2.). Also, the technology being inadequate is the type of harm that is reported most (n = 41; 16% of the identified studies). Given that the state of technology is the most reported harm and also has the potential to influence the most benefits negatively, we consider this one of the main practical concerns related to tutor robots.

Because the technological limitations have a strong influence on the potential impact of social robots in education, it is important to consider scenarios in which the technical abilities are improved when discussing our results. Technological improvements could not only result in the potential benefits being realised, technological improvements could also solve seven out of the eleven identified harms. For example, the loss of motivation could be prevented by robots that are more technologically advanced, improvements in robot design and interaction could prevent children from feeling discomfort, and robots that are easy to use and useful for teachers can prevent the increase of workload. The same argument seems to apply for the cost of the robot, the technology being too complicated, inadequate, and disruptive. In a scenario where the technical abilities of social robots are improved, four key issues would remain (1) privacy and security, (2) control and accountability (3) social implications, and (4) loss of human contact.

2.6.1 Privacy and Security

Due to the robot's abilities to collect and store personal data, the privacy and security of both children and teachers are impacted. Open issues are which data is stored, how the data is used and who has access to the data. In discussing these questions, we look at current privacy legislation such as the Global Data Protection Regulation (GDPR), which is the regulation in European Union law related to the processing of personal data and privacy. *Personal data*, broadly speaking, is all information that can be used directly or indirectly to identify a person (EU GDPR Art. 4 (1), such as name, location data, and camera images. Just as personal data, *processing* has a broad definition, which almost entails all actions which are performed on personal data, such as collection recording and storage (EU GDPR Art. 4 (2). The robots' ability to process personal data makes the GDPR relevant.

Data minimisation is one of the key principles related to the processing of personal data under the GDPR (Art. 5 (1) lit c), it dictates that the processed personal data should be adequate, relevant and limited to what is necessary in relation to the purposes for which they are processed. Taking this into account, a robot should only process the minimal amount of personal data needed for a predefined goal. If a robot were to help build e-portfolios of children, it might only be necessary to store whether a child provided right or wrong answers, instead of the camera images and voice recordings. And this data should be used only for *"specified, explicit and legitimate purposes and not further processed in a manner that is incompatible with those purposes"* (EU GDPR Art. 5 (1) lit b). Taking this into account, schools should be explicit about the purpose of the robot tutors they are going to apply and limit the data collection to the bare minimum required.

The GDPR also provides guidance for who should have access to the personal data of children processed by the robot. For children below the age of 16, the processing is lawful *"only if and to the extent that consent is given or authorised by the holder of parental responsibility over the child"* (EU GDPR Art. 8 (1). This does not only apply for consent, but also to the parents' access to the data in children's e-portfolios. However, the EU member states may lower the age, although not below 13 years, which has been done by many European countries (Livingstone, 2020). From that point on, children also have the right to access their data.

As the GDPR has provided guidance to which data is stored, how the data is used and who has access to it, practical and technical implications are still left open. For example, how can a robot be designed to personalise its learning experience to specific children with a minimal amount of personal data? As studies in our review show, even with relatively straightforward personalisation, the performance of children can be increased. Whether the collection of detailed personal data for a more personalised learning experience justifies the privacy risks involved therefore requires attention in future research. Furthermore, as robots are also reported to be possibly used at home, they might also impact the privacy of other residents, such as family members. The perspectives of these stakeholders have not yet been taken into account in the extant literature.

The GDPR also provides manners to ensure the appropriate security for personal data, and who should be accountable. It states that an organisation (e.g., the school) is responsible to implement appropriate technical and organisational measures to ensure a level of security appropriate to the risk (EU GDPR Art. 32 (1).

2.6.2 Control and accountability

Related to the more practical issues of the control and maintenance of the robots, one might argue that this does not differ from other innovative educational technologies, such as virtual reality, laptops and online applications, where teachers and IT-support personnel are often in control of the technology and responsible for its maintenance. However, because the robot can also act autonomously, if powered by AI, it can also impact the autonomy of the teacher to shape the lessons based on his or her own experience.

In discussing the effect of an autonomous (AI) robot tutor on control and accountability, we draw insights from a field that has already studied the effect of autonomous machines in detail, the field of self-driving cars. There are six levels of driving automation, from no driving automation to full driving automation (On-Road Automated Driving (ORAD) committee, 2018). In the first three levels (levels 0,1 and 2) the car provides warnings sights, such as blind-spot warnings, lane centering and adaptive cruise control. In these levels, the car is driven by a human, even when the automated features are engaged, and the driver must constantly supervise the support features. In level 3 and 4, the car can drive by itself, however, under limited conditions and the car will not operate unless all required conditions are met, such as a traffic jam chauffeur feature. In the last level (5), the car can drive fully autonomous under all conditions (On-Road Automated Driving (ORAD) committee, 2018).

Looking at these autonomy levels of self-driving cars, the current robot tutors seem to be at the level of 2 or 3, with limited abilities for autonomy and only usable under specific conditions. The impact on the control and accountability in these cases remains limited as the teacher would still be in control, or directly supervising the robot. Level 5 robots with full *teaching* automation, would fully impact control and accountability. At this level, a robot would fully autonomously teach children and make decisions on teaching strategies. In these cases, the responsibility for learning may shift and also include the robotic industry, as they are the producers of these autonomous robots. How far their responsibility would go, and to what extent this is desirable or responsible should be discussed in future research.

2.6.3 Social implications and Loss of human contact

The studies in our review have shown that children can form (social) bonds with a robot. However, the negative effect on concepts such as friendship, trust, respect, and deception are mostly reported in conceptual, non-empirical studies. When considering the impact of other IT-technologies used by children, such as (social media) apps and mobile phones, robot tutors could likewise impact children's interaction with others. Children might become too attached to a robot tutor, just as young people can show symptoms of behavioural addiction related to their mobile phones as reported by Walsh et al. (2008). This may result in children who prefer the interaction of a robot over that of their human peers, which may risk the loss of human contact. However, empirical research on attachment or children building relationships with social robots and its possible negative impact on children's relations with others is not found in our review.

To prevent children from feeling deceived by a robot, special attention can be given during the introduction of a robot tutor, explaining to children that a robot is a tool, not a human. When a robot is going to process data, it might also be desirable that it explains what data the robot is storing, and how the data is going to be used. This could prevent children from feeling deceived or unfairly treated.

In general, no study in our review reported on considering replacing teachers with robots a good idea. Studies in this review reported on robots for educational purposes as an aid to the teacher, relieving workload and assisting in teaching tasks, but not as a substitute of the human teacher in a broader sense. With such a robotic assistant, teachers would be able to devote more time to *real* human contact, focused on the individual child, rather than repetitive and administrative tasks. In such a scenario children would also still see their human teachers, classmates and friends at school, as the robot is often placed in the same space as the existing class or school building. Therefore, as long as a robot is not considered a substitute for the human teacher in a broader sense, the effect on the possible loss of human contact seems limited.

The balanced overview of harms and benefits provided above can be used as a basis for developing moral guidelines to implement social robots in the educational system. From the systematic review, it appears that a large proportion of the potential harms are related to current technical limitations in the (autonomous) functioning of robots. Four potential harmful considerations will remain, however, if robotic technology moves forward, as discussed in the above. However, in this overview, the impact and considerations of other stakeholders, such as the robotic industry and parents, are not yet included. Even though the harms and benefits related to teachers and children as primary stakeholders may be considered primary for developing moral guidelines, we argue that these views are also needed as a wider base to identify the moral values in the broader context. Therefore, future research should complement the current systematic review with information derived from other relevant stakeholders such as the robot industry, parents, and educational policymakers, for example, through interviews or focus groups. Including these stakeholders is crucial because they can provide real-life context, which is important in bridging the gap between ethics research and practice (Stahl & Coeckelbergh, 2016).

In conclusion, whereas the review revealed that four key issues remain of most importance for the stakeholders teachers and children when future robot tutors have become more technologically advanced and solve many of the currently reported potential harms, this might vary for different stakeholder groups. These four key issues (i.e., privacy and security; control and accountability; social implications; loss of human contact) may potentially undermine the large variety of benefits that are reported in the reviewed studies. In all, each of these potential harms and benefits may implicate moral values and should underlie the development of moral guidelines for robot tutors. In doing so, it is important to make a comparison between the perspectives of various relevant stakeholders in future research. From there, we can start drawing up guidelines for the implementation of robots in education. Such guidelines will be helpful in responsibly implementing robot tutors in educational practices to relieve current pressures in education.

CHAPTER 3

MORAL CONSIDERATIONS ON SOCIAL ROBOTS IN EDUCATION: A MULTI-STAKEHOLDER PERSPECTIVE

This chapter is published as: Smakman, M.H.J., Vogt, P.A., & Konijn, E.A. (2021). Moral considerations on social robots in education: A multi-stakeholder perspective. *Computers & Education*, 174, 104317.

Abstract. Social robots are a promising new technology for primary education. However, they also introduce practical and moral challenges and there is an increasing demand for guidelines for a responsible, safe introduction of social robots. In this study, we identified and compared the moral considerations associated with the introduction of social robots in primary education from the viewpoint of direct and indirect stakeholders by conducting focus group sessions (*N* = 118). In total, we identified and compared stakeholder considerations related to 17 moral values. Overall, each of the stakeholder groups considered social robots a potentially valuable tool for education. Many similarities and only few conflicting views across the various stakeholder groups were found. Particularly among the teachers, parents, and policymakers, there were many similarities on the issues reported and their considerations were often aligned. These insights into the moral considerations of the various stakeholders involved, provide a solid base to develop guidelines for implementing social robots in education as requested by scholars and society.

3.1 INTRODUCTION

Social robots are a new type of robots that are increasingly studied in the educational domain. Compared to other types of robots currently used in education, social robots are less used for learning programming skills or how to build a robot, but rather to serve as a tutor or peer that helps children during their learning process. For children, social robots showed to improve cognitive (e.g., knowledge, comprehension, application, analysis, synthesis and evaluation) as well as affective outcomes (e.g., the learner being attentive, receptive, responsive, reflective, or inquisitive) (Belpaeme, Kennedy, et al., 2018). Other benefits for children include greater enjoyment in learning (Alemi et al., 2017; Jones et al., 2014), more personalised learning (Johnson & Lester, 2016) and beyond the classroom learning (Kory Westlund et al., 2016). Social robots also introduce potential benefits for teachers, such as improved job satisfaction (Shih et al., 2007) and reduced administrative workload (Han, 2010; Han et al., 2009; E. Lee & Lee, 2008). However, although social robots hold potential for education, they also introduce new moral challenges.

Especially in European studies, the urgent need for moral considerations and guidelines for social robots in education is voiced (Belpaeme, Kennedy, et al., 2018; Pandey & Gelin, 2017; Serholt et al., 2017; Sharkey, 2016; Tolksdorf et al., 2020). The call for more explicit attention for the impact of technology is also reported by a recent systematic literature review on ethics in Child-Computer Interaction research, which concluded that design ethics (which focuses on the impact of technology) is underdeveloped in this field and should be addressed more explicitly (Mechelen et al., 2020). Without the proper guidelines for building and implementing social robots, the moral values upheld in education are at risk of being undermined.

Social robots are studied to assist teaching tasks for different subjects, such as teaching first and second language (Alemi et al., 2015; Chang et al., 2010; Eimler et al., 2010; Gordon et al., 2015; Kwok, 2015; Shih et al., 2007; Wang et al., 2013), teaching the times tables (Konijn & Hoorn, 2020) and sign language (Kose & Yorganci, 2011; Uluer et al., 2015). Broadly speaking, social robots have three key elements, being: physical embodiment, the robot following social norms, and having some form of autonomy (Bartneck & Forlizzi, 2004). The benefits of social robots can be traced back to these elements and set social robots apart from other types of learning technologies, subsequently creating new moral issues.

The physical embodiment of the robot makes them directly present in the same physical space as the pupil. This physical and visual presence is linked to enhanced motivation levels of learners (Belpaeme et al., 2015; Y. Kim &

Baylor, 2016). Compared to having no physical embodiment, such as in the virtual presence on a tablet, robots with physical embodiment have shown to result in greater enjoyment. Furthermore, children perceive embodied robots as friendlier, and they are also reported to accept the robot as an authority (Fridin & Belokopytov, 2014b). The physical embodiment also creates opportunities for learning where physical presence is preferred, such as with handwriting (Hood et al., 2015; Salvini et al., 2016), sign language (Kose & Yorganci, 2011; Uluer et al., 2015), and dance (Ros et al., 2014; Ros & Demiris, 2013). However, the robot sharing the same physical space as a pupil also poses safety related issues. In contrast to, for example a virtual avatar, a robot can physically harm a child or physically damage the educational environment (Sitte & Winzer, 2004). Teachers specifically raised concerns about pupil's safety when they interact with a physical robot (Serholt et al., 2017).

By following social norms the robot can take on roles such as that of a tutor, a peer, or that of a naïve learner (Hood et al., 2015). These new roles can boost a child's self-confidence on a topic (Ghosh & Tanaka, 2011), relieve loneliness (Liu, 2010) and enhance learning performance (Zaga et al., 2015). However, studies show that the stakeholder perceptions on what role a robot should have are inconsistent. Children for example report on the robot being a potential servant or a friend (Lin et al., 2009), a private tutor, or even a possible rival (Shin & Kim, 2007). Similarly, parents are reported to consider robots as a potential friend for their children, while others would accept educational robots primarily as mechanical tools (Choi et al., 2008; Richards & Calvert, 2017). The robot's ability to following social norms and to take on new roles has raised questions related to the effect on children's trust (Johnson & Lester, 2016; Sharkey, 2016) and the meaning of friendship (Richards & Calvert, 2017). Children might become socially isolated as a result of a child bonding with a robot and preferring a robot over their human peers (Kennedy, Lemaignan, et al., 2016), which could have a dehumanising effect on children (Serholt et al., 2017).

The ability of a robot to react (autonomously) to its environment based on sensors such as cameras and microphones, allows the robot to tailor its interaction to children's individual needs, which is a cutting-edge form of personalised learning (Miliband, 2004). Even with a limited form of personalisation by a robot, the performance of pupils can be increased, outperforming children who didn't get personalised support (Leyzberg et al., 2014; Kory Westlund & Breazeal, 2015). However, the robots' ability to record the behaviour of children and move in the same physical space raises privacy issues (Leite et al., 2013; Sharkey, 2016). European children have been recorded to regard the storage of personal information unacceptable (Serholt & Barendregt, 2014). Although European teachers also considered privacy an issue, they mention that the privacy of children in schools is already compromised by the storage of sensitive personal information of children in educational technologies. However, these teachers considered the storage of detailed data of affective signals more intrusive compared to current technologies (Serholt et al., 2017).

As social robots and their associated benefits are being introduced in education, it is important to take into account the effect these robots might have on different stakeholder groups and what they perceive as valuable because their perceptions may differ and conflict (Ligtvoet et al., 2015). However, the existing scientific literature has focused mainly on the potential effects of social robots on children and teachers, overlooking many other stakeholders involved in implementing robots in education, such as parents, policymakers and the robot industry (Smakman & Konijn, 2020). Thus, not only do social robots pose a risk to undermine the moral values related to teachers and children, but they may also impact the other stakeholders.

This study firstly aimed at identifying and comparing the moral considerations associated with the introduction of social robots in primary education from the viewpoint of the missing perspectives. Secondly, we aimed at validating and expanding the knowledge on the already reported values of teachers and children from the extant literature. To this end, we conducted focus group sessions with children, teachers, parents, the robotic industry, and governmental policymakers/advisors.

In the following, we elaborate on our methodological approach to identify the moral considerations, following the Value Sensitive Design (VSD) methodology, which is used to account for values when designing and implementing technology (Flanagan et al., 2008; Friedman, 1997; Friedman et al., 2013; Friedman & Kahn, 2003). Then, we detail the participants of our focus group sessions and describe and compare their moral considerations, thereby providing the stepping stones for the moral guidelines needed for the responsible use of social robots in education.

3.2 MATERIAL AND METHODS

3.2.1 Values Sensitive Design

Our methodological approach to identify, examine, and compare the moral considerations of different stakeholders related to social robots in education is based on the Value Sensitive Design (VSD) methodology. This is a scientifically accepted methodology for the integration of values of stakeholders in the design and implementation of new technologies (Friedman et al., 2013). In this study, *value* is defined as "what a person or group of people consider important in life" (Friedman et al., 2013, p.86), which is a common definition in the ethics of technology.

VSD has already been applied in the context of new technologies and children, such as for parental software (Nouwen et al., 2015) and online apps (Badillo-Urquiola et al., 2020), but also in the field of social robots for healthcare (Van Wynsberghe, 2013). VSD provides a clear approach to systematically account for human values in the design of technology. This approach can be split into four phases: 1) value discovery, 2) value conceptualisation, 3) empirical value investigation, and 4) technical value investigation (Spiekermann, 2015). The results of the four phases are requirements for the responsible design and implementation of innovations in social contexts, such as social robots in education, which can be used for moral guidelines.

The first phase starts with identifying the stakeholders related to technological innovation in a certain context (such as social robots in education), secondly, the harms (e.g., downsides, concerns, negative effects) and benefits (e.g., opportunities, positive effects) related to the technology from a stakeholder perspective are identified and later linked to values. In the second phase, value conceptualisation, the values are broken down into norms and conflicting norms are analysed. The empirical value investigation and technical value investigation phase, then, prioritise the norms and values and create (design) requirements which can be used for taking into account the values of the different stakeholders when designing and implementing technology.

Our study completed the value discovery phase. As a starting point, we first evaluated and linked the harms and benefits related to robot tutors that were identified by a systematic literature review (Smakman & Konijn, 2021) onto values regarding new technology, design and robotics reported in earlier studies (Friedman & Kahn, 2003; Serholt et al., 2017; Sharkey, 2016; Van Den Hoven, 2014). In total these studies revealed thirty-seven values being potentially relevant. After evaluating the values in light of the harms and benefits identified by the systematic literature review we found fourteen values being relevant. These values served as a starting point for the focus group sessions presented in this paper.

3.2.2 Participants

Research in 'ethics by design' places emphasis on the importance of including different stakeholder groups early in the design and implementation phases of a new, novel technology such as social robots in education (Friedman et al., 2017). There are multiple methods for choosing which stakeholder groups to include (Winkler & Spiekermann, 2021). However, a commonly used and accepted strategy is to focus on the potential impact of a technology, rather than on the experience stakeholders have with a technology (Friedman et al., 2017; Miller et al., 2007). Based on the potential impact of social robots in education, we therefore selected teachers, parents, representatives of the robot industry, governmental policymakers, and children.

For qualitative research in ethics and technology, such as this focus group study, participants can be selected based on their role (Miller et al., 2007), for example, being a teacher or a parent. Therefore, via purposeful sampling, participants were selected based on their role. The criterion for participants to be included in our study was: being a primary school teacher, being a parent with one or more children in primary school, being an employee of a company building or selling (social) robots, being a governmental policymaker, or being a child in primary school. Participants were recruited through newsletters of robotic companies, messages on social media, snowballing (Ghaljaie et al., 2017), primary schools and direct e-mails. In total, 118 participants in the Netherlands agreed to participate in our study (see Table 3.1). The study was approved by the Institutional Ethical Review Board. All adult participants provided active, verbal consent; the parents of children participating in the focus group sessions provided informed consent for their children. The focus group sessions with children were conducted in common primary school classrooms with the children's teacher present, during a workshop on robots.

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Table 3.1. Overview of the focus group sessions.

Stakeholder group	*Teachers*	*Parents*	*Robot industry*	*Governmental policymakers*	*Children*
Focus group session (*N*)	3	2	3	3	3
Participants (*N*)	18	11	13	20	56
Male/ female	8/ 10	5/ 6	6/ 7	11/9	31/24*
Age range	26-59	33-49	22-75	19-62	9-12*
M-age	40.1	41.45	37	41	10.6*
SD	11.65	4.27	17.49	12.09	1.03

** One child did not record her/his gender and age*

The robot experience of participants differed from no prior experience with social robots to having multiple years of experience in applying robots in education for some. To familiarise participants with social robots in education, we used a video with a general explanation of different types of robots, their current capabilities and footage of children interacting with a NAO in autonomous mode in a classroom setting. Using video footage of social robots to familiarise participants with the phenomenon is commonly used in child-robot interaction studies (Ahmad et al., 2016; Rosanda & Istenič Starčič, 2019; Serholt et al., 2017), and even has benefits over using real robots as discussed by Belpaeme (2020). In addition, we provided a presentation and a live interaction between the participants and the robot in physical space. We adapted the live robot interaction with children to the classroom setting where the interaction took place, which resulted to slightly differ from the live robot interaction with adults. The steps to familiarise participants with the abilities of social robots are presented in more detail in the next sections.

3.2.3 Materials

In the current study, we examined the moral considerations of stakeholders by designing two-hour long focus group sessions. In total fifteen focus group sessions were held. Focus group sessions are group discussions aimed at exploring a specific set of issues (Kitzinger, 1994), such as people's views on social robots in education. These sessions consist of a small group of people - usually between four to six people each (Breen, 2006) - with similar demographic variables, in our case being a member of the same stakeholder group. We considered focus group sessions an appropriate method for the aim of this study because focus group sessions do not just look at the perceptions of stakeholders, but also look at why or how these perceptions are formed and may address controversial points of view. Thereby, focus groups can give a deeper insight into the reasons behind participants' attitudes, as opposed to what their attitudes are (Kitzinger, 1994).

Following the VSD-methodology (Friedman et al., 2008; Spiekermann, 2015; Van Den Hoven, 2014), our focus group sessions aimed at identifying the harms (e.g., downsides, concerns, negative effects) and benefits (e.g., opportunities, positive effects) of social robots for the stakeholders to gain insight into their considerations. To analyse the data collected during the focus group sessions (see below), all harms and benefits expressed by the participants were categorised under values that were previously identified (Smakman & Konijn, 2020), summarised in Table 3.2. We added an extra category, named miscellaneous, for the considerations that could not be (fully) categorised under a specific value.

Table 3.2. Values related to robot tutors based on their harms and benefits (Smakman & Konijn, 2020).

Values related to robot tutors	*Description*
1) Psychological welfare	This value concerns the robots' capability to influence psychological or social aspects (e.g., a robot acting as a person of trust, or one that comforts a child).
2) Happiness	This value concerns the robots' capability to provide pleasure/fun.
3) Efficiency	This value concerns the usefulness and versatility of the robot.
4) Freedom from bias	This value concerns the potential bias of the robot, such as gender or racial biases.
5) Usability	This value concerns to what extent the robot is accessible and usable for all users.
6) Deception	This value concerns the robots' ability to make children believe something that is not true, such as pretending that the robot cares about a child or keeping information from children
7) Trust	This value concerns the issue of children's trust in robots and whether this can be violated.
8) Friendship	This value concerns the friendship bond that can develop between a child and a robot, and whether this is acceptable.
9) Attachment	This value concerns the possibility that children will get attached to the robot, and whether this is desirable.
10) Human contact	This value concerns the robots' effect on human contact of children with friends, teachers and other humas.
11) Privacy	This value concerns the effect of the robots' ability to collect personal data on children, and if this data may be shared with others.
12) Security	This value concerns the IT security of the data that the robot collects via sensors.
13) Safety	This value concerns the physical safety of children when interacting with robots
14) Accountability	This value concerns the robots' effect on who is accountable for the actions of robots and their effects. Someone accountable is obliged to accept the consequences of something.

The procedure of focus group sessions with adult stakeholders. The focus group sessions with the adult stakeholders opened with a short presentation on the purpose and urgency of the study, followed by a short (five minutes) neutral video about the use and capabilities of social robots in primary education (available online at https://osf.io/xc5vt/). The video included a general explanation of different types of robots, their current capabilities and footage of children interacting with a NAO robot in autonomous mode in a classroom setting. By using this video, we intended to provide all participants with basic knowledge of social robots. The video was created to show a neutral view on social robots, not to influence the participants, but merely to stimulate them for the discussion.

The video was followed by a live demonstration of a NAO robot to get the participants more familiar with the topic and engaged for discussion. The physically present NAO robot performed a short calculation exercise and had a short question and answer session with the participants. During the demonstration, the NAO robot was partly teleoperated (Wizard of Oz style) by an assistant-facilitator. During the teleoperated parts of the interaction, the assistant-facilitator selected which applications or scripts the robot should run. It also enabled us to customise the introduction of the robot based on the participants. However, the calculation exercise was completely autonomous to allow participants to interact as if the robot was in a real-life classroom situation. The participants were made aware of which parts were teleoperated and which parts were autonomous interaction. By both showing footage of the NAO robot in real-life educational settings, and letting participants interact with the robots (both in autonomous mode and teleoperated), we created a narrative of the actual performance of social robots in conditions likely to be encountered in real-life classrooms.

After the demonstration, the facilitator first asked all participants to take their stakeholder perspective in mind and write down all the opportunities related to educational robots they could think of on different Post-its. These opportunities were then discussed and further elaborated on by the participants. After the opportunities were discussed, the facilitator asked the participants to do the same exercise but now for the specific stakeholder concerns.

When both exercises were finished, the discussion moved on to the final part of the session. This part consisted of a free debate wherein the participants had the opportunity to add anything that was not discussed and possibly introduce a new opportunity, issue or concern. This routine was applied for all the conducted focus group sessions with adults.

The procedure of focus group sessions with children. The focus group sessions with children were conducted in common classroom settings, with the children's teacher present. The children first got a short 10-minute presentation on robots in education, followed by a demonstration of a NAO-robot. The NAO-robot introduced itself, danced, and practised arithmetic with the children. Children were also encouraged to ask questions to the NAO-robot. The robot's introduction, dance and arithmetic exercises were all fully autonomous. However, given the current state of the technology, such as the limitations of the automatic speech recognition for children's speech (Kennedy et al., 2017), the free format questions and answering part of the interaction was teleoperated.

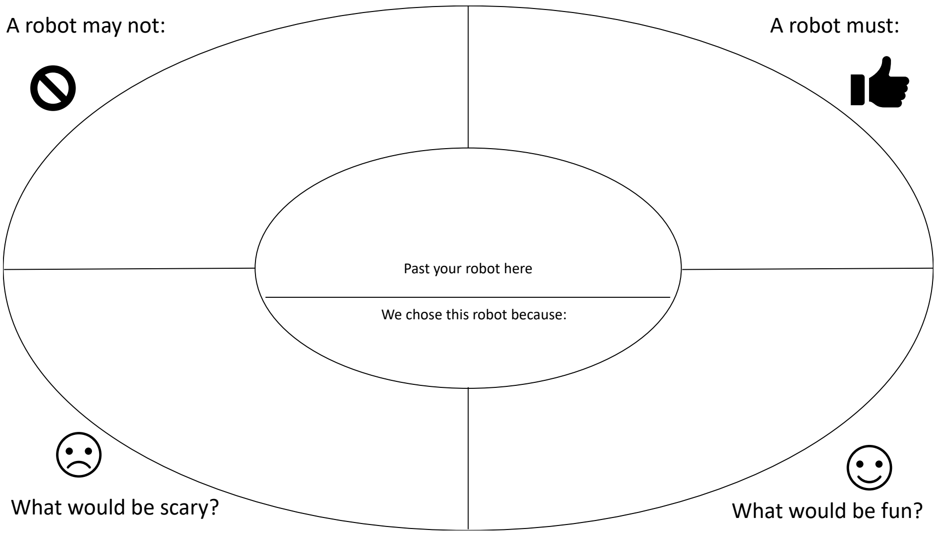

Figure. 3.1. Poster used in the sessions with children (Serholt & Barendregt, 2014).

After the general introduction, children were divided into small groups of 4-5 children. The groups were shown several pictures of social robots for education and were asked to pick one. Thereafter, following a procedure used by other researchers to elicit children's attitudes towards social robots (Serholt & Barendregt, 2014), we asked the children to write on a poster (see Figure 3.1). The poster consisted of five questions that helped to elicit what children see as opportunities and concerns for social robots in primary education.

3.2.4 Analysis

After the final focus group session, all audio recordings were transcribed and combined with the notes, Post-its, and posters taken from the sessions. All transcriptions were then analysed using an inductive and deductive coding process. To identify patterns within and across the data, we used a thematic analysis method (Braun & Clarke, 2006). Following the phases of thematic analysis (Braun & Clarke, 2006), we first familiarised ourselves with our data by reading all the transcripts. Second, we created initial codes based on all the opportunities and concerns expressed by the participants. Third, we randomly read samples of the data and created thematic codes. Fourth, we checked if the themes/issues identified worked in relation to the coded extracts of the second step. Fifth, we applied the codes onto new sample texts derived from our focus group transcriptions. Using this iterative process, we then created our final coding thematic scheme which we applied to all data collected, shown in Table 3.3 as 'issues'. Finally, we categorised the identified themes with the previously identified values (cf. Table 3.2). For the themes/issues that could not be (fully) categorised under a specific value, we added an extra category named "miscellaneous", which was later subdivided in newly identified values. Two additional, independent research assistants reviewed this process to reduce the chance of any possible bias and a coding scheme was constructed for further analysis.

3.3 RESULTS

In the following, we present the values related to social robots using the considerations voiced by the key stakeholders during the focus groups sessions. The similarities and differences of the stakeholders' considerations are thereafter presented in the Discussion section.

3.3.1 Psychological Welfare & Happiness

The value of psychological welfare refers to emotional states such as mental health, comfort and sense of peace (Friedman & Kahn, 2003). We clustered this value with the value "happiness" (enjoyment) because they are closely related, and the considerations of the participants often overlapped. In this section we will both report views related to the robots' impact on children, but also regarding their impact on other stakeholders, such as parents and teachers.

Impact on children. All stakeholder groups mentioned benefits for social robots that could increase the level of psychological welfare and happiness of children in and outside schools. The robot was considered to be fun and motivational for children by all stakeholder groups. As expressed by one of the teachers: "*If I would put [the robot] in my class…, well [the children] would really enjoy that. Really*!". And: "*robots are fun and motivational*" as stated by a policymaker. The excitement of children for the robot could spark new interests, such as for programming, according to the teachers. The children reported that the robot should be able to support, coach and motivate them to reach higher grades. Also, the robot having infinite patience and not being judgemental was considered to make children feel more at ease.

At school, the policymakers and teachers considered the robot a potential aid for children for learning to deal with social issues and stressful situations. Teachers mostly agreed that a robot without negative emotions and with patience could make children feel safe. However, teachers preferred that social skills should be taught by humans, not robots. Children reported being concerned about robots threatening people, which according to the children, they should not do.

Although all stakeholder groups voiced potential benefits related to psychological welfare and happiness, there were also potential harms mentioned related to these values. Some parents mentioned being worried about the potential negative long-term social implications. This concern seems to be related to the uncertainty of the potential impact on children, as one parent stated: *"I don't believe this should even be tested on children because we don't know what effect this will have on children, and that worries me greatly"*.

Teachers seemed more concerned with the technical ability of a robot to provide children with a good educational environment. They were worried a robot would not be able to adequately interpret answers given by children. Consequently, the robot would not be able to provide children with satisfactory feedback. Parents considered it important that the data recorded and used to provide advice to children, should still be interpreted by a human. Not only to accurately interpret the data, but parents also feared that teachers could become less involved/informed with their pupil's mental well-being, as expressed by a parent: *"the teacher would be less informed about a child's wellbeing and emotional level, because the robot only focusses on cognitive gains, and there's so much more to humans, skill-wise"*.

The robot could also result in children being demotivated, according to some teachers. The novelty effect was a concern for some participants, teachers feared that the robot would not be able to keep children motivated and enjoyed over extended periods. Some teachers mentioned that the robot should not replace them. However, the potential of a social robot replacing a teacher was quickly dismissed among the teachers after they concluded that the robot technology was nowhere near satisfactory enough.

Impact on parents and teachers. Parents stated a few ways robots could provide them, as a parent, a sense of peace. This sense of peace was related to the opportunity for the robot to help with homework exercises (also see section 3.3.2, subsection Beyond the classroom learning). Especially for parents who are not able to help their children with their homework, the knowledge that their child would get proper support from the robot would give these parents a sense of peace.

Parents indicated that a robot would save time spent by parents making sure homework was done properly, allowing them to spend their spare time differently with their children Also, parents indicated that the robot having infinite patience and not being judgemental to their children would make them feel more at ease. However, not all capabilities of the robot had a positive impact on the parents. The robot's ability to collect personal data of children worried some parents and would give them a feeling of unease. In section 3.3.8 on Privacy, the data collection by the robot will be further elaborated. Following the data collection, teachers voiced concerns on the potentially increased workload related to the analysis of the collected data. A teacher noted, *"I can imagine that if you are going to revisit all the footage the robot records on one day... times 30 children... [] who is going to check all of that [the data collected], and when?"*. This potential increase in workload, which could result in increased stress levels of teachers, and lower job satisfaction was a shared concern among teachers. Parents, however, considered the robot mainly beneficial for lowering the workload of teachers.

3.3.2 Applicability

We renamed the original category 'efficiency' to 'applicability', as the related harms and benefits seemed more related to the usefulness and to the quality of being relevant or appropriate than to being efficient.

Learning topics. Robots were considered to be potentially useful tools for teaching, supervising, taking exams, and motivating children. Policymakers specifically stated that robots could support children and teachers in achieving a higher level of digital literacy. However, teachers voiced concerns regarding the robot not being able to provide *"deeper levels of education"*. Deeper levels of education were referred to by the teachers as not only giving the answer to a question but to provide insight into how this answer was achieved. Children seemed to agree on this point, reporting that the robot should be able to *"explain things and listen to them"*. The majority of teachers argued that these deeper levels are one of the most important subjects in education. Teachers did consider the robot a great tool for learning programming.

Applicability of the data collection and usage. Teachers and parents discussed the possibility of a robot that would help to build e-portfolios of children by recording and analysing data, such as audio and video fragments of children and their test results. Using these data, the robot could adjust its teaching to children's specific needs, as mentioned by a policymaker: "*Robots can help pupils who need extra support with exercises, but robots can also help pupils who need more challenge individually*". The collected data were also considered to be valuable by the robotic companies and policymakers. Robotic companies mainly considered the data valuable for product improvement. However, they also voiced the opportunity to invent new products and services based on the collected data. Policymakers reported that the data could be used to monitor the performance of schools. Based on this data the government could adjust its policies, which was considered a potential benefit by the policymakers.

Parents argued that the collected data could generate a more accurate and sophisticated profile of their child's educational development. Some parents even going as far as stating that this would be a better method compared to the currently used heavily weighing exams at the end of primary school. The robot was also considered to potentially be able to provide advice regarding a child's future education, an idea which some parents were open to. However, parents considered it important that the data should still be interpreted by a human. Furthermore, the majority of parents saw opportunities for a robot that gives (non-binding) advice about children's educational progress and level. Parents agreed that a robot should not make these decisions autonomously.

The data could also improve parent-teacher conversations. According to parents, the data (e.g., audio and video) collected by the robot, could be used in these conversations to provide insight into what happens at school.

However, the participants also expressed other concerns. Some parents voiced concerns about the current state of technology being inadequate for a proper two-way conversation with children, as the current state-of-the-art robots still seemed heavily reliant on human input. This reliance on human input was also considered to be a potential source for technical errors and the robots providing children with incorrect information. Because of potential misinformation, some parents and policymakers argued they would not blindly accept the robot's judgement.

Beyond the classroom learning. The use of the robot outside the classroom, such as at home, was also discussed in the focus group sessions. Most parents and some teachers agreed that the robot could be a possible tool for education at home. Parents reasoned that the robot could make sure the children were motivated to do their homework and that it was done properly. This was considered to improve the quality of the learning process according to parents. However, teachers also voiced strong reservations about letting children take the robot home, such as: "*It's too expensive. We don't let them take laptops home* *either"*. This opinion was shared among most teachers. They also argued that, for a robot to be useful at home, the robot should be *"plug-and-play"*, which they did not consider the current robots to be. Although most parents considered the robot a potential aid for learning at home, they also expressed that home should be a place where the learning process stops and where children can relax and do something other than learning.

3.3.3 Freedom from bias

Freedom from bias is defined in this study as the robot's ability to treat every user equally, independently of his or her characteristics. Multiple policymakers voiced benefits related to a neutrally programmed robot. *"If you are capable to design a robot without prejudice, assumptions and bias, the robot will add value to education"* as stated by a policymaker. This opinion was broadly shared among the other policymakers and also mentioned by the representatives of the robot industry.

Although an unbiased robot could add value to education, some policymakers were concerned about the robot's ability to correctly recognise children. This could lead to the robot being unintentionally biased due to the robot responding better to specific characteristics of children over others. This could lead to some children gaining an advantage over other children based on their characteristics. Finally, the policymakers argued that the person who programmes the robot (e.g., the teacher or the robot industry) could be (un)intentionally biased when programming a robot, resulting in a biased robot that would prefer some children over others. Some teachers did only slightly touch upon this value saying that if children would know that they would not be judged by a robot, this could be perceived by children as an opportunity to say anything a child wants.

Parents did not voice opportunities or concerns related to this value. However, some children reported that the robot should *"treat everyone equally"* and that the robot should not *"have a favourite child"*, which indicated that the robot potentially being biased is also a concern among children.

3.3.4 Usability

In this study, we defined the value usability as the value that makes it possible for all relevant stakeholders to become successful users of the new technology by ensuring equal access regardless of user knowledge, user diversity, or technological variety (Friedman & Kahn, 2003).

Although robots could provide extra attention to children, the parents, teachers, representatives of the robot industry, and policymakers, all voiced concerns related to usability. The concerns related to 1) the (un)equal distribution of robots due to the high costs of robots, and 2) the IT-knowledge and skills of the teachers.

Parents were concerned that children of low-income families could potentially be excluded from using robots due to the high cost. Parents and policymakers both discussed the option that the school would buy the robots, not the parents. However, this also led to a potential unequal distribution. If schools were responsible for investing in robots, this could lead to *"a form of social segregation where there's a big difference in who gets access to the robot and who doesn't, and I believe in equal rights for a good education regardless of what school my children go to"*, as voiced by a parent. According to policymakers, this could be harmful to equal learning opportunities for children. Teachers all agreed that every child should have the same rights and opportunities to work or learn with social robots, regardless of school or grades.

The second concern regarding usability was the knowledge and willingness of teachers to work with robots. Most teachers considered the robot not plug-and-play, which might make it difficult for some teachers to work with a robot. As one teacher stated: *"I think in practice you will always have people within your team who just can't work with it or who will not work with it"*. Workshops for working with social robots, to increase the overall experience and knowledge among teachers, were considered useful and necessary by both teachers and policymakers. Using robots could be extra challenging for (older) teachers with a low level of digital literacy, according to a few of the policymakers.

Both concerns related to the cost of the robot, and the knowledge and willingness of teachers could lead to unequal opportunities for children. *"There will be a difference between schools who use the knowledge, expertise and resources to implement robots in the right manner and schools who are not able to do this,"* as summarised by a policymaker. According to the robotic industry participants, teachers are still reluctant, or even "*very hesitant*", to buy tutor robots due to technical skills/issues.

3.3.5 Friendship and Attachment

Friendship and attachment are values that relate to children forming friendship relations with robots, and to children becoming (emotionally) attached to the robot. All stakeholders reported harms and/or benefits related to these values, except the children. Most teachers considered a potential relationship with a robot to be similar to the relationship children have with dolls or hand puppets. One teacher said: *"we give those [hand puppets] magical powers too [to entertain the children]. Toddlers believe that, and I think you can do that with a robot as well. While playing, they're discovering things."* Some teachers also considered the friendship relation potentially beneficial for special needs children (e.g., in the Autistic Spectrum Disorder). However, the teachers were concerned about older children forming bonds with a robot: *If your 10-, 11-, 12-year-old are saying 'the robot is my friend', then I would find that somewhat worrying".* Teachers were concerned that friendships with a robot could have a negative impact on the social skills of these older, 'regular' children. This concern was brought up multiple times, and was also reported in the focus group sessions with parents. Policymakers also reported these concerns, however, they seemed more focused on the vulnerability of young children, the implications on the development of social skills and the potential negative impact on the function of teachers for being a role model for their pupils.

Teachers, parents and policymakers all reported concerns that the social bond between children and the robot could lead to children becoming too attached to the robot. There were, however, subtle differences in their considerations. Parents and teachers draw parallels to addictive video games, tablets and smartphones, causing children to prefer gaming over talking to their siblings, parents and/or other children. A few participants of both stakeholder groups also reported that the robot could potentially cause children to take on robotic behaviour. This will be discussed in more detail in the section "Human Contact" below. Some of the policymakers reported to be concerned about what would happen if children get attached to a robot and the robot needs to be replaced, or when the robots are suddenly breakdown.

3.3.6 Trust and Deception

The values trust and deception are closely related, and they are therefore combined in this section. Trust relates to a child trusting a robot, and the potential impact on children when this trust is violated. Deception is associated with the robot's ability to let a child believe something that is not true and the robot being honest to children.

Policymakers discussed that children could find it easier to approach a robot with their problems than approach a human teacher. Children could share secrets or problems which they would normally not share with the human teacher. However, teachers in one session reported that if a child would only trust a robot, this might be an indicator that something is *"wrong"* with the child. When this would happen, the teachers agreed that the child involved should be monitored to see whether there are underlying issues. Some parents also expressed to be concerned about children disclosing sensitive information only to a robot without others finding out.

Policymakers argued that by letting children trust robots (e.g., by letting children share their secrets with robots), the educational system also instils trust into robots to respond correctly. *"We have actually instilled a kind of trust in robots. Maybe my children also have the confidence that they are actually addressing their problems to the robot, but it is possible that the robot could not react adequately"* as voiced by a policymaker. This view was shared among the policymakers.

Another concern was related to the robots passing on information that a child told the robot in confidence, potentially leading children to feel deceived. The policymakers were divided on this subject. They considered that the information should be passed on when the robot is not able to respond appropriately (e.g., provide a solution to the child's problem). However, they also acknowledged that passing this information on could harm the social bond between the children and the robot. The participants of the robot industry also expressed concerns related to the passing on of sensitive information told by children to the robot. As nicely illustrated by one of the industry participants: *"When children are alone with the robot and they do something bad and then, afterwards, the teacher points them out on this while the teacher was not there…. [] the full trust in the robot is gone"*. Some teachers also reported being concerned about the negative effect on children's trust when information would be passed on to others. According to teachers, children should be made aware which data could be retrieved by others: as a teacher said as follows: *"A child should know that it [data collected by a robot] can be revisited"*. This was a shared view among all teachers. Teachers considered it appropriate to explain the data collection in more detail to older children, as opposed to young toddlers. More considerations on which information should or should not be shared, and with whom is reported in the "privacy" section below.

3.3.7 Human Contact

The value of human contact relates to the impact of social robots on both the quality and the quantity of human contact. Parents and policymakers discussed potential benefits related to human contact. Due to robots taking over administrative tasks, human teachers could potentially save time for human contact with the children according to policymakers. However, the robot costing more time than it would save, was a general concern voiced by the teachers. This concern was shared by some of the participants of the robot industry.

Parents stated that the robot could also be used to promote human contact by encouraging children to work and play together. Also, the robot's ability to promote kindness was considered a potential benefit by some parents. Related to kindness are some statements made by the children participating in this study. Some children stated it would be wrong if a robot would *"swear or bully"* and deemed it important that the robot should not *"threaten other people"*. According to other children, a teaching robot should *"be nice"*.

Policymakers, the robot industry, teachers and parents voiced concerns related to human contact. All four considered the potential effect of a robot's lack of social skills problematic. According to most policymakers, this could harm children's human intuition to recognise and respond to (non-)verbal human communications. Some parents and teachers feared that children would prefer working with robots to working with their classmates. This could potentially lead to *"regressed social and emotional development",* according to some teachers and parents. A few parents even feared that their children would adopt *"robotic behaviour"* due to learning with a robot. According to the teachers, emotional development is something which can't be taught by a robot. This was brought up during multiple sessions with teachers. Human contact was favoured over contact with a robot by the teachers.

3.3.8 Privacy

The value of privacy refers to the ability to do things without anyone else knowing, infringing, or influencing them. All stakeholders, except children, voiced concerns and opportunities related to this issue.

Parents, teachers, the robotic industry and policymakers all mentioned wanting an insight into the data collected by the robot, however, for different reasons. The robotic industry considered the data valuable for product improvement. The policymakers reported that they would like to use the data to improve their policies, by monitoring the performance of schools. Teachers considered the data valuable for teaching purposes and enhanced personalised learning. And parents reported that they should have the right to access the data that is recorded of their children. Some parents also reported that they should have the right to tell the school to delete all the data collected by the robot. Most teachers reported to agree that parents should be granted the right to access their children's data and that this is already common practice. However, they also reported that, before the data is sent to the parents, it should first be checked by a teacher. A few teachers expressed that in some cases it is best to talk to the parents before showing them the collected data, to provide context with the material. As one teacher explained: *"Parents have the right to check everything. But you don't have to do that straight away. You can also say, 'come back later'. I think you should think this through as a school, not just say 'all right, here is the data'".* Most of the policymakers considered sharing children's data with the robotic industry to be potentially problematic because the goals of a school are not always the same as that of a commercial company. They voiced concerns that the goal of making a profit would potentially conflict the goal of schools and the Ministry of Education. Most teachers considered sharing data with third parties such as the robotic industry and the government to be no problem as long as all the data are anonymised.

The ownership of the data was an open issue discussed by the policymakers. They discussed whether the school, parents, children, or the manufacturer of the robot should be the owner of the data. They did not reach a consensus on this issue. The lack of clear guidelines on how to deal with the data collection of robots was a concern among parents. They voiced concerns related to the use and distribution of the data, especially for audio and video containing personal information. Some parents stated that before accepting a social robot into the school of their children, it should be clear which parties are going to use the data and for what purposes. Teachers, however, reported that there are privacy laws in place to protect children's privacy. Some teachers even reported that they *"can't do anything"* without the permission of parents. A few parents furthermore mentioned fearing being forced to opt-in if their school started using the data collected by robots. Some parents expressed concerns like fear that they would be forced to give up their child's privacy for them to go to school.

Children should have the right to be a child without being continually observed. This was a shared opinion among policymakers. They stated that the data collected by robots could haunt children in their later lives. Most parents and policymakers voiced concerns related to this issue, especially given the sensitive nature of the data. Finally, some teachers also expressed concerns related to the video or audio materials in which multiple children would be visible. It was unclear how this data should be shared with parents, according to the teachers.

3.3.9 Security and Safety

The impact of social robots on the values of security and safety was discussed by parents, teachers, robotic industry participants, policymakers, and children. Whereas security focuses on IT security, safety relates to the physical safety of children and their surroundings.

The policymakers voiced two concerns related to the security of a robot. First, robots entering schools bring new security questions, making a secure IT-environment more difficult to manage for schools. Second, they considered a robot hackable which could lead to the children being spied on and, if the robot was reprogrammed by the hacker, even negatively influence children.

A majority of the parents were hesitant to accept a robot due to its security issues. One of the key issues was the lack of guarantee that all the sensitive information stored would be stored safely. Some parents also voiced concerns related to the physical safety of the children by questioning its durability. Teachers, on the other hand, did not seem very concerned with the physical safety of the children. According to some teachers, there are toys at school that are more unsafe than a social robot. They did consider the physical safety of the robot to be a potential issue. While discussing if children should be left unsupervised with a robot, the teachers agreed that some children could be left unsupervised, while others could not. They drew parallels between a laptop and a robot, stating that the children who could be left alone with a laptop could also be left alone with a robot. Opposed to teachers, a majority of the policymakers did consider the physical safety of children an issue. They considered a robot a potential risk to the physical safety of children when a robot could gain physical control over children. There were also several arguments made by the children that relate to safety, ranging from the robot beating children to unwanted sexual contact. According to children, a robot is not allowed to: *"suddenly hurt someone"*, *"kill"* or *"sexually assault"* someone.

During the focus group sessions with the robot industry, the participants mentioned that there is a lot of pressure on robotic companies to innovate and to keep releasing new products onto the market. Participants reported being concerned that some products, therefore, would be introduced too soon, which could impact the effectiveness and potentially also the safety and security of their products.

3.3.10 Responsibility and Accountability (new)

The values of responsibility and accountability are closely related, however, they are different. Someone responsible should take care of something or someone, while someone accountable is obligated to bear the consequences of something or someone. The value accountability could already by identified through earlier research (see Table 3.2), however, our results also relate to the value of responsibility. Therefore, we included this newly identified value.

The policymakers, teachers, parents, and the robotic industry all reported concerns related to these values. The robotic industry reported that it is unclear if they can be held responsible or accountable for any negative consequences from the use of social robots in education. This led to some companies being hesitant to develop robots for the social domain, according to some participants. Most teachers considered the supplier of the robots accountable for the maintenance, purchase, software updates, and security of the robot.

However, inside the classroom they considered the teachers responsible for what happens. Some parents voiced concerns related to becoming too depended on robots for parenting tasks. They considered the responsibility for raising and supporting the development of children foremost the job of parents, not robots. Some policymakers also stated that it is unclear who should be held accountable when a robot does not function properly. The participants discussed this topic and considered the school, the manufacturer and other parties, but could not come to an agreement on who should be held accountable.

3.3.11 Autonomy (new)

The value of autonomy concerns the teacher's ability to choose his/her learning methods and actions and is one of three newly identified values related to social robots in education. Some policymakers were concerned that robots could limit the teachers' autonomy. *"If you have an artificial intelligence-driven system, that bases its answers on the answer of 10.000 teachers, do you dare to overrule this decision?"* The policymakers discussed that the robot could become too prescriptive to the learning process, making the teacher an assistant to the robots, as opposed to the robots being an assistant to the teacher. The other stakeholders did not voice considerations related to this value.

3.3.12 Flexibility (new)

The third and last newly identify value is Flexibility. Flexibility refers to the ability to move the robot around and to be transported. Some parents expressed the concern that the robot could be too big and bulky to be brought home. Especially parents who bring their children to schools by bicycle could be limited in bringing the robot to their home. The other stakeholders did not voice concerns related to this value.

3.4 DISCUSSION AND CONCLUSIONS

To address the moral challenges related to social robots in education, this study reports on focus group sessions among direct and indirect stakeholders regarding their perceptions on the usage of these robots. The extant literature has mostly focused on the impact that social robots would have on children and teachers, however, the other stakeholders were not involved. Filling this gap is important given the sensitive nature of education, the vulnerability of children, and design ethics being underdeveloped in Child-Computer Interaction research. More insight into the moral considerations of the various stakeholders involved provides a solid base to develop guidelines for implementing social robots in education as requested by scholars and society.

Results of the focus group sessions showed more similarities across the views of stakeholder groups than differences. In Table 3.3, we present a summary of the moral considerations on which stakeholder groups agreed or disagreed. Table 3.3 shows which issues participants within stakeholder groups generally agreed upon (A; agree), issues they disagreed with (D; disagree), issues of which no general agreement could be reached among the participants within a stakeholder group (U; unresolved) and issues that were not discussed in specific stakeholder groups (N; not mentioned).

Table 3.3. Summary of the considerations per stakeholder group.

Values	Issues: *Social robots in education…*	*Teachers*	*Parents*	*Robotic industry*	*Policymakers*	*Children*
Psychological welfare and Happiness	Are fun and motivational for children	U	A	A	A	A
	Can make children feel safe/ sense of peace	A	A	N	A	N
	Could have negative long-term social implications	U	A	N	N	N
	Increased workload for teachers	A	N	N	N	N
Applicability	Are useful for simple teaching tasks, supervising, taking exams and motivating children.	A	A	A	A	A
	Can build e-portfolios/collect data of children, monitor progress/development	A	U	N	A	N
	Can be used outside the classroom	U	A	N	N	N
Freedom from bias	Can be (un)intended bias	N	N	A	A	A
Usability	Can cause unequal learning opportunities due to unequal access	A	A	N	A	N
	Require new (IT) knowledge from teachers and can be met with the reticence of teachers	A	N	A	A	N
Friendship and Attachment	Can harm the social skills of children	A	A	N	A	N
	Can be beneficial for special needs children	A	N	N	N	N
	Can cause children to become too attached due to the forming of social bonds	A	A	N	A	N
Trust and Deception	May not pass on sensitive information told in confidence, this violated trust.	A	A	A	U	N
	Can cause children to trust robots over humans.	A	N	N	A	N

Table 3.3. Continued.

Values	Issues: *Social robots in education...*	*Teachers*	*Parents*	*Robotic industry*	*Policymakers*	*Children*
Human Contact	Can increase the quantity and quality of time teachers spent on personal contact with children.	U	A	N	A	N
	Can harm the social skills of children	A	A	A	A	N
Autonomy *(new)*	Harm the autonomy of the teacher	N	N	N	A	N
Flexibility *(new)*	Are difficult to transport	N	A	N	N	N
Privacy	Gathers data I want access to	A	A	A	A	N
	May not share data with (all) others	U	A	N	A	N
	Lack of clear privacy guidelines/laws	D	A	N	N	N
Security and Safety	Cause IT security issues	A	A	U	A	N
	Can compromise children's physical safety	D	A	N	N	A
Responsibility *(new)* and Accountability	Cause ambiguities on who is responsible and accountable for the robot(s) (actions).	A	A	A	A	N

Note. (A = agree; D = disagree; U = unresolved, N = not mentioned)

Important results can be found in the newly identified values, and the issues on which all stakeholder agreed, versus those on which stakeholders disagreed related to the earlier identified, theoretical values. The newly identified values were not yet identified through the harms and benefits in a systematic literature review on moral considerations and social robots in education (Smakman & Konijn, 2020). The newly added values are *autonomy*, *flexibility,* and *responsibility*. Our study further shows that the stakeholders considered all 14 values, that were identified at the start, relevant. Thus, each of these values are relevant from the perspectives of multiple stakeholders. When adding the newly identified values to the list of values already identified, the total number of values that might be affected by the implementation of social robots in education, comes to 17 values.

Each of the various stakeholder groups considered social robots fun and motivational for children. Although teachers had some concerns on the current state of technology to keep children motivated, they overall agreed on this (potential) benefit. This positive impact is also mentioned in earlier research, where parents reported positive attitudes towards motivational robots for education (Oros et al., 2014). Furthermore, each of the stakeholder groups considered the robot being applicable for (simple) teaching tasks, supervision, taking exams, and motivating children. Teachers mostly considered the robot a prime tool for simple teaching tasks and for teaching programming skills. Teachers in earlier research voiced similar opinions, considering the robot mainly as an additional teaching tool for teachers, and less suited for novel concepts (Serholt et al., 2017). These results indicated that social robots do hold potential for education. However, other considerations seem to stand in the way of these benefits.

The (social) bond between a robot and a child could enhance motivation and create an enjoyable learning experience. However, teachers, parents, and policymakers all voiced concerns related to children becoming too attached to the robot caused by the social bond between child and robot. Also, they worried that this could harm the development of children's social skills. The forming of social connections between robots and humans is central to the field of social robotics (Belpaeme, Baxter, Read, et al., 2013). Therefore, these fears and considerations should be taken into account by robot builders and users. If a social bond is unacceptable for crucial stakeholders, then social robots for education might be designed differently. However, the level of experience with social robots could influences people's perceptions, as pointed out by other researchers (Serholt, Barendregt, et al., 2014). It might, therefore, be wise for robot builders and (future) users of social robots to acquaint stakeholders with this new technology before their implementation.

The various stakeholders in our focus groups also voiced strong views on data collection through a robot, related to the security of the data collected by the robot, and to privacy issues. Participants in each of the adult stakeholder groups reported concerns related to the security of the sensitive data that could be collected by the robot. Similar concerns of teachers were also found in earlier research (Serholt et al., 2017). The collection of (personal) data is needed for robots to personalise their responses to children, which in turn is reported to improve the learning outcomes compared to non-personalised interaction (Gordon et al., 2016). Furthermore, data collection is needed for building e-portfolios, which again is considered a benefit reported by the teachers, parents, and policymakers in our study. Although schools are used to handle personal, sensitive information of children, their current infrastructure might not be adequately secure for social robots to safely store such (large amounts of audio-visual) data.

Whereas some stakeholders voiced concerns related to privacy, all stakeholders (except the children) reported that they wanted access to the data collected by the robot. Reasons varied from increasing personalised learning, improved governmental policies, to improving social robots. These different reasons could guide the amount of access each stakeholder should get. For instance, robotic companies and policymakers could be granted rights to fully anonymised data for improving products and policies, whereas parents could be given access to a dashboard with overall data on their children. Teachers could be granted full access to the data, on which all stakeholders agreed. However, one scenario was overlooked - relating to the effect on children's trust.

Participants in each of the adult stakeholder groups expressed concerns related to children's trust being harmed when a robot would pass on information to others which was told to the robot in confidence. To autonomously detect which information was told in secrecy, robots would need to have sophisticated speech recognition. Whereas social robots rely heavily on language interactions, this still does not work reliably with children (Kennedy et al., 2017). Therefore, it might be advisable to store only aggregated data related to educational tasks, and not all the recordings of child-robot-interaction. This could solve the issue until there is an adequate technical solution.

Some methodological limitations should be noted. The current study was solely executed in the Netherlands. Therefore, the results provide insights into a Dutch (and perhaps Western European) perspective on social robots in education. Although a substantial total number of 118 people participated in our focus group sessions, we acknowledge that due to the limited number of participants per stakeholder group, the results might not be representative for the whole population within a stakeholder group. Nevertheless, the results provide important insights into the considerations of a wide range of different stakeholders and much-needed directions and pointers for further research for implementing social robots in education while keeping in mind the values upheld in education. Some of the categories identified in our study may not directly appear "moral" issues. However, using Friedman's et al. (2008) definition of values, in our study, moral values refer to what stakeholders consider important and valuable with regard to the impact of a technology, which is a common definition in ethics of technology as discussed in the introduction section. Further research should focus on quantitative data on how the stakeholders consider the issues underlying the seventeen moral values related to social robots in education. Such a method would allow for more participants from the relevant stakeholder groups and allow quantitative comparisons across groups. Results of such a study, combined with the qualitative results of the current study, can be used as a solid basis for creating the first guidelines for the responsible use of social robots in education in view of the different perspectives at stake.

To conclude, this study aimed to identify and compare the moral considerations of the key stakeholders related to social robots in primary education. We conclude that all stakeholders consider social robots as a potentially valuable tool for education. We identified a list of 17 values that are considered to be influenced when social robots enter education. Overall, we found many similarities and only few conflicting views across the various stakeholder groups. Particularly among the teachers, parents, and policymakers, there were many similarities on the issues reported and their considerations were often aligned. In sum, each of the adult stakeholder groups agreed that social robots 1) are fun and motivational for children; 2) are useful for simple teaching tasks, supervision, taking exams, and motivating children; 3) provide valuable data; and 4) cause ambiguities related to responsibility and accountability. Although many open issues still need to be addressed, stakeholders appear to agree that social robots could have great potential for education. Guidelines that address these issues are crucial for each of the stakeholder groups to accept social robots as useful in primary education. Therefore, further research is needed to start drawing up these guidelines to allow the implementation of social robots in the educational system as a justified, safe, and morally responsible new technology for children to expand their learning experiences and be prepared for the future.

CHAPTER 4

ATTITUDES TOWARDS SOCIAL ROBOTS IN EDUCATION: ENTHUSIAST, PRACTICAL, TROUBLED, SCEPTIC, AND MINDFULLY POSITIVE

This chapter is published as: Smakman, M. H. J., Konijn, E. A., Vogt, P. A., & Pankowska, P. (2021). Attitudes towards social robots in education: Enthusiast, practical, troubled, sceptic, and mindfully positive. *Robotics*, 10(1), 24.

Abstract. While social robots bring new opportunities for education, they also come with moral challenges. Therefore, there is a need for moral guidelines for the responsible implementation of these robots. When developing such guidelines, it is important to include different stakeholder perspectives. Existing (qualitative) studies regarding these perspectives, however, mainly focus on single stakeholders. In this exploratory study, we examine and compare the attitudes of multiple stakeholders on the use of social robots in primary education, using a novel questionnaire that covers various aspects of moral issues mentioned in earlier studies. Furthermore, we also group the stakeholders based on similarities in attitudes and examine which socio-demographic characteristics influence these attitude types. Based on the results, we identify five distinct attitude profiles and show that the probability of belonging to a specific profile is affected by such characteristics as stakeholder type, age, education and income. Our results also indicate that social robots have the potential to be implemented in education in a morally responsible way that takes into account the attitudes of various stakeholders, although there are multiple moral issues that need to be addressed first. Finally, we present seven (practical) implications for a responsible application of social robots in education following from our results. These implications provide valuable insights into how social robots should be implemented.

4.1 INTRODUCTION

The use of social robots in education has been subject to extensive moral debate. Their use in early education in particular (e.g., kindergarten and primary school) has raised several moral issues, ranging from the impact of robots on the role of caregivers and teachers, to issues related to dehumanisation, privacy and accountability (Serholt et al., 2017; Sharkey, 2016; Tolksdorf et al., 2020).

Despite such moral concerns, social robots are increasingly introduced in primary education in the role of a tutor or teacher, and as a peer or a novice (Belpaeme, Kennedy, et al., 2018). The aspect that sets social robots apart from other physical (educational) robots is that social robots are following social norms and have some form of autonomy (Bartneck & Forlizzi, 2004). These unique features and elements, combined with their physical embodiment, enable social robots to have the ability to improve cognitive (e.g., knowledge, comprehension, application, analysis, synthesis, and evaluation) and affective (e.g., the learner being attentive, receptive, responsive, reflective, or inquisitive) outcomes of children (Belpaeme, Kennedy, et al., 2018). More specifically, the use of robots to teach children a broad range of topics is currently being trialed. These topics include first and second language (Alemi, Meghdari, Basiri, et al., 2015; Gordon et al., 2015; Kwok, 2015; Van den Berghe et al., 2019; Wang et al., 2013), sign language (Kose & Yorganci, 2011; Uluer et al., 2015), imitation-specific tasks for children with autism spectrum disorder (ASD) (Aresti-Bartolome & Garcia-Zapirain, 2014), times tables (Konijn & Hoorn, 2020), and dance (Ros et al., 2014; Ros & Demiris, 2013).

As social robots are increasingly finding their way into regular education, it is important to critically examine the moral issues raised by an increasing number of scholars (Belpaeme, Kennedy, et al., 2018; Pandey & Gelin, 2017; Serholt et al., 2017; Sharkey, 2016; Tolksdorf et al., 2020). This is of particular importance given the fact that children are a vulnerable group and that primary education is currently facing a number of challenges, such as shrinking budgets, more diverse classrooms, and (as a consequence) increased teacher workload. Furthermore, according to a recent literature review, ethics in Child-Computer Interaction is an understudied field that should be given more attention (Mechelen et al., 2020). The development of moral guidelines regarding the construction and implementation of social robots in primary education could ensure that the potential of social robots is being realised, while values in education are not undermined.

When developing such guidelines, it is important to include different stakeholder perspectives, as robots can impact both direct and indirect stakeholders, and the moral considerations of these groups can differ and even conflict (Friedman et al., 2008, 2013; Ligtvoet et al., 2015). Direct stakeholders are parties who directly interact with a system (in this case the social robot). Indirect stakeholders are those who are affected by the use of the social robots, but are not in direct contact with it (Friedman, 1997), such as, for example, parents and government policymakers. A systematic literature review (Smakman & Konijn, 2020) showed that stakeholders other than teachers and children are largely overlooked in the existing literature. An exploratory qualitative study, which relied on focus group discussions with five different stakeholder groups, found both similar as well as conflicting views on how social robots should be used in education across the various stakeholder groups (Smakman et al., 2021). However, due to the exploratory nature of the focus groups study of Smakman et al. (2021), a rather limited number of participants per stakeholder group took part in the discussions. Therefore, in this study, we conducted a large-scale quantitative analysis that allows us to more systematically examine stakeholder-driven differences and similarities in moral considerations about the use of social robots in education. In addition, we investigated whether differences could be further explained by varying socio-demographic characteristics, such as age, previous experience with robots, and education level.

This study contributes to the existing body of knowledge by focusing on empirically examining a wide range of moral issues and values related to the use of robots in education that have been identified in existing literature. To this end, we developed a questionnaire that concerns moral issues regarding the use of social robots in education that are relevant for both direct and indirect stakeholders. Using this questionnaire, we aimed to answer the following three research questions: RQ 1) what are the attitudes of stakeholders on the moral issues related to social robots in education? RQ 2) how can the attitudes related to the moral issues be categorised? And RQ 3) what socio-demographic characteristics influence the attitudes of stakeholders on the moral issues related to social robots in education? The results of our study can be used to get a better understanding of the various perspectives on moral considerations related to the use of robots in education. This can provide a solid basis for the development of moral guidelines that respect and take into account the concerns of different stakeholders.

The remainder of the paper is structured as follows. The second section provides a brief overview of the existing literature on stakeholder attitudes regarding the use of social robots in education. Then, the third section describes the methodology used in our study and the fourth section summarises the results obtained from the different analyses. Finally, the fifth section provides an in-depth discussion of the results, which includes an overview of the implications of the findings, and provides concluding remarks.

4.2 THEORETICAL BACKGROUND

The literature available to date that relates to the attitudes of stakeholders on the moral impact of social robots in education is rather scarce. However, there is a considerable number of studies that focused on perceptions related to (social) robots both in general and in education specifically. One of the largest surveys conducted that is related to attitudes towards the impact of robotics is the Special Eurobarometer 460 (European Commission, Directorate-General for Communication, 2017). The survey was conducted in 2017 and the sample included a total of 27,901 EU citizens from 28 member states. The results show that overall robots are considered desirable for jobs that are too hard or too dangerous for people to perform. Furthermore, robots that help people to do their jobs and carry out daily tasks at home are also considered beneficial for society.

Although these results paint a promising picture regarding the acceptance of robots in society, some concerns related to the impact on jobs and the work performed were also mentioned. In particular, people indicated that they feel uncomfortable about the use of robots in specific situations (rather than in general), such as when providing services and companionship. Almost nine out of ten respondents considered careful management as a necessary requirement for the implementation of robots and artificial intelligence in society (European Commission, Directorate-General for Communication, 2017).

The results of the survey also show that various demographic characteristics, such as gender, age, education level, and social economic status (SES), influence individuals' attitudes towards robots. Specifically, women, older people, individuals with lower education, and those experiencing financial stress, overall seem less likely to be positive about the use of robots (European Commission, Directorate-General for Communication, 2017).

While the Eurobarometer results reflect the attitudes of EU citizens in general, the literature on the impact of social robots in education to-date has mainly focused on the attitudes and perceptions of teachers and school children (Smakman & Konijn, 2020). Multiple studies, conducted in different countries and cultures, found that overall children, including those with special needs (e.g., ASD), have a positive attitude towards social robots (Alemi, Meghdari, Basiri, et al., 2015; Hood et al., 2015; Jones & Castellano, 2018; Shin & Kim, 2007; Wei et al., 2011). The stance of teachers seems somewhat more cautious than that of the pupils. Specifically, the idea of social robots being widely adopted in education was not met with enthusiasm by all teachers interviewed/surveyed.

Teachers in special education specifically have been shown to be highly sceptical towards the use of social robots in education; they considered the potential role of robots to be mainly mechanical and repetitive (Diep et al., 2015). Furthermore, teachers in several countries voiced concerns related to the implications that the use of social robots can have on children's development (Kennedy, Lemaignan, et al., 2016; Reich-Stiebert & Eyssel, 2016; Serholt et al., 2017). According to some, robots could have a dehumanising effect on children (Serholt et al., 2017), and children could become more socially isolated if they were to develop a social bond with a robot (Kennedy, Lemaignan, et al., 2016). Some teachers also voiced concerns related to privacy, the role of the robot, the effects on children, and responsibility issues (Serholt et al., 2017). Furthermore, teachers were also concerned with the ability of the robot to properly recognise emotions through facial expressions, which they considered an important skill required for teaching (Ahmad et al., 2016). Finally, they also expressed their concern about not having the necessary skills to control the robot, which could result in it not being used (Ahmad et al., 2016).

On the other hand though, some teachers have foreseen multiple roles for robots in education, such as the robot being a buddy, a friend, an assistant or a helper (Ahmad et al., 2016). Other teachers have reported to see a potential in the robot's ability to enhance and facilitate the educational process (Fridin & Belokopytov, 2014a), promote learning beyond the classroom (e.g. learning at home) (Kory Westlund et al., 2016), reduce the anxiety of low-achieving students (Chang et al., 2010), and help and motivate students when learning complex or difficult topics (Shih et al., 2007; Sumioka et al., 2017). The limited and often small-scale qualitative studies on the attitudes of other stakeholders, such as parents, government policymakers, and the robot industry, also do not give a consistent view on how social robots should be used in education. For example, according to a study conducted in Spain, parents appear to accept educational robots as mechanical tools, whereas Korean and Japanese parents have been reported to see robots as a potential friend for their children (Choi et al., 2008).

Given these mixed results and findings about the attitudes towards the use of social robots in education, and the reported need for moral considerations and guidelines, the current study took a more systematic approach. In addition to a quantitative analysis of a relatively large group of different stakeholder groups on their attitudes regarding moral issues related to social robots in education, we also examined how these attitudes can be categorised, and how various socio-demographic factors may influence them.

4.3 METHOD

In this section, we discuss the data collection and sampling method, which includes a description of the questionnaire design. This is followed by the data analysis plan that provides an overview of the methods and models used in the statistical analyses.

4.3.1 Participants and design

The data for the analysis were collected in Spring 2020 using the online survey software Qualtrics. Through purposeful sampling (a method in which participants are sampled based on certain traits or qualities that they possess (Koerber & McMichael, 2008)), we approached six stakeholder groups: 1) primary school teachers, 2) university students of education, 3) parents with primary school children, 4) educational policymakers/advisors working for the government, 5) primary school directors/management, and 6) employees of the robotic industry. These groups were approached via multiple online channels and were provided a link to the online questionnaire. The channels used included direct e-mails, messages on online forums and social media, as well as messages in newsletters of schools and professional organisations.

A total of 810 respondents started the questionnaire; however, following the data cleaning and preparation phase, 515 respondents were retained and included in the analyses. All collected data are available via the Open Science Framework (https://osf.io/a3jsv/). The data collected were cleaned, prepared, and analysed using IBM SPSS Statistics (v24).

When cleaning the data and preparing them for analysis, we first dropped all respondents who did not complete the questionnaire, i.e. those who missed multiple items or stopped halfway (n=266). Respondents who completed it in less than five minutes were also discarded (n=14), given that it is not feasible to read the introduction and answer 69 statements in only 5 minutes. Furthermore, where possible, we also manually recoded the 'Other' stakeholder category into one of the remaining five categories, based on the respondents' written text. An overview of the socio-demographic characteristics of the sample used for the analyses is shown in Table 4.1.

Table 4.1. Overview of the socio-demographic characteristics of the participants (*N* = 515).

Socio-demographic characteristics		%
Age	18-26 years	19%
	26-35 years	20%
	36-45 years	23%
	46-55 years	19%
	>55 years	18%
Experience with robots	No Yes	77% 23%
Gender	Male	42 %
	Female	58%
Gross Income	Low (< €2.816 p/m)	21%
	Middle (€2.816 - €5.632 p/m)	51%
	High (> €5.632 p/m)	15%
	No answer	12%
Highest finished education level	Secondary school	11%
	Vocational education (MBO)	11%
	University of Applied Sciences (HBO)	45%
	University of Science (WO)	33%
Stakeholder group	Parents with primary school children	18%
	Primary school teachers	12%
	Primary school directors/management	12%
	Government educational policymakers/advisors	17%
	Employees of the robotics industry	10%
	Students of education	17%
	Other	12%

4.3.2 Materials and methods

A schematic overview of the study's methodology per research question is presented in Figure 4.1. The construction of the questionnaire and the scales is discussed below. The methods used to answer each of the research questions are discussed in more detail in the results section.

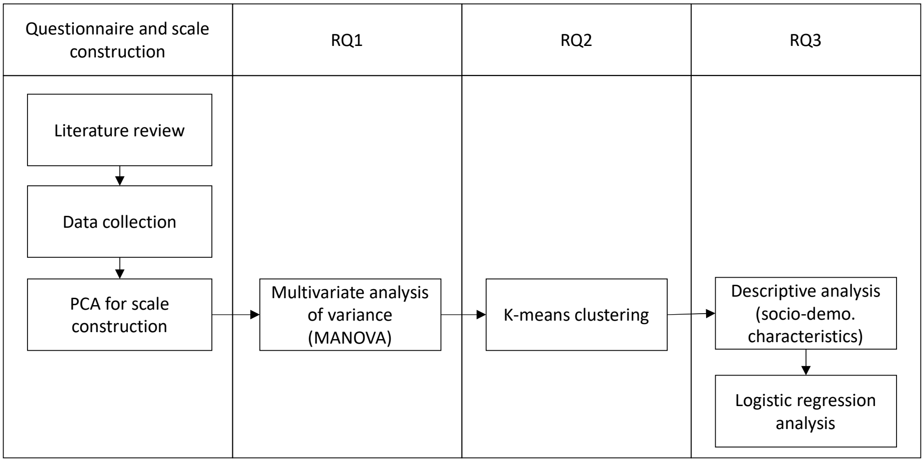

Figure 4.1. Study methodology per research question (RQ).

Construction of the questionnaire. To develop our questionnaire, we first reviewed the literature and transcripts of a previous study, in which focus group sessions were held with various stakeholder groups about the moral considerations regarding social robots in education (Smakman et al., 2021), to identify the relevant moral values and the underlying issues. As there are many definitions of morality in the literature, for this study, we take a broad notion of the concept. We define moral issues as any consideration about what is good or bad regarding social robots in education, thereby including considerations of what robots should and should not do, as well as perceived benefits and harms. On a higher level, these moral issues can be linked to values, which refer to "what a person or group of people consider important in life" (Friedman et al., 2008).

In total, 294 passages from the literature (Smakman et al., 2021; Smakman & Konijn, 2020) were coded and could be mapped to a list of 17 relevant moral values (shown in Table 4.2, below). For each value, multiple issues were formulated and each represented a key issue as reported in the literature and the focus group discussions. Based on these issues, we constructed multiple statements for each value. The statements, as a basis for the questionnaire, were drafted and reviewed by four researchers, after which they were reviewed by three independent experts. Finally, all initial items were pre-tested on clarity and reliability by distributing the preliminary questionnaire to 50 IT bachelor students. Based on the results of the pre-test, some of the questionnaire items were edited or omitted. The final questionnaire can be found online (https://osf.io/a3jsv/).

In total, 69 items were derived that represent the issues of all 17 moral values. These 69 items were included in the final questionnaire as statements. Participants were asked to indicate their level of agreement with each statement on a six-point scale: strongly disagree (1), disagree (2), slightly disagree (3), slightly agree (4), agree (5) and strongly agree (6). A 6-point scale was chosen because it lacks a neutral point, therefore forcing people to decide their level of agreement with the statement (Presser & Schuman, 1980).The questionnaire items were balanced in positive and negative wording to prevent acquiescence bias. In the questionnaire, after answering all questions related to a specific moral value, respondents were given the possibility to further elaborate on their opinion in an open textbox.

Table 4.2. Relevant moral values for robot tutors derived from previous research (see text).

Values/constructs	*Explanation/example issue*
Accountability	This value/construct is related to the effect robots have on who is accountable for the actions of robots and their effects. Someone accountable is obliged to accept the consequences of something.
Applicability	This value/construct is related to the usefulness and versatility of the robot for education.
Attachment	This value/construct is related to the possibility that the child will get attached to the robot, and whether this is permitted/ desirable.
Autonomy	This value/construct is related to the effect that the robot has on a teacher's autonomy. Autonomy refers to the freedom of a teacher to make independent decisions.
Deception/ Sincerity	This value/construct is related to the robot's ability to make children believe something that is not true, such as pretend that the robot cares about a child or keeping information from children.
Flexibility	This value/construct is related to how easy it is to move and transport the robot.
Freedom from bias	This value/construct is related to the possible bias of the robot, such as gender or racial biases.
Friendship	This value/construct is related to the friendship that can develop between a child and a robot, and whether this is permitted/ desirable.
Happiness	This value/construct is related to the extent to which a robot provides pleasure/fun.
Human contact	This value/construct is related to the effects of a robot on human contact.
Privacy	This value/construct is related to the effect of the robot's ability to collect personal data on children, and if this data may be shared with others.

Table 4.2. Continued.

Values/constructs	*Explanation/example issue*
Psychological welfare	This value/construct is related to the influence of the robot on psychological/social aspects, such as a robot may act as a person of trust, or may comfort a child.
Responsibility	This value/construct is related to the effect on teachers' responsibility for the robot. Someone responsible is obliged to take care of something.
Safety	This value/construct is related to the physical safety of children when interacting with robots.
Security	This value/construct is related to the IT security of the data that the robot collects.
Trust	This value/construct is related to the trust that a child has in a robot, and whether this can be violated.
Usability	This value/construct is related to the availability of the robot. Availability indicates the extent to which a robot is accessible to users.

The questionnaire started with a neutral introduction about robots in education to provide context to the participants. This was followed by a brief active consent procedure to participate in this study. Upon approval, the participants were first asked to answer several socio-demographic questions related to gender, age, income, educational level, years of working experience, number of children, number of children in primary education, experience with robots, and province of residence. Additionally, they were asked to which stakeholder group they belong to out of the following seven groups: 1) primary school teachers, 2) university students of education, 3) parents with primary school children, 4) educational policymakers/advisors working for the government, 5) primary school directors/management, and 6) employees of the robotic industry and 7) other, namely: (which was followed by an open text field).

Psychometric analyses of the scales. To analyse the results of the questionnaire, we first reversed the items, for which the statements had a negative (rather than a positive) formulation. Secondly, we ran a principal component analysis (PCA) to examine to which extent the 69 items measure the constructs/values regarding the use of social robots in education as intended. The Keiser-Meyer-Olkin measure of sampling adequacy (0.864) and the Bertlett's test of sphericity ($p < 0.001$) marked the data as suitable for PCA. To determine the valid number of constructs, we made use of the scree-test (Cattell, 1966). Also, to obtain clearer and more interpretable constructs, we rotated the solution using the Varimax rotation method. Then, we examined the obtained item loadings per extracted factor and removed items that were considered non-discriminatory. That is, items that loaded on multiple components and when the difference between at least two of these loadings was smaller than 0.2 were removed. Furthermore, we removed items that loaded less than 0.3 on all component. This was an iterative process. That is, each time weakly and cross-loading items were removed, we ran the PCA again (on the remaining items), using the Varimax rotation. We then selected the optimal number of components based on the scree-plot, inspected the item loadings once more, and removed non-discriminatory and weakly loading items. This process was repeated five times and eventually, we extracted six clear and interpretable components based on a total of 46 items representing 15 out of the 17 values (the items representing freedom from bias and responsibility were dropped during the process). It is worthwhile mentioning that, while one of the components (number 6) only contained two items, we decided to keep this component due to the specific content of these items and the fact that they represent a unique and interesting aspect of moral values with regards to the use of social robots in schools.

Next, we constructed six scales based on the PCA results. More specifically, for each scale we calculated the mean of all the items that loaded on the corresponding component. We also checked for the internal consistency (i.e., reliability) of the scales using Cronbach's α and obtained satisfactory results (ranging from $\alpha = 0.679$ to $\alpha = 0.907$). The specific Cronbach's α per scale and loadings of the items included in the derived subscales, are summarised in Table S2 online (https://osf.io/a3jsv/).

Out of the six extracted scales, the first was labelled *Social interaction and bonding*, because items that related to attachment, friendship and psychological well-being were grouped under this component, and to a slightly lower degree also, human contact, and sincerity. The second component reflected happiness, availability and usability, and was therefore named *Usefulness, availability and fun*. The third component included relatively high loadings of accountability and also somewhat of IT safety and was therefore labelled S*table accountability and IT safety*. Component four was labelled S*incerity and flexibility* as items related to sincerity and flexibility loaded relatively high on this component. The fifth component included items that reflected trust, physical safety, and data privacy and was therefore labelled *Trust, data also to parents without a teacher as the gatekeeper*. Finally, the sixth component included highly loading items on data privacy related to sharing data with third parties and was therefore labelled *Data share with third parties*. Table 4.3 provides a summary of the six scales.

Table 4.3. Summary of the six scales.

Scale	*Label*	*Description*	*Items(n)*
1	Social interaction and bonding	Social robots may socially interact and form social bonds with children, such as friendship bonds. They may be used to aid the psychological wellbeing of children, and for learning social skills.	16
2	Usefulness, availability and fun	Social robots are useful and fun for children and parents and improve the job satisfaction of teachers. They should be made widely available for schools.	11
3	Stable accountability and IT security	Social robots do not jeopardize the accountability structure in schools and can be used without an IT security certificate.	6
4	Sincerity and flexibility	A robot must be honest to children and keep promises made to children. Also, the robots need to be flexible (movable).	5
5	Trust, data also to parents without a teacher as the gatekeeper	A robot must keep secrets told to by a child, and not share them with the parents of teachers. Teachers are not gatekeepers of data, parents should have access to data. It is safe to let children interact with robots without supervision.	6
6	Data share with third parties	Data collected by the robot may be shared with third parties, such as government and robot companies to improve policies and products.	2

4.4 RESULTS

4.4.1 Stakeholder Perspectives

To answer RQ 1 (what are the attitudes of stakeholders on the moral issues related to social robots in education?), we ran a multivariate analysis of variance (MANOVA) to investigate whether attitudes and perceptions of moral issues regarding the use of social robots in education (estimated using the six scales) differ by stakeholder group.

The results of the MANOVA analysis confirmed that there is a statistically significant difference in the attitudes regarding the use of social robots in schools based on stakeholder group ($p < 0.05$). Furthermore, as can be seen in Table 4.4, the results also show that the effect of stakeholder group was significant for all six scales, with the one exception of scale number 4 ('Sincerity and Flexibility'), for which there were no significantly differences. The per group means for all six scales are illustrated in Figure 4.2 below and the results of the post-hoc tests can be found in Table S3 online (https://osf.io/a3jsv/).

Table 4.4. The effects per scale including the significance level.

Dependent Variable	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	*p*
Social interaction and bonding	18.670	6	3.112	4.417	< 0.001
Usefulness, availability and fun	11.632	6	1.939	3.482	0.002
Stable accountability and IT safety	8.653	6	1.442	2.180	0.044
Sincerity and flexibility	5.845	6	.974	1.641	0.134
Trust, data also to parents without teacher as gatekeeper	36.956	6	6.159	9.806	< 0.001
Data sharing with third parties	37.811	6	6.302	4.032	0.001

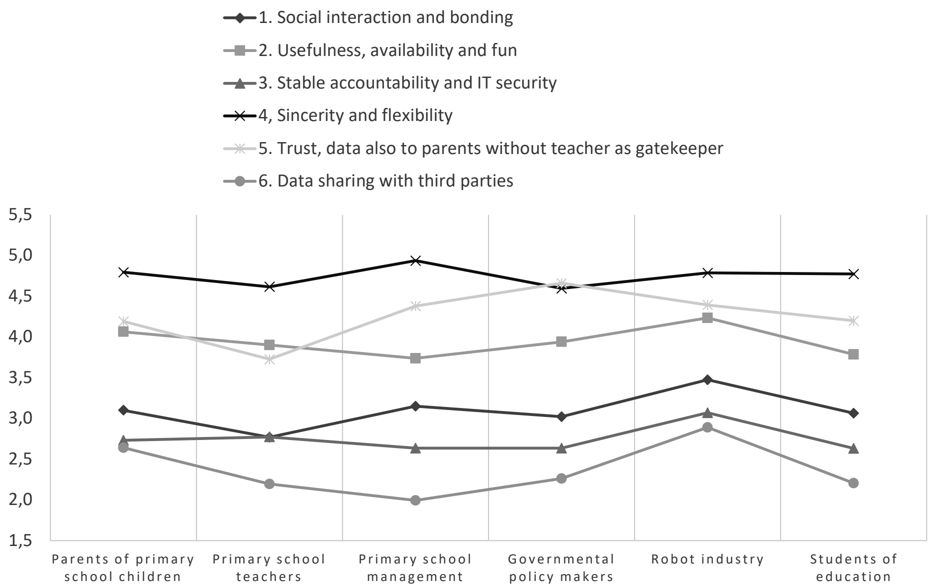

Figure 4.2. Stakeholder means for all six scales; based on 1-6 point scales (ranging from 1 = totally not agree, 6 = totally agree).

As can be seen in Figure 4.2, the scores for most scales differ among the six stakeholder groups. More specifically, on average, all stakeholder groups rank lowest on scale 6, reflecting 'Data sharing with third parties'. Then, they also score low on scale 3 (i.e., Stable accountability and IT safety), except for teachers. Finally, they score in the middle on scale 1 (i.e., 'Social interaction and bonding'). Compared to the aforementioned three scales, all stakeholder groups score higher on scale 2 (i.e., 'Usefulness, availability and fun'), scale 5 (i.e., 'Trust, data also to parents without a teacher as the gatekeeper'), and on scale 4 (i.e., 'Sincerity and flexibility').

With regards to specific differences, the results of the post-hoc test confirm that:

- For scale 1 (Social interaction and bonding), the employees of the robotics industry score significantly higher than teachers and government policymakers.
- For scale 2 (Usefulness, availability and fun), the employees of the robotics industry score significantly higher than primary school management and students of education.
- For scale 3 (Stable accountability and IT security), the employees of the robotics industry score significantly higher than government policymakers and students of education.
- For scale 4 (Sincerity and flexibility), there are no significant differences by group.
- For scale 5 (Trust, data also to parents without a teacher as the gatekeeper), teachers score significantly lower on this scale than all other groups. Also, government policymakers score significantly higher than parents with children in primary education, and students of education.
- For scale 6 (Data sharing with third parties), the robotics industry show a significantly higher mean than primary school teachers, primary school management, and students of education. Also, parents with children in primary education have a significantly higher mean than primary school management.

In summary, in relation to RQ1, there are significant differences with regards to the attitudes of stakeholders on the moral issues related to social robots in education. However, some similarities can also be found. Overall, the stakeholders seem most concerned about issues related to data sharing with third parties, the effect robots could have on the accountability system in schools, IT safety, and social interaction and bonding. What is more, the stakeholders also considered robots useful, fun, and objects that should be made widely available. They also considered it important that the robots are trustworthy and sincere towards children, and that the robot is flexible (movable).

4.4.2 Cluster Analysis

To answer RQ2 (How can the attitudes related to the moral issues be categorised?), we performed a cluster analysis on the six constructed scales (shown in Table 4.3) to identify groups among the respondents with regards to attitudes on moral issues related to the use of social robots in schools. Initially, we applied hierarchical clustering to the data using Ward's method (Ward, 1963). The agglomeration schedule, the dendrogram, and the icicle plot suggested a solution with two or four clusters. However, in both cases, one of the clusters contained almost all observations (504 and 510 respectively) and the remaining cluster(s) contained 5 observations or fewer. As clusters with such small sizes are very difficult (or even impossible) to work with, we decided to switch to a partition-based clustering, specifically k-means clustering (Lloyd, 1982). In doing so, we considered multiple solutions with the number of clusters ranging from two to ten. Based on the plot of the within-cluster sum of squares against the number of clusters, we decided that the solutions with five and six clusters fit the data best. We then decided to only keep the solution with five clusters as this provided more clearly distinguishable and evenly sized clusters.

The results of the k-means cluster analysis with $k = 5$ are shown in Table 4.5. In the table, a higher positive score indicates a positive or favourable attitude towards the construct that the scale represents or measures, while a higher negative score indicates a negative, unfavourable attitude towards it. For example, the relatively high score on scale 1 (*Social interaction and bonding)* of respondents belonging to cluster one, indicates that these respondents have a positive attitude towards robots having social interaction and allow for the robot to bond with children. The relatively high negative score on scale 4 (*Sincerity and Flexibility)*, indicates that participants in this cluster consider robots inappropriate for social interaction and bonding.

Based on their respective scores on the six scales considered (shown in Table 4.5), we named the identified clusters as follows: 1) Enthusiast, 2) Practical, 3) Troubled, 4) Sceptic, and 5) Mindfully Positive. The description of each cluster is provided below.

Enthusiast (cluster 1). Enthusiast (n = 135) show relatively positive attitudes towards the use of social robots in education. They consider the robots' capacity for social interaction and bonding with children to be useful and safe. The results also indicate that they believe robots should be universally usable and fun. They have no strong opinions on the impact of social robots on IT security and accountability. In general, the Enthusiast also have no strong views on whether robots should be trustworthy and sincere to children, or flexible (movable). Finally, they consider data sharing with third parties (e.g., the government and robot industry) relatively non-problematic.

Table 4.5. Final cluster centres per scales, including cluster size.

	Clusters					
Scales	*Mean Cl 1 Enthusiast (n = 135)*	*Mean Cl 2 Practical (n = 87)*	*Mean Cl 3 Troubled (n = 143)*	*Mean Cl 4 Sceptic (n = 33)*	*Mean Cl 5 Mindfully Positive (n = 117)*	*Overall Mean (N = 515)*
1. Social interaction and bonding	3.70 (SD 0.66)	2.60 (SD 0.67)	2.71 (SD 0.54)	1.73 (SD 0.52)	3.69 (SD 0.56)	3.11 (SD 0.86)
2. Usefulness, availability and fun	4.37 (SD 0.52)	3.86 (SD 0.54)	3.69 (SD 0.56)	2.31 (SD 0.70)	4.31 (SD 0.54)	3.95 (SD 0.76)
3. Stable accountability and IT safety	2.97 (SD 0.72)	2.85 (SD 0.67)	2.26 (SD 0.54)	2.39 (SD 1.54)	3.02 (SD 0.73)	2.73 (SD 0.82)
4. Sincerity and flexibility	4.89 (SD 0.55	4.43 (SD 0.69)	5.07 (SD 0.44)	3.43 (SD 1.42)	4.82 (SD 0.65)	4.75 (SD 0.77)
5. Trust, data also to parents without teacher as gatekeeper	4.33 (SD 0.67)	3.43 (SD 0.65)	4.34 (SD 0.78)	5.11 (SD 0.89)	4.60 (SD 0.65	4.29 (SD 0.83)
6. Data sharing with third parties	3.93 (SD 0.70)	3.13 (SD 0.74)	1.41 (SD 0.55)	1.11 (SD 0.30)	1.57 (SD 0.57)	2.38 (SD 1.27)

Practical (cluster 2). The Practical (*n* = 87*)* are shown to have no strong views about robots being universally usable or fun, or on the impact they might have on IT security and accountability. Similarly to the Enthusiast, they also consider data sharing with third parties to be non-problematic, although to a lesser extent. However, unlike those in cluster 1, they do consider social interaction and bonding with robots undesirable. This could imply that this group sees robots more as a technological tool, rather than as social actors. This could also explain why this group does not deem it necessary for robots to be trustworthy and sincere to children.

Troubled (cluster 3). The Troubled (*n* = 143*)* group refers to individuals with strong views against sharing data with third parties. Furthermore, respondents belonging to this cluster believe that robots should not be used for social interaction and they should not bond with children. They consider the robot disruptive to the stability of the schools' accountability and IT security systems. With regards to sincerity and flexibility, they find it important that the robot is sincere to children and easy to move.

Sceptic (cluster 4). The Sceptic (*n* = 33) are the group with the least positive attitudes towards the use of social robots in education. They consider the robots' capacity for social interaction and bonding with children inappropriate and potentially dangerous. Furthermore, they believe that robots should not be universally usable or fun. They also consider the impact of robots on IT security and the stability of the schools' current accountability system worrisome. According to them, social robots should be trustworthy and should not pass on secrets told by children to others (e.g., teachers). Lastly, they consider it problematic to share data collected by the robot with third parties.

Mindfully Positive (cluster 5). The Mindfully Positive (*n* = 117), like the Enthusiast, are characterised by relatively positive attitudes towards robots. They consider social interaction and bonding to be non-problematic, they think robots are fun and should be made widely available, and they consider the impact on accountability and IT safety to be low. However, they are also cautious about and disapproving of the sharing of data with third parties. Finally, they think robots should be honest to children and not keep information away from them, and they also believe that secrets told by children to the robot should not be passed on.

In summary, in relation to RQ2, the attitudes related to moral issues regarding social robots in education can be categorised into five clusters. One cluster has strong positive attitudes (Enthusiast), while another cluster has strong negative attitudes towards social robots in education (Sceptic). The remaining three clusters do not have a strongly dismissive attitude toward the use of social robots in education, although they each have their own moral issues they consider relevant and important.

4.4.3 Descriptive analysis of the socio-demographic characteristics of each cluster

To answer RQ3 (which socio-demographic characteristics influence the attitudes of stakeholders on the moral issues related to social robots in education?), we first examined the distribution of stakeholders and socio-demographic characteristics across the five clusters and then conducted a logistic regression analysis (which is described in the following section).

The distributions of stakeholder group, age, gender, income, education, and experience with robots across the five clusters are summarised in Table 4.6; for each of the characteristics, the highest value across the five clusters is presented in bold and the lowest are italicised.

Table 4.6. Distribution of socio-demographic characteristics per cluster.

Socio-demographic characteristics		*Cluster (CL)*				
		Cl 1 Enthusiast	*Cl 2 Practical*	*Cl 3 Troubled*	*Cl 4 Sceptic*	*Cl 5 Mindfully Positive*
Stakeholder group	Parents with primary school children	**22%**	20%	*11%*	18%	20%
	Primary school teachers	*7%*	**28%**	14%	9%	*7%*
	School directors/ management	10%	*3%*	**18%**	15%	14%
	Government policymakers/advisors	15%	*14%*	17%	**30%**	20%
	Employees of robotics industry	**20%**	6%	*5%*	6%	12%
	Students of education	14%	18%	**24%**	18%	*12%*
	Other	12%	11%	10%	*3%*	**16%**
Experience with robots	No	*67%*	**92**%	82%	88%	69%
	Yes	**33**%	*8%*	18%	13%	31%
Gender	Male	45%	36%	*34%*	48%	**51%**
	Female	55%	63%	**66%**	52%	*49%*
Income	Low (< €2.816 p/m)	*20%*	31%	24%	**35%**	22%
	Middle (€2.816 - €5.632 p/m)	59%	55%	**66%**	57%	*52%*
	High (> €5.632 gross p/m)	18%	14%	10%	*9%*	**26%**
Highest finished education level	Secondary school	*9%*	**17%**	12%	13%	*9%*
	Vocational education (MBO)	11%	**18%**	*8%*	13%	9%
	University of Applied Sciences (HBO)	47%	43%	47%	**53%**	*39%*
	University of Science (WO)	32%	23%	32%	*22%*	**44%**

Note. Bold print indicates the highest value across the five clusters, the lowest are italicised.

With regards to the distribution of stakeholder groups, primary school teachers are underrepresented in the clusters Enthusiast, Mindfully Positive, and Sceptic, whereas they are overrepresented in the cluster Practical. However, in the Practical cluster, the school directors/management and the employees of the robotics industry are underrepresented. The employees of the robotics industry are also less present in cluster Troubled and the cluster Sceptic. Finally, the respondents belonging to the government policymakers/advisors are clearly more represented in the cluster Sceptic, compared to the other clusters.

Concerning age, we found that older people (>55) are underrepresented in the cluster Enthusiast, compared to the other age categories. Furthermore, there is a relatively large group of people aged older than 46 in the cluster Sceptic, compared to the younger age-groups. Those above 46 years of age are also underrepresented in the cluster Practical.

Regarding experience with robots, respondents with a little to no experience seem to be overrepresented in the clusters Practical, Troubled, and Sceptic, compared to the other two clusters.

For gender, clusters Enthusiast, Sceptic, and Mindfully Positive have a good gender balance. However, in cluster Practical and Troubled, there are more female than male respondents.

Concerning income, no major differences were found except for two: people with a high income are more represented in the cluster Mindfully Positive and people with medium income are more represented in the cluster Troubled.

Regarding education level, there are fewer respondents with low or medium education (secondary school or vocational education) in the cluster Mindfully Positive compared to respondents with a university education.

In summary, answering RQ3, the descriptive analysis provided some insights into the distribution of socio-demographic characteristics within each of the five clusters considered. Most importantly, parents with primary school children and employees of the robotics industry were more often represented in the Enthusiast group, primary school teachers in the Practical group, students of education in the Troubled group, and government policymakers/advisors were more often in the Sceptic group.

4.4.4 Logistic regression analysis

To determine which of the socio-demographic characteristics significantly predict group membership, we conducted a logistic regression analysis. The regressions used cluster assignment as the dependent variable and assessed the effect of aforementioned socio-demographic characteristics on the probability of belonging to a certain cluster. More specifically, in this final step, we made use of five binary logistic regression models, wherein for each of the regressions the dependent variable was defined as belonging to a specific cluster, as opposed to belonging to any of the four remaining clusters. Table 4.7 provides an overview of the regression analysis results (where the logit regression coefficients were transformed to odds ratios, for further details see (Field, 2018)).

Table 4.7. Effect of socio-demographic characteristics on the probability of belonging to a specific cluster.

Socio-demographic characteristics	*Odds Ratio (OR)*				
	Cl 1 Enthusiast	*Cl 2 Practical*	*Cl 3 Troubled*	*Cl 4 Sceptic*	*Cl 5 Mindfully Positive*
Stakeholder: Parents with children in primary school	1.023	1.478	0.456	4.562	1.228
Stakeholder: Primary school teacher	0.305**	6.525***	1.076	1.416	0.497
Stakeholder: Primary school director/management	0.581	0.423	1.865	3.092	1.210
Stakeholder: Government policymakers	0.714	1.116	1.151	7.627*	0.878
Stakeholder: Robot industry	1.850	0.937	0.482	4.523	0.634
Stakeholder: Student of education	0.846	1.182	2.720**	3.013	0.322**
Age: 18-25	0.928	1.560	0.535	0.079**	3.353*
Age: 26-35 years	0.980	1.627	0.899	0.107**	1.467
Age: 36-45 years	0.988	1.331	0.963	0.502	1.001
Age: 46-55 years	1.639	1.070	0.748	0.570	0.810
Experience with robots: Yes	1.742**	0.241***	1.040	0.682	1.253
Gender: Male	0.770	1.076	1.026	1.431	1.155
Highest finished education: Secondary school	0.953	3.667**	0.878	2.552	0.433
Highest finished education: Vocational education (MBO)	1.166	2.792**	1.024	1.947	0.343**
Highest finished education: University of Applied Sciences (HBO)	1.103	1.393	1.057	2.877*	0.569**
Income: low	0.853	0.538	1.627	27.864***	0.512
Income: medium	0.959	0.528	2.624**	4.174*	0.475**

*Notes. (*** = Sig . < 0.01; ** Sig. < 0.05; * Sig. < 0.10).* Ref. categories: Stakeholder group: Other, Age: >55; Experience with robots: No; Gender: Female; Highest finished education: University of Science (WO); Income: high

Cluster 1, Enthusiast. The results of the first regression analysis (DV: belonging to cluster one), suggest that teachers are significantly less likely to belong to cluster one (Enthusiast) compared to the other stakeholder groups ($OR = 0.305$ $p < 0.05$).

Furthermore, people who had experience with robots have a significantly higher likelihood of belonging to this cluster of the Enthusiast compared to those with little to no experience ($OR = 0.574$ $p < 0.05$).

Cluster 2, Practical. The results of the second regression (DV: belonging to cluster two), suggest that being a teacher (as opposed to belonging to the 'other' stakeholder group) and having little to no experience with robots (compared to having experience) significantly increases the likelihood of belonging to cluster 2 ($OR = 6.525$ $p < 0.01$ *and* $OR = 4.143$ $p < 0.01$). Furthermore, having Secondary school or Vocational education (MBO) as highest level of completed education, significantly increases the likelihood of belonging to this group of Practicals compared to having a degree of a University of Science (WO) ($OR = 3.667$ $p < 0.05$ *and* $OR = 2.792$ $p < 0.05$).

Cluster 3, Troubled. For cluster three, Troubled, the regression analysis showed that being a student of education (as opposed to belonging to the 'other' stakeholder), and having a medium (rather than high) income both increase the likelihood of belonging to the Troubled cluster ($OR = 0.720$ $p < 0.05$ *and* $OR = 2.624$ $p < 0.05$).

Cluster 4, Sceptic. The probability of belonging to cluster four is shown to be significantly, positively affected by having a low income (as opposed to high) ($OR = 27.864$ $p < 0.01$). Additionally, being under 35 significantly decreases the likelihood of belonging to this cluster, compared to being older than 55 (age: 18-25 ($OR = 0.079$ $p < 0.05$) and age: 26-35 ($OR = 0.107$ $p < 0.05$)). The results further suggest a trend, wherein government policymakers (rather than the 'other' stakeholder groups), individuals with an education at the level of University of Applied Sciences (HBO) (as opposed to those with a University of Science degree (WO)) and those with a medium income (compared to high income) are more likely to belong to the Sceptic cluster ($OR = 7.627$ $p < 0.1$ *and* $OR = 2.877$ $p < 0.1$ *and* $OR = 4.174$ $p = <0.1$)

Cluster 5, Mindfully Positive. The regression analysis revealed five significant results for the cluster. Being 18-25 years of age (as opposed to older) significantly increased the likelihood of belonging to this cluster ($OR = 3.353$ $p < 0.05$). The probability of belonging to this cluster is shown to be significantly negatively affected by being a student of education ($OR = 0.322$ $p < 0.05$), having a vocational education (MBO) or university of Applied Sciences (HBO) education as highest education (compared to University of Science - WO) (*OR* = 0.343 $p < 0.05$ *and OR* = 0.569 $p < 0.05$). Lastly, having a medium income also had a negative effect on the likelihood of belonging to the Mindfully Positive cluster of Mindfully Positive (compared to low or high income) (*OR* = 0.475 $p < 0.05$).

In summary, answering RQ3, the logistic regression analysis showed which socio-demographic characteristics influence the attitudes of stakeholders. With regards to stakeholder groups, teachers were significantly less likely to belong to the Enthusiast group, and significantly more likely to belong to the Practical group. Government policymakers/advisors show a trend for belonging to the Sceptic group. Other socio-demographic characteristics that significantly affected the probabilities of belonging to a specific cluster included age, experience with robots, education level, and income.

4.5 DISCUSSION AND CONCLUSIONS

This study aimed to examine and categorise the moral issues of stakeholders related to the use of social robots in primary education, and to examine the influence of various socio-demographic characteristics. To this end, we constructed a questionnaire that included items representing a comprehensive list of moral issues based on the relevant literature and earlier focus group sessions. Our results indicate that, although there are multiple issues that need to be addressed first, social robots have the potential to be implemented in education in a morally responsible way, while keeping in mind the attitudes of direct and indirect stakeholder on moral issues related to social robots in education.

Using psychometric analyses, we constructed six scales that measure attitudes regarding moral issues related to robots in education. Based on the content of the items, we labelled the scales as follows: 1) Social interaction and bonding, 2) Usefulness, availability and fun, 3) Stable accountability and IT safety, 4) Sincerity and flexibility, 5) Trust, data also to parents without a teacher as a gatekeeper, and 6) Data sharing with third parties. These scales cover 15 out of the 17 values that were extracted from the literature and focus group sessions (shown in Table 4.2). The construction of the six scales was based on the results of a Principle Component Analysis (PCA), which was conducted using the questionnaire responses regarding attitudes and opinions about social robots and their use in education. It is important to note that, given the exploratory nature of our study, our results do not provide a comprehensive overview of all the moral issues surrounding the topic, especially given the complex and multi-layered nature of these issues, that often also depend on specific wording. Nevertheless, our results do provide valuable insights into numerous moral issues related to social robots in education and they serve as a starting point for future research that aims to further investigate the moral issues related to implementing robots in education.

The scales constructed were used to measure the attitudes of the following six stakeholder groups: 1) parents with primary school children; 2) primary school teachers; 3) school directors/management; 4) government policymakers/advisors; 5) employees of the robotics industry, and 6) students of education. In this study, stakeholders were grouped based on their role (e.g., teacher, parent, or policymaker) and further based on their interactions with the robots (i.e., direct vs. in-direct). Alternatively, the stakeholders could also be divided based on their priorities and/or underlying interests. However, given the lack of literature on these aspects, we chose a division based on role and robot interaction. It is important to note that our division could result in a situation wherein stakeholders who belong to the same group have different opinions related to moral issues regarding the use of social robots in education. Therefore, further research focusing on these moral issues should also include an analysis of the interests and priorities of stakeholders, which could potentially lead to a more detailed and disaggregated division of stakeholders. Finally, as this is an exploratory study, future research should also test and assess the validity of the questionnaire used and the scales constructed.

In the following section, we will first discuss the results of our analysis in relation to the three research questions of this study: RQ 1) what are the attitudes of stakeholders on the moral issues related to social robots in education, RQ 2) how can the attitudes related to the moral issues be categorised, and RQ 3) what socio-demographic characteristics influence the attitudes of stakeholders on the moral issues related to social robots in education? Then, we will elaborate on the (practical) implications of our study for the application of social robots in primary education.

4.5.1 RQ1, Stakeholder attitudes

In answering RQ1, we found both similarities and (significant) differences among stakeholder groups in terms of their attitudes regarding moral issues related to robots in education. Overall, stakeholders considered robots useful and fun, and expressed that robots should be made widely available for schools. Usefulness is shown to be strongly correlated with usage behaviour (Davis, 1989); therefore, the relatively high overall score on the scale that included usefulness appears promising for the actual use of social robots.

The stakeholders also showed relatively positive attitudes regarding the need for robots to be trustworthy and sincere towards children and keep promises made to children; they also acknowledged the need for the robot to be flexible (movable). The moral issues stakeholders seemed most concerned about were data sharing with third parties, the effect robots could have on the schools' accountability systems and IT safety, and lastly, the social interaction and bonding of children with robots.

It is worthwhile mentioning that the employees of the robotics industry were relatively cautious about the data sharing aspect, although they were significantly less negative than primary school teachers, school directors/management, and students of education. Earlier research (Goudzwaard et al., 2019) reported that employees of the robotics industry believe that such data is valuable for the improvement of their products and services. Our results add to this literature by showing that, although the data can be seen as valuable, even the employees of the robots' industry consider the sharing of data with third parties as potentially problematic. Teachers had significantly more negative attitudes related to the ideas of the robot being trustworthy, and the data being shared with parents without a teacher as gatekeeper than all other stakeholder groups. This could be explained by the finding that teachers view themselves as the gatekeepers of children's data, as has been reported in previous studies (Van Ewijk et al., 2020).

All stakeholders consider social robots potentially disruptive for the schools' accountability structures and are concerned about the impact of robots on IT security. Interestingly, stakeholders from the robot industry, representing the manufacturers of robots, were the group that considered robots to be the least disruptive for the schools' accountability structure or IT security (significant difference compared to government policymakers, and students of education). This might be explained by the experience that employees of the robot industry have with robots as well as their technological knowledge. However, the difference could also be explained by a potential lack of insights about the school systems. With regards to social interaction and the bonding of children with robots, no strong positive or negative attitudes were found among the stakeholder groups. This could indicate a cautious, but not dismissive, attitude towards the idea of children socially interacting and bonding with robots.

4.5.2 RQ2, Five types of moral attitudes towards social robots in education

When answering RQ2, we found five types of attitudes on moral issues related to the use of social robots in education, which we labelled as follows: Enthusiast, Practical, Troubled, Sceptic, and Mindfully Positive.

The Enthusiast group represents the most positive attitude towards social robots, whilst the Sceptic group represents the most negative one. These two groups can also be found in the literature, where some stakeholders are strongly in favour of social robots (Sumioka et al., 2017), while others have highly negative associations (Kennedy, Lemaignan, et al., 2016; Reich-Stiebert & Eyssel, 2016; Serholt et al., 2017).

The other three clusters show no strong dismissive attitudes towards social robots in education, although they each have their own moral issues that they consider relevant. The Practical group considers robots to be useful, but not for social interaction and bonding. The Troubled group has strong negative attitudes towards the sharing of data with third parties. Furthermore, the Troubled believe that robots should not be used for social interaction. They consider robots to be disruptive to the stability of the school's accountability systems and their IT security. With regards to sincerity and flexibility, individuals belonging to the Troubled group deem it important that the robots be sincere to children and easy to move. In contrast, the Mindfully Positive consider social interaction and bonding with robots to be non-problematic, they think robots are fun and should be made widely available; they also consider the robots' impact on accountability systems and IT safety to be low. However, they are sceptical about the sharing of data with third parties. Finally, they think robots should be honest to children and they should not keep information from them; they also believe that secrets told to the robot by the children should not be passed on.

4.5.3 RQ3, which socio-demographic characteristics influence the attitudes of stakeholders

In answering RQ3, we found that several socio-demographic characteristics significantly predict the attitudes of respondents on the moral issues related to social robots in education.

With regards to the stakeholder groups, teachers were significantly less likely to belong to the Enthusiast group, while they were significantly more likely to belong to the Practical group. This finding seems to be in line with previous research, which indicates that some teachers consider robots more as tools than social actors (Diep et al., 2015). This could be explained by the lack of experience with robots as 92% of all individuals in the Practical group, which was dominated by teachers, had no to little experience with robots. These attitudes have the potential to change once teachers become more exposed to robots; to illustrate, a study has shown that having been introduced to robots and informed about their abilities, teachers viewed them as harmless tools, much like hand puppets (Van Ewijk et al., 2020). It might therefore be advisable, when deciding to use social robots in education, to first familiarise teachers with this technology and initially use robots only as tools. Then, once teachers are experienced with the use of robots as tools, these robots can potentially be used for social interaction as well. Another potential explanation could be related to the teachers' lack of self-confidence regarding the basic knowledge needed to use social robots. These confidence issues are likely a result of the fact that the ICT proficiency of teachers appears to not keep up with rapid technological change and the opportunities it brings about in education (Hsu, 2017). Increasing familiarity with these new technologies, during workshops and/or small-scale lectures, can provide teachers with the necessary (basic) knowledge and consequently improve their self-confidence (Scaradozzi et al., 2019). To ensure that the implementation of social robots in education is successful, it is also crucial to allow teachers to commit a significant amount of time to the integration of educational technologies in their teaching. The importance of this aspect stems from the fact that teachers who are early adopters of technology and who are given sufficient time to incorporate the technology in their teaching are shown to be more likely to adopt new technologies, even when they are complex (Aldunate & Nussbaum, 2013).

Our analysis also revealed that government policymakers were most likely to belong to the Sceptic group. The members of this group find it problematic that data about children can easily be shared via the robot with third parties, such as the government. This is an interesting finding as earlier research (Smakman, Berket, et al., 2020) suggests that government policymakers have considered such data sharing to be a potential benefit of the use of social robots in education. The Sceptic cluster also had the least favourable attitude towards making robots widely available. This could be explained by the ability of policymakers to foresee the consequences of such a policy on a broader (national/regional) scale, compared to the other stakeholders.

Moreover, this group of government policymakers also contained the largest proportion of people aged 46 and above. Young people (18-35 years of age) were significantly less likely to belong to this Sceptic group. This is consistent with earlier research results showing that younger people are more accepting of robots than older people (European Commission, Directorate-General for Communication, 2017). In contrast, students of education, despite being young, were significantly more likely to belong to the Troubled group and significantly less likely to belong to the Mindfully positive group, whereas in general, the youngest group (18-25 years of age) shows a trend towards belonging to the Mindfully positive group.

In line with previous research (European Commission, Directorate-General for Communication, 2017), we found that having experience with robots had a significant effect on the likelihood of belonging to the most positive group, the Enthusiast cluster. Other significant results were found for education level and income. Namely, people with low income were significantly more likely to belong to the Sceptic group, while people with medium income were more likely to belong to the Troubled group and less likely to belong to the Mindfully positive group. The negative attitude of people with low income is also found in the literature (European Commission, Directorate-General for Communication, 2017), and can be explained by concerns related to the robots not being universally accessible, as had been reported by parents (Smakman, Jansen, et al., 2020). Individuals with a University of Applied Science degree showed a trend of belonging to the Sceptic group and were significantly less likely to belong to the Mindfully positive group. This finding seems to contradict earlier research that reports a more positive attitude towards robots by those with higher education (European Commission, Directorate-General for Communication, 2017). This could potentially be explained by the suggestion that respondents with higher education might be potentially more knowledgeable about the impact of social robots in education.

4.5.4 Implications for the design and implementation of social robots in (primary) education

Based on the results of our study, we can derive seven implications for future research and practice. Please note that this study was solely conducted in The Netherlands and that attitudes might differ among countries and cultures (Choi et al., 2008). For worldwide implications, future research should explore the attitudes of stakeholders in different countries and cultures and examine how they differ depending on the country or cultural context considered.

A first implication of our results is that robots should be honest to children and keep promises made to them. In line with this, robots should keep secrets told to them by the child, and not share these with parents or teachers. A second implication is that social robots are overall considered useful and fun and should be made widely available for schools. Only a small group of sceptics have negative attitudes related to this. The scepticism might be explained by the implications this would have on a national or regional policy level, such as cost implications. If so, the attitudes of government policymakers (who are more likely to belong to this group of sceptics), might change when robots would first be made available at schools for experimental use only. Third, robots should not share data with third parties, such as the government or robotics companies and manufacturers that could use the data to improve their policies or products. Fourth, future research should examine the IT security risks and the impact on schools' accountability systems of the use of social robots in schools, as this is a concern raised by many of the stakeholders. A fifth implication of our results is that the utilisation of robots that socially interact with children and form social bonds with them should be approached with caution as many stakeholders, including teachers, have relatively negative attitudes towards this. Given that experience with robots increases the likelihood to have a more positive attitude to this issue, it is advisable to first familiarise stakeholders with social robots. This could be done by first using robots as tools rather than as social actors, which the vast majority of the survey participants is not opposed to. Sixth, schools in areas with lower economic status might expect more sceptical stakeholders, given that low income is a strong predictor of belonging to the Sceptic group. A seventh and last implication is that schools might turn to their younger employees first for the adoption of social robots, as they are less likely to belong to the Sceptic group.

The implications mentioned above provide valuable insights into how social robots should be implemented, while keeping in mind the considerations related to moral issues of direct and indirect stakeholders. This can be seen as a first step towards the creation of moral guidelines for the use of social robots. Future research should focus on translating these insights into more robust design and implementation requirements for the robotics industry and for schools, thereby ensuring they have the right tools to responsibly design and implement this new promising educational technology.

CHAPTER 5

DO ROBOTIC TUTORS COMPROMISE THE SOCIAL-EMOTIONAL DEVELOPMENT OF CHILDREN?

This chapter is published as: Smakman M.H.J., Konijn E.A. & Vogt P.A. (2022) Do Robotic Tutors Compromise the Social-Emotional Development of Children? *Frontiers in Robotics and AI*.; 9:734955. doi: 10.3389/frobt.2022.734955.

Abstract. Social robots are reported to hold great potential for education. However, both scholars and key stakeholders worry about children's social-emotional development being compromised. In aiming to provide new insights into the impact that social robots can have on the social-emotional development of children, the current study interviewed teachers who use social robots in their day-to-day educational practice. The results of our interviews with these experienced teachers indicate that the social robots currently used in education pose little threat to the social-emotional development of children. Children with special needs seem to be more sensitive to social-affective bonding with a robot compared to regular children. This bond seems to have positive effects in enabling them to more easily connect with their human peers and teachers. However, when robots are being introduced more regularly, daily, without the involvement of a human teacher, new issues could arise. For now, given the current state of technology and the way social robots are being applied, other (moral) issues seem to be more urgent, such as privacy, security and the workload of teachers. Future studies should focus on these issues first, to ensure a safe and effective educational environment for both children and teachers.

5.1 INTRODUCTION

Social robots are gradually being introduced in primary education. They provide new opportunities for improving cognitive outcomes, such as learning a second language (Konijn et al., 2022; Vogt et al., 2019), rehearsing the times tables (Konijn & Hoorn, 2020), learning sign language (Luccio & Gaspari, 2020) and training handwriting (Aktar Mispa & Sojib, 2020). In addition, social robots are used to support motivational and affective elements of learning (e.g., the learner being attentive, receptive, responsive, reflective, or inquisitive) (Belpaeme, Kennedy, et al., 2018). Although social robots show potential as learning or teaching companions for children, according to a recent literature review (Johal, 2020), other studies on the use of social robots in education have reported that it is too early to conclude that robots are, for instance, effective as language tutors (Van den Berghe et al., 2019), or more effective than human teachers or other types of technology (Woo et al., 2021). Furthermore, both scholars (Sharkey, 2016; Woo et al., 2021) and stakeholders (Smakman et al., 2021) have voiced concerns related to social robots potentially harming children's social-emotional development.

Social robots differ from other types of robots used in education, such as STEM robots. Other than STEM robots, social robots are designed to take on social roles such as that of a tutor or peer that assists children during their learning process. Having physical embodiment, the option to act (semi-) autonomously, and the capability to interact with humans by following social norms, can be considered as the three defining capacities for social robots (Hegel et al., 2009). Using these capacities, a robot can act as a social entity, such as in the role of a tutor, a peer, or that of a naïve learner (Hood et al., 2015). The feeling that users are socially connected with robots is central to the field of social robotics (Belpaeme, Baxter, Read, et al., 2013).

Children's social-emotional development is not only important during childhood, but also for adulthood and public health, because it is associated with substance abuse, mental health, workplace and academic performance (Cherniss, 2000; Denham, 2006; Tremblay, 2020). Children's social-emotional development can be characterised by five domains: 1) social competence, 2) attachment, 3) emotional competence, 4) self-perceived competence, and 5) temperament/personality (Denham et al., 2009). Milestones in social-emotional development domains differ per developmental period of children. For the purpose of this study, we will focus on the milestones associated with the primary school period. The first domain, social competence, can be defined as a child's ability and effectiveness in social interaction (Rose-Krasnor, 1997). Children's general developmental tasks related to social competence that should be assessed in primary school are the formation of dyadic friendships, solidification of peer status, and general diminution of physical aggression. Related to attachment, children in primary school should begin to balance the connection to parents and peers. The milestones for children in primary school related to emotional competence are the ability to understand complex emotions, such as unique perspective and ambivalence, and to be able to apply cognitive strategies to regulate emotions. Children's self-perception of competence can be defined as *"one's evaluations of one's own abilities, including the child's own assessment of his/her cognitive, physical and social abilities, especially in comparison with those of others"* (Denham et al., 2009, p. 44). During primary school, children's views of their own competence become more complex, earlier notions of self-perceived competence are solidified and social evaluations by peers and teachers become more important (Denham et al., 2009). Lastly, for the domain temperament/personality, children's personality attributes become increasingly differentiated during primary school. In earlier research, social robots have been reported to potentially influence several aspects of the social-emotional development domains, such as social competence (Peter et al., 2021) and attachment (Coeckelbergh et al., 2016)

Key stakeholders, such as teachers, parents, and policymakers, have also voiced concerns related to the potential social-affective bond that children may develop with a robot (Serholt et al., 2017; Smakman, Berket, et al., 2020; Smakman, Jansen, et al., 2020). They report worries in the field that such a bond could harm children's social-emotional development (Smakman et al., 2021). Children bonding with robots could lead to children preferring the interaction with robots over that of their human friends and teachers, potentially resulting in the loss of human contact (Pandey & Gelin, 2017; Sharkey, 2016), social isolation (Kennedy, Lemaignan, et al., 2016) and dehumanisation (Serholt et al., 2017). Children could also start to expect too much from robots, which could lead to children ending up feeling deceived or feeling anxious when the robot is absent (Sharkey, 2016). These potential risks related to the social-affective bond that children may develop with a robot might harm the children's social-emotional development. According to a recent study (Pashevich, 2021), it is still unclear what kind of effect social robots might have on the social-emotional development of children.

Children have been reported to perceive social robots as entities with whom they will likely form social relationships (Van Straten et al., 2020). What kind of relationships children form with robots is still unclear. For example, children are reported to perceive social robots as potential private tutors (Shin & Kim, 2007), possible rivals (Shin & Kim, 2007), and even friends (Y.-C. Lin et al., 2009). Various scholars argue that this newly perceived bond with technology might influence children's behaviour, both positively and negatively. Researchers have found that robots seem able to elicit socially desirable behaviour among children, such as sharing, but they may also elicit socially undesirable behaviour, such as aggressive behaviour (Peter et al., 2021). Children have also been recorded to express bullying behaviour towards an educational robot (Kanda et al., 2012) and others have expressed concerns related to the robot becoming a bully or becoming subject to bullying (Diep et al., 2015). What type of children are more susceptible to the influence of the robot on social-emotional domains, however, is still unclear. According to a recent study (Tolksdorf, Viertel, & Rohlfing, 2021), the influence of individual variables, such as shyness, are still understudied in the field of child-robot interaction.

Measuring social-emotional development is complex. For each domain of children's social-emotional development, there exist multiple measurement instruments such as the *Rothbart Child Behaviour Questionnaire* for emotional competence (Putnam & Rothbart, 2006), and the *Social Skills Rating System* for social competence (Van der Oord et al., 2005). Furthermore, these scales differ per developmental period and pose challenges in their use in longitudinal studies (Denham et al., 2009). Child-robot interaction (CRI) studies in education are often short-term studies and rarely deploy robots for more than a few days, according to reviews on social robots in classrooms (Rosanda & Istenič Starčič, 2019; Woo et al., 2021). Systematic, long-term evaluation of the potential negative impact of social robots' potential on children's social-emotional development is lacking. This might be explained by social robots still being a nascent technology. An accepted approach to evaluate the potential long term (negative) impact of nascent technology is to include stakeholders into the design and evaluation of technology (Friedman et al., 2008).

Teachers are one of the most important stakeholders when implementing social robots in education. They are not only responsible for the learning process in a classroom, but they also play a key role in children's social-emotional development (Denham et al., 2009). They could therefore provide insights into the potential compromising role of social robots. However, in the extant literature on teachers' perspectives on social robots, teachers have had little experience with robots (Chootongchai et al., 2021; Van Ewijk et al., 2020; Xia & LeTendre, 2020). Additionally, researchers have pointed out that the level of experience with robots could influence stakeholders' perspectives (Serholt, Barendregt, et al., 2014). People with experience to working with robots are significantly more likely to have a positive attitude towards social robots, compared to people with little to no experience (Smakman et al., 2021). This makes it hard to evaluate the potential harms and benefits voiced by teachers in earlier studies.

The lack of experience of stakeholders combined with the limited empirical data, make it hard to evaluate the reported potential risks related to children's social-emotional development. Given that studies are often short-term and stakeholders' worries are hard to evaluate, there is a need to examine the impact that social robots have on children's social-emotional development now that social robots are entering day-to-day education for longer periods of time. Therefore, this study aims to assess the impact of social robots in primary education on the social-emotional development of children. To this aim, we conducted in-depth interviews with teachers who have applied social robots in their day-to-day education. These primary school teachers all have a thorough knowledge of the social-emotional development of the children in their classroom, as this is part of their daily job. Therefore, in our opinion, they are most appropriate persons to assess the impact of social robots on children. Besides the impact on children's social-emotional development, we examined which children, according to the teachers, would be more susceptive to social robots, and what the teachers would consider best practices for using social robots responsibly. In the next section, we will first describe our methodology, followed by our results. Thereafter, we will discuss our main findings in light of earlier research and discuss our conclusions.

5.2 MATERIALS AND METHODS

5.2.1 Participants

For qualitative research, such as this interview study, participants can best be selected based on their understanding of the phenomenon (Creswell & Creswell, 2009; Kuper et al., 2008). Therefore, via purposeful sampling, participants were selected. The criterion for participants to be included in our study was: being a primary school teacher in the Netherlands with first-hand experience in using social robots in a real-life educational setting. Participants were recruited through newsletters of robotic companies, messages on social media, snowballing (Ghaljaie et al., 2017) and direct e-mails. Nine experienced teachers agreed to participate in our research (Mean age = 36; SD = 10; 8 Female, 1 Male). On average, they had 12 years of working experience, ranging from 1.5 years to 35 years. The participants ranked their own experience with robots on a 1–5-point rating scale (1 = having very little experience and 5 = having very much experience). The mean score for the experience with robots was 3.66 (SD = 0.82). In total, the participants supervised/facilitated the child-robot interaction of 2,660 primary school children from all primary school levels/grades. General information about the teachers who participated in the interviews is shown in Table 5.1.

Table 5.1. Data on participants in the interviews.

Interview #	Gender	Age	Experience as a teacher (years)	Experience with robots (1-5 scale)	Children interacting with a robot (*n*)
1	F	39	14	4	600
2	F	25	3	3	57
3	F	36	13	2	20
4	F	42	10	5	700
5	F	57	35	4	540
6	F	28	7	3	200
7	M	39	12	4	500
8	F	25	1,5	4	25
9	F	35	14	4	18

5.2.2 Materials and Measures

In setting up our interview guidelines (Taylor, 2005), we followed the five phases of the framework for the development of a qualitative semi-structured interview guide created by Kallio et al. (2016). First, we established that a semi-structured interview would be a rigorous data collection method in relation to our research question, because it allows the interviewer to improvise follow-up questions based on the teachers' answers and it allows room for participants' verbal expressions. Second, we created an initial set of questions targeting teachers' perspectives on the robot's influence on children's social-emotional development based on existing literature. These questions included four main themes. The first questions were related to the social demographic data of the participant, such as age and gender, because these are shown to influence people's perception of robots (European Commission, Directorate-General for Communication, 2017). The second type of questions was about how the teachers applied the robots in their classroom. These included which robot they used, but also what role the robot was given in the classroom. Earlier research has shown that children react differently to, for example, a robot as a peer, compared to that of a robot as a teacher (Zaga et al., 2015). Furthermore, role switching has also been shown to have potential as a motivational strategy (Ros et al., 2016). The third and fourth themes were related to the possible perceived social-affective bond of children with the robot and its potential influence on children's social-emotional development. After setting up the initial interview protocol, two expert scholars in social robotics reviewed the interview guide to validate the coverage and relevance of the content. Furthermore, as prescribed by Kallio et al. (2016), the feedback of the experts was used to reformulate the questions and to test the implementation. This resulted in the final list of interview questions, which can be found online (https://osf.io/qne96/).

5.2.3 Procedure and analysis

Over a span of two months, from February to April 2021, the data for this study were collected. Due to the COVID19 pandemic, all interviews were conducted online via Microsoft Teams. The interviews started with a short introduction about the purpose of the study, after which the questions started. As mentioned, the interviews were semi-structured (Kallio et al., 2016), which allowed us to deviate somewhat from the formal set of interview questions when needed, and to explore the thoughts and beliefs of participants in more detail. In general, each interview lasted between 45 minutes and 1 hour. At the end of the interview, we inquired whether participants would like to voice any other potentially relevant information related to child development and robots in education. Lastly, we asked participants if they could provide us with names of other teachers who had applied social robots in their education and might be willing to participate in this study. All interviews were recorded, for which all participants provided active verbal consent. Afterwards, the recordings were transcribed. All transcriptions were then analysed using an inductive and deductive coding process through a qualitative data analysis application (ATLAS.ti, version 9). To identify patterns within and across the data, we used a thematic analysis method (Braun & Clarke, 2012). First, we coded the text based on the main themes of the interview questions (participant data, use of robots, social-affective bond, and social-emotional development). Thereafter, we randomly read samples of the data and created thematic codes, shown in Figure 5.1. We then applied the codes onto new sample texts derived from our interview transcriptions. Using this iterative process, we created our final coding scheme which we applied to all data collected. The themes were coded by a scholar with considerable experience in conducting qualitative studies in social robotics and education. The final coding scheme can be found online (https://osf.io/qne96/). Lastly, the effects of the robots on children derived from the thematic analysis were linked to the appropriate domains of children's social-emotional development reported in the literature (Denham et al., 2009). This was done during a mapping workshop by the first author and two undergraduate students.

5.3 RESULTS

All participants had experience with applying humanoid robots in their education, being either with the Nao robot (SoftBank Robotics, 2020) or the Alpha mini-robot (Ubtech, 2021). One participant also had experience with other types of robots, such as the Innobot, Probot, Bluebot, Microbot, and Ozobot. Experience with applying robots ranged from six years to a couple of months. The participants had applied the robots in their day-to-day education for teaching children arithmetic, language, geography, presentation skills, physical education, and computational thinking. Eight participants had used the robots as a social entity (as a tutor or peer), sometimes combined with using the robot purely as a tool, such as for learning programming. One participant had used the robot just as a tool for teaching programming. The number of interactions with the robot per child ranged from just one to sixteen times per period of ten weeks. The time children had spent working with the robot ranged from 15 minutes to one hour per interaction. None of the participants systematically measured the effect of the robot during their lectures. The teachers used robots in all classes of the primary school, which included children from age 4 up to 12 years.

5.3.1 Place in education

Eight out of nine teachers mentioned that social robots (should) have a place in primary education. They considered the robot a good educational tool, mainly because it can enrich the lessons. *"Some children learn more easily from books, another child learns more easily from a screen with interactivity, and a robot gives an extra dimension to education [...] it is one of the means by which you prepare children for a future"* as one teacher indicated. The teachers overall stated that they viewed the robots as additional support for the teacher, or to provide help for solving problems (such as knowledge gaps) by means of targeted help. Teachers had applied the robot in small groups and in one-to-one interaction settings. Most teachers indicated that the robot has a clear novelty effect and that children are fascinated and amazed by the robot. Most of the teachers stated that the children are enthusiastic about the robot and are (more) motivated to work and learn with the robot.

One teacher did not consider social robots to have a place in primary education, for two reasons: 1) because of the high cost and 2) because of a lack of impact in primary education. Although the teacher stated that the robot does create a deeper kind of learning, because of the social interaction, she considered the robot best for special education. In special education, the teaching methods would be more open-minded for using robots and not so restricted and formalised as in regular primary education, according to this teacher. Three other teachers also indicated that the high cost of the NAO robot was an issue. Especially for teaching programming skills, they considered nonsocial or non-humanlike robots cheaper and therefore more appropriate.

Overall, the teachers indicated that the current social robots require a lot of work from the teacher. As one teacher explained: *"It is really labour-intensive for the person who sets up and prepares the robot, and this is still an impeding factor."* Teachers also indicated that it will take some time before other teachers are acquainted with robots because the educational methods change rapidly every few years, which also takes time to implement. Furthermore, the lack of evidence that robots are (more) effective makes it hard to convince school management to invest in the implementation of social robots, according to one teacher.

5.3.2 Impact on social-emotional development?

It should first be noted that none of the teachers systematically measured the robot's effect on the children's social-emotional development. Due to the relatively broad age range of the children that interacted with the robot (4 to 12 years), which covers both the primary school period and the preschool/early childhood period, and because the general developmental tasks that should be assessed in each dimension of social-emotional development differs for each developmental period, we decided to describe the perceived impact based on the themes derived from our thematic analysis (Braun & Clarke, 2012).

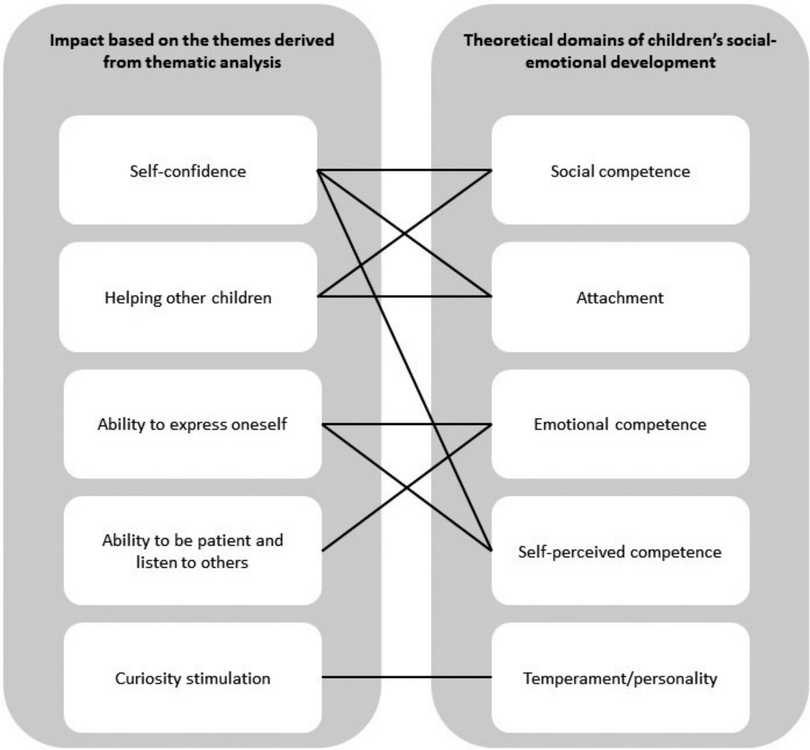

Figure 5.2. Overview of themes based on the interviews and the linked theoretical constructs of social-emotional development, based on the literature.

All teachers indicated that social robots can have a positive impact on the social-emotional development of children. They reported several examples of how children's social-emotional development could be affected by social robots, such as by boosting children's self-confidence and by increasing children's ability to express themselves. All reported impact was considered positive. Only a few occasions were reported where some (mainly young) children were afraid of the robot. Based on the thematic analysis, we were able to distinguish five positive effects which were reported by the teachers, being: 1) Self-confidence, 2) helping other children, 3) ability to express oneself, 4) ability to be patient and listen to others and 5) curiosity stimulation. Thereafter, we linked the themes to the appropriate domains of children's social-emotional development, shown in Figure 5.1. In the next sections, we will present the results based on the derived themes and discuss their potential effect on the theoretical domains of children's social-emotional development.

Self-confidence. Almost half of the teachers reported higher self-confidence as a positive result of child-robot interaction. Children who were shy to talk in public or in groups could give presentations together with the robot, which could bolster the self-confidence of the children. One teacher explained: *"giving presentations causes a lot of stress in children. I think it is good if you give them a choice, that they can give the presentation, in the first instance, completely by the robot, and then for example together, so that children, perhaps unconsciously, are presenting in front of groups. This way they will get used to it, in a very safe manner [...] you actually take away a lot of stress"*. Also, teachers indicated that children who are a bit shy or socially less capable, could become the robot expert of the class, which would boost their self-confidence: *"I could put children who are socially not very strong in the spotlight so that they would become a robot expert. They were then able to teach other children or help the teacher, so they grew in their whole being because of this..., this changed their [social] position and place in the group",* as one teacher explained. Furthermore, teachers reported that children more easily practice subjects they find difficult with the robot because a robot does not judge or laugh at them when they give a wrong answer. This is also reported to create more social interaction between children, as one teacher who used the robots for extra support in language learning described: *"We have a school where several children come from a different culture. They have difficulty speaking Dutch, and they don't speak Dutch at home. They find it difficult to speak in public, and a robot helps them with this and thus helps with their own language development, which also makes it easier for them to make contact with peers. That is what we have seen, it absolutely had an impact"*. None of the teachers reported negative outcomes related to the self-confidence of children. Although, some teachers reported practical issues related to the speech of the robot that sometimes lacks the proper pronunciation, especially with longer words.

The capability of the robot to contribute to children's self-confidence can be (in) directly linked to three of the five social-emotional domains. First, the increased social interaction between children, caused by the increased self-confidence of shy children, could lead to the formation of dyadic friendships, which is linked to the social-emotional domain of *social competence*. Furthermore, this could lead to a more balanced connection with their peers, which is related to the social-emotional domain of *attachment*. Lastly, the robot could contribute to the domain of *self-perceived competence*, because it could result in a child's increased ability to assess one's own social abilities in comparison with those of others.

Helping other children. Several teachers indicated that they applied the robot to enhance social interaction between children. For example, by giving some children the role of robot expert, they created a new role in the group. According to teachers, this did not only increase children self-confidence (cf. Section 3.2.1), but it also allowed the robot experts (often the socially weaker children) to more easily interact with other classmates. Also, by letting children work with the robot in small groups, the interaction between children in the groups was stimulated. Furthermore, when the robot was used by multiple groups in sequence, the last group could help the next group when they encountered difficulties. One teacher expressed concerns about when the robot would be used for one-on-one tutoring, which could potentially lower the contact with other children. The teacher considered this as part of the broader trend of (smart)phone use and time spent on a computer, which seems to lower personal, face-to-face contact. However, the teacher could not tell whether the robot caused children to interact less with each other. Likewise, this was not reported by any of the other interviewed teachers.

The option to apply a social robot to stimulate helping behaviour can be (in) directly linked to two of the five social-emotional domains. The introduction of social robots, which allows for the creation of new roles in the classroom as indicated by the teachers to stimulate interaction, and can be linked to the domains of *social competence* and *attachment*.

Ability to express oneself. Some teachers reported on children who, before the introduction of the robot, would not be willing to talk to the teacher, or did not want to learn. However, after the robot was introduced in the classroom, these children started to talk. First to the robot, and thereafter to the teacher. Teachers said that they expected that children would more easily express certain things to robots than to their teachers. *"I think that a robot could definitely be used for that [emotional support] as well [...] because it is something that is a bit further away from you and a bit less personal, so I think it is easier to discuss* *more difficult things [...] and certainly in the social, emotional area",* as voiced by one of the teachers. Some teachers used the robot as a means to let children talk about their feelings by letting the robot express emotions. This has led to the opportunity to talk about emotional feelings. One teacher compared this to hand puppets that are currently used in the Dutch educational system to start conversations on difficult subjects, which the teacher considered a similar tool.

Children opening up to a robot about their feelings relates to two of the five social-emotional domains. First, it could allow children to cope with negative emotions, learn about emotions and emotional expressiveness, which is linked to *emotional competence*. Second, it allows for the possibility for children to get more insight into their own social competence, which is related to the domain of *self-perceived competence*.

Ability to be patient and listen to others. Two of the teachers reported on the robot's ability to teach children to be patient and listen more carefully to others. This was mainly caused by the robot's script that did not allow a child to go any faster, according to the teachers. "*You have to keep calm and you also have to keep your impulses in check [...] you also have to be careful, children are normally rumbling everywhere, in a manner of speaking, but that is really not possible. So yes, there is really something being asked of them*", as one teacher reported. The teachers indicated that the robot made children listen more to others and wait their turn. However, they also indicated that the robot would need to be in the classroom for longer periods to make a lasting impact on these skills.

The ability to be patient and more carefully listen to others could, in theory, contribute to understanding the unique perspective of others, which can be linked to *emotional competence*.

Curiosity stimulation. Several teachers indicated that they have seen how robots can stimulate children's curiosity. Most teachers reported on the robot being something "magical" or "special". This made children curious to learn about and from the robot, also for subjects they would otherwise dislike or even avoid. One teacher experienced the following: *"I had one child at that time, who did not want to learn. That does not happen often, but he really did not want to, he had no interest at all in reading or in letters or in math or something else, but that robot... that was really it. Once that robot was there, he did everything. That was so special, he did everything he had to do, but not with me, but with the robot. With me, he just closed down, but with the robot, he did it all."* The teacher indicated that she did not encounter this behaviour often. Other teachers mentioned that they had also experienced how robots stimulated and motivated children, although they voiced that they did not consider the currently limited interactions enough to have a long-lasting effect on children's curiosity.

The ability of the robot to stimulate curiosity can contribute to the social-emotional domain of temperament/personality. By stimulating children's curiosity, they could become more encouraged to follow and experience aspects that suit their personality, which can be linked to the *temperament/ personality* domain.

In summary, the teachers expressed five ways by which social robots can impact the theoretical domains of children's social-emotional development, which is illustrated in Figure 5.1. Children potentially getting attached to the robot was a topic that came up regularly during the interviews. Therefore, we decided to discuss attachment as a topic separately in the next section.

5.3.3 Attachment

Almost half of the teachers indicated that children can feel emotionally attached to a robot. Some indicated that this attachment would not be different from how children attach to other objects children like, such as video games and toys. One teacher saw a child with bonding problems getting emotionally attached to the robot, but did not encounter this with other (typically developing) children. Some teachers indicated that while young children could feel attached to the robot, older children, around the age of 11-12, would consider the robots merely as a tool.

Another teacher reported on a child talking about the robot as his best friend, while other participants indicated that they have seen children interact with the robot as if it were their buddy. In several interviews, teachers indicated that children showed a kind of empathy and affection towards the robot. As one teacher experienced: *"they [children] also immediately asked when he [the robot] would come back, and everyone wanted to take care of it, you really noticed that the care aspect really came up there. Such that it had actually become a kind of a buddy."* Another teacher indicated to be concerned that children would view the robot as a best friend, however, this teacher did not encounter this in her own classroom. Furthermore, several teachers indicated that for children to become attached to a robot, the robot would have to be present much more often than is possible in the current educational system.

What would be considered 'too attached'? When asked for signals that would indicate that children are too attached to the robot, teachers expressed two main indicators: 1) when it results in less contact with their human peers, and 2) when children would get upset when the robot was not around. However, four teachers indicated explicitly that they have not encountered this in their classes, and that the way robots are being applied nowadays poses little risk for children to become too attached. *"In the current education you don't get it [attachment issues] very quickly, only if you always have a robot in class"* and *"I see few risks in the way in which we now use robots"* as explained by two other teachers. The other five teachers did mention encountering attachment issues in their classes.

Although the teachers did not encounter children becoming too attached to the social robots, this might be due to the short interaction time and the limited number of interactions children had with the robot. Therefore, we continued to further ask the teachers on what type of children would be more susceptible to getting attached to social robots.

Children who are more susceptible to getting attached to social robots. The current literature does not provide a solid basis for deriving insights into what kind of children would be more susceptive to getting attached to social robots. To gain more insight into which children might be at risk to become 'too attached' to a social robot, we conducted a thematic analysis to differentiate between types of children based on the interview transcripts (Braun & Clarke, 2012). The teachers expressed four types of children who would be more susceptible to getting attached to social robots.

- The first type, indicated by seven of the nine teachers, is timid, socially less strong, and could have an autism spectrum disorder (ASD). However, regarding ASD, it should be noted that one teacher explicitly stated that these usually are children of which the teachers think they have ASD because it is mostly not yet diagnosed at this young age. Indeed, a number of studies reported successful interactions of social robots specifically focusing on children with ASD (e.g., Huijnen et al., 2016; Di Nuovo et al., 2020).
- The second type of children concerns children who are interested in science and engineering. "The children who are just very interested in robots and programming", as one teacher explained. This is in line with common applications of robots for STEM education (e.g., Ahmad et al., 2020).
- The third type of children that can be considered more sensitive for the robot's interaction, as indicated by two teachers, are children who are underachievers on a certain subject, such as language learning or math. Studies indeed reported good results for language learning (E. A. Konijn et al., 2022; Vogt et al., 2019) or rehearsing the times tables (E. A. Konijn & Hoorn, 2020).
- The fourth and final type of children who are more sensitive to social robots are children with special needs, such as children with attention deficit hyperactivity disorder (ADHD), highly sensitive children, highly gifted children, and children sensitive to game addiction. Seven teachers indicated that these children can be considered more sensitive for child-robot interaction in

education: "the children who have a certain need [...] children with ADHD, or just children who are highly gifted, they could be attracted in a certain way if it suits them, and then there are many possibilities to work with this", as explained by one teacher. In earlier studies the potential for children with ADHD have been discussed before (e.g., Fridin and Yaakobi, 2011)

Table 5.2. Best practices and success factors for applying social robots in primary education.

#	*Title*	*Description*
1	Apply when needed	Make sure there is a clear *why* for applying social robots, robots are means not ends. Social robots are considered to be an addition to the teacher, not a replacement. When applying the robot every day, the novelty effect can wear off. Use social robots for a specific aim or goal.
2	Teacher stays involved	The role of the teachers stays very important, he/she should be present during the child-robot interaction, or at least close by. Also, the teacher can judge which children potentially get too attached to the robot, and which children would benefit most from the interaction. This might lead to an increase in the number of teaching assistants needed to facilitate the robot interaction.
3	Proper introduction	Teachers should pay specific attention to the introduction of the robot. Children should first be told what a robot is, and what is it going to do, before they start to interact with a robot.
4	Small groups	Learning with robots is best done in small groups. This not only allows children to continue communicating with their peers, but it can also stimulate children to interact with each other and not get socially isolated.
5	Vertical groups	Let children of different age groups work together with the robot, make use of the older, more experienced children to introduce and guide younger children.
6	Separate room	When a small group of children is working with the robot, this is distracting for the other children in the classroom. Therefore, the robot should not be in the same room as where other children are who do not work with the robot.
7	Team effort and mindset	For robots to be sustainably implemented in schools, the technology needs to have the support of the teacher-team including the school management. A teacher in the role of a robot ambassador can be appointed to introduce the robot to other teachers, making it easier to implement the robot.
8	Parents	The parents of the children should be informed pro-actively by the schools when social robots are going to be used. This is the responsibility of the school.

The teachers expressed several best practices to ensure that these types of children would not get too attached to the robot. The best practices expressed also included general remarks on how social robots could be implemented in a responsible way, according to these experienced teachers. In the next section, we present these findings.

5.3.4 Best practices and success factors for child-robot interaction in education

The interviewed teachers reported about what they considered best practices and success factors when applying social robots in primary education. In total, they reported eight best practices and success factors for applying social robots in primary education. To provide an overview of these best practices and their description we present them in Table 5.2.

5.4 DISCUSSION

The main goal of this interview study was to examine whether social robots in primary education compromise the social-emotional development of children. Therefore, we interviewed primary school teachers who supervised the child-robot interaction of more than 2,600 unique children in a real-life school environment. Nearly all child-robot interactions reported by our interviewees were one-on-one or small group interactions in which a humanoid robot took the role of a tutor or peer. Each robot was used for teaching children a specific subject or skill in a school environment.

The main finding of our study is that the participating teachers experienced no negative effects on the social-emotional development of children caused by the child-robot interactions that would have a lasting negative impact. In contrast, teachers expressed seeing five positive effects of social robots related to the social-emotional development of their pupils, being 1) increased self-confidence, 2) helping other children, 3) increased ability to express oneself, 4) increased ability to be patient and listen to others, and 5) curiosity stimulation. These five themes could be linked to all domains of children's social development reported in developmental literature, as discussed in the introduction and summarised in Figure 5.1.

The social robots seemed especially useful for introducing the learning by teaching paradigm (Fiorella & Mayer, 2013). This allows for some children to take on new roles, such as that of an expert. This can have a positive effect on children's social-emotional development. For example, by giving children an expert role, or by letting experienced groups help other groups. Novel technologies, such as social robots, seem appropriate to support children in such roles. The robot's impact on the children's ability to be patient and to listen carefully was reported to be caused mainly by the current state of technology that does not allow children to respond quickly, and due to the intonation of the robot which is sometimes lacking. Given that automatic speech recognition based on child-robot interaction has been shown to be a complex issue (Kennedy et al., 2017), it is unlikely that robots will be able to respond quickly to children's verbal reactions in the near future. Therefore, we consider that the robot's positive impact on children's ability to be patient and to listen will remain for the foreseeable future. However, teachers indicated that they wondered whether the effect on children's ability to be patient and to listen would impact the children in the long run. The other three effects, increased self-confidence, ability to express oneself, and curiosity stimulation, seem all specifically useful for children with special needs.

Four types of children were identified by the interviewed teachers, three of whom could specifically benefit from social robots and be receptive to interacting with a social robot. These children are considered to have special needs, either the timid, socially less strong children potentially with ASD, underachievers, or children with other special needs, such as ADHD or attachment issues. According to the teachers, these children could potentially benefit the most from social robots in education when it comes to their social-emotional development and are indeed often addressed in studies (e.g., Fridin & Yaakobi, 2011; Huijnen et al., 2016; Konijn & Hoorn, 2020). As a downside, the interviewed teachers reported that these children might get more attached to the robot in the long run, which could, in theory, lead to less human contact and children getting upset when the robot would not be around. However, this has not been observed by our teachers, and they further indicated that the robot would need to be present much more for this to occur.

To ensure that some children will not get too attached to the robot, teachers have indicated that they should supervise the child-robot interaction, or at least be close by. The teachers in our study mentioned that applying social robots in education is labour-intensive, and requires time and effort to use and implement. This is in line with another study reporting about teachers being worried that social robots would increase the workload of teachers (Reich-Stiebert & Eyssel, 2016). A recent review on robots in classrooms came to similar results, concluding that "the current generation of commercially available robots, like NAO or Pepper, do not have sufficient programming to be readily integrated into classrooms without extensive support and resource mobilisation" (Woo et al., 2021, p.9).

The comparison of the bond between children and robots to the bond between children and other humans might not be the best way forward. Although some children seem to behave as if they are friends with a robot (Fior et al., 2010), robots are still a different entity. When comparing human-robot interaction to interaction between humans, Black (2019) argues against developing empathy with robots because children cannot experience the kind of affect toward robots that they develop with other humans, such as their human peers and teachers. However, if we use the robot to simulate human interaction, by letting children work together, this doesn't seem to be a big problem. Furthermore, for social robots to be able to support children in primary education, there seems to be no need for very humanlike robots with extensive empathy capabilities; current studies on the use of social robots in education do, most of the time, not use very humanlike robots with extensive empathy capabilities, and still show promising results (e.g., Konijn and Hoorn, 2020). One might argue that robots need extensive empathy capabilities for teaching social skills to children who cannot learn these with their human peers because of disorders, such as ASD. Although humanoid robots with extensive empathy capabilities might help this specific group of children, there seems little reason to equip robots with far-reaching human embodiment when it comes to assisting regular children in their school process.

The social bond between child and robot challenges the fundamentals of friendship and relationships, according to Richards and Calvert (2017). However, according to the teachers in our study, such social bonds are infrequent and similar to the bond children have with other technologies or artefacts, such as smartphones and (hand) puppets. Thus, the negative impact of social robots on the fundamentals of friendship and relationships, for now, seems limited.

Other researchers have found that robots seem able to elicit socially desirable behaviour among children, such as sharing (Peter et al., 2021). However, according to the same researchers, this may also apply to socially undesirable behaviour, such as aggressive behaviour (Peter et al., 2021). Children have been recorded to express bullying behaviour towards an educational robot (Kanda et al., 2012). Others have also expressed concerns related to the robot becoming a bully or becoming subject to bullying (Diep et al., 2015). However, following the best practices of the participants in our study, when teachers stay involved in the child-robot interaction, this scenario seems unlikely. Teachers or teaching assistants could intervene when such undesirable behaviour occurs. Nevertheless, the results of other researchers emphasise the importance to be careful in how robots are presented to children because robots (in videos) have been shown to negatively influence children's pro-social behaviour and willingness to share resources in an experimental setting (Nijssen et al., 2021).

The participating teachers did not report major privacy issues related to the child-robot interaction, except one related to IT security, and they did not use extensive personalised data collection by the robot. This might be due to the relatively simple, not highly personalised child robot interaction currently used in schools. In other studies, privacy has been reported to be a major issue related to social robots in education (Sharkey, 2016; Smakman et al., 2021). Data collection allows personalised interaction, which is one of the key benefits, according to scholars (Jones et al., 2017; Jones & Castellano, 2018; Kanda et al., 2012; Shimada et al., 2012; Woo et al., 2021). Although the teachers in our study did not report on major privacy issues, given the need for data collection for personalised learning, we consider the issue crucial for integrating social robots in education in a responsible way and should therefore be subject for further research.

One limitation of this study is that, although the participants had experience with using a social robot in their day-to-day education and supervised the child-robot interaction of over 2,600 unique children, the total number of participants was limited. However, given that all participants had experience with using a social robot in their day-to-day education, combined with the large number of unique children they supervised, they still provide valuable insights into the currently observed effects of social robots on children. The gender distribution was unequally balanced, with only one male participating teacher. However, this can be considered a reflection of the gender distribution in Dutch primary education, where approximately 80% is female (Traag, 2018). It should also be noted that this study was carried out solely in the Netherlands, therefore the results may differ in other countries. Furthermore, none of the teachers systematically measured the robot's effect on the social-emotional development of children. The evaluations in this study are solely based on the teachers' previous experiences and observations. The experiences of these teachers could differ from how children experienced the robot interaction. Further studies could compare the perceptions of children to the perceptions of their teachers. Future studies in child-robot interaction could also include the Social Skills Rating System (SSRS) or the social Skills Improvement System-Rating Scales (SSIS-RS) (Gresham et al., 2011), to systematically measure the impact of social robots in children's development.

In conclusion, our study indicates that the social robots currently used in education pose little threat to the social-emotional development of children according to teachers who applied these robots in their day-to-day education. Children with special needs seem to be more sensitive to social bonding with a robot compared to regular children. However, this social-affective bond seems to have more positive effects enabling them to more easily connect with their human peers and teachers.

Given that the best practices reported in this study are taken into account, we consider that social robots pose more benefits than harms concerning the social-emotional development of children. However, when robots are being introduced more regularly, daily, without the involvement of a human teacher, new issues could arise. For now, given the current state of technology and the way social robots are being applied, other (ethical) issues seem to be more urgent, such as privacy and security issues, and the workload of teachers.

CHAPTER 6

GENERAL DISCUSSION

The introduction of social robots in primary education has led scholars and stakeholders to raise moral concerns related to issues such as privacy (Sharkey, 2016), responsibility (Serholt et al., 2017) and the loss of human contact (Pandey & Gelin, 2017). To advance the knowledge on the moral concerns related to social robots in primary education, there is a need to empirically study what values are impacted by the introduction of these robots and the moral considerations of different groups of stakeholders (e.g., parents, robot industry). Therefore, this dissertation aimed to identify the relevant values - what people consider important in primary education - and moral considerations of various stakeholders related to social robots in primary education, thereby providing a first step towards a guideline on how social robots can be designed and used in such a way that robots do not undermine these values and moral considerations. This dissertation presented a mixed-method approach, following the Value Sensitive Design (VSD) methodology (Friedman & Hendry, 2019), to offer a comprehensive and nuanced overview of the moral values and considerations of stakeholder groups, and provide new insights into the moral challenges of designing and using social robots for primary education.

We first conducted a systematic literature review, which provided a broad overview of the potential harms and benefits of social robots (Chapter 2). Second, we set up focus group sessions with the stakeholder groups to identify the moral considerations of various types of stakeholders regarding the use of social robots in primary education (Chapter 3). Third, based on results in chapters 2 and 3, we created a questionnaire to identify and quantify differences in the moral considerations between (and within) stakeholder groups, which resulted in new attitude profiles (Chapter 4). Furthermore, we identified the factors that influenced the moral considerations of key stakeholders. Lastly, we interviewed primary school teachers who had experience with using social robots in their classrooms, which resulted in new insights specifically on the often-mentioned impact of exposing children to robots over a longer period, as well as best practices for implementing social robots in education (Chapter 5).

In the following sections of this chapter, we will reflect on the four studies that were conducted. We will first summarise the main results of each study. Thereafter, the theoretical implications of the results are discussed, followed by the methodological strengths and limitations. Additionally, the practical implications that together form the code of conduct (see Appendix A) are discussed. Next, the lessons learned and suggestions for future research are presented. Finally, we will reflect on the overall conclusion that can be drawn from this research.

6.1 SUMMARY OF MAIN RESULTS

Chapter 2 presented a systematic literature review (*N* = 256) to identify the potential harms and benefits related to social robots in primary education. Following the steps of the VSD approach (Friedman & Hendry, 2019; Spiekermann, 2015), these harms and benefits are later (in Chapter 3) used to identify the relevant values, what stakeholders consider important in education. For an in-depth description of the conceptual relationship between harms and benefits, values, and moral considerations, see Chapter 1, section Morality and Technology. Additionally, we mapped the harms and benefits to the specific stakeholder group that would be impacted by the harms and benefits reported. Furthermore, we categorised the identified studies according to their methodological approach (e.g., conceptual, empirical). Findings indicate that social robots provide five main (potential) benefits for primary education: (1) increased motivation and enjoyment, (2) reduced anxiety, (3) new opportunities for education (e.g., new social interaction and roles), (4) personalised learning, and (5) reduced administrative work. Next to these reported benefits, we found a broad and diverse scheme of eleven potential harms (e.g., downsides, negative impact, concerns), including the disruption of the educational process and the loss of human contact. Most of these harms were argued to be caused by the technological limitations of the social robots that are currently used and studied in classrooms, such as the robot's limited ability to interact autonomously with children as well as the current state of speech technology. If these technological limitations were to be solved, four key clusters of issues would remain: (1) privacy and security, (2) control and accountability, (3) social implications, and (4) loss of human contact. Next to the identified issues, results showed that all reported harms and benefits in the literature were related to the teachers and children. The perspectives of other stakeholder groups, such as parents, governmental policymakers, and the robot industry were overlooked in the reviewed literature.

In **Chapter 3,** we reported a focus group study (*N* = 118) that examined the stakeholder perspectives that were missing in the literature, as reported in Chapter 2. Results of the focus group sessions with parents of primary school children, representatives of the robot industry, educational policymakers/advisors working for the government, teachers, and primary school children, showed that seventeen values are relevant to social robots in primary education. Overall, stakeholders agreed on many issues. As an example, all stakeholders considered social robots as being a potentially valuable tool for fun and motivational purposes and applicable for (simple) teaching tasks, supervising children and taking exams. There were some issues about which stakeholder groups disagreed. Parents, for example, viewed the robots as potentially harmful to children's physical safety. Teachers, however, considered the robots harmless for children's physical safety. Overall, the results of Chapter 3 support the argument that social robots pose moral challenges due to the number of values robots could potentially undermine.

Chapter 4 presented a quantitative study (*N* = 515) that explored the differences in the moral considerations between (and within) stakeholder groups. Based on the results of the literature review (Chapter 2) and the focus group sessions with stakeholders (Chapter 3), a systematic questionnaire was created that identified distinct attitude profiles as well as socio-demographic characteristics that influence the probability of belonging to a specific profile. Findings revealed five distinct attitude profiles: (1) Enthusiast, (2) Practical, (3) Troubled, (4) Sceptic, and (5) Mindfully Positive stakeholders. Overall, the Enthusiast group represents the most positive attitude towards social robots (primarily based on their positive attitudes towards robots' social interaction and bonding, usefulness, and their relatively non-problematic attitude regarding safety and privacy), whilst the Sceptic group represents the most negative one (primarily based on their negative attitudes towards robots' social interaction and bonding, usefulness, and their worrisome attitude regarding the robot's impact on IT security, accountability and privacy). The other three clusters show no strong dismissive attitudes towards social robots in education, although they each have their own moral issues that they consider relevant. For example, the Practical group considers robots to be useful, but not for social interaction and bonding.

Results also showed that multiple socio-demographic characteristics significantly predict belonging to an attitude profile membership. For example, stakeholders with a low-income level were significantly more likely to belong to the group of stakeholders who are sceptic about social robots in education. Other factors, such as age, robot experience, and education level also served as strong predictors for the attitude profiles. Overall, the findings of this study highlight that the moral considerations of stakeholders can be classified into five attitude profiles and that socio-demographic characteristics seem to be able to predict individual stakeholder attitudes.

In **Chapter 5,** we reported on a qualitative study with in-depth interviews to examine the impact of a specific concern that has often been mentioned in the previous studies. That is, many stakeholders voice concerns about exposing children to robots over a longer period of time, which would negatively impact children's social-emotional development. In addition, this study aimed to further identify best practices from experienced teachers. Based on in-depth interviews with primary school teachers who had used robots in their day-to-day education (*N* = 9, who supervised the child-robot interaction of 2660 unique children), the results show that social robots can impact children's social-emotional development in multiple ways. However, no lasting negative impact on children's social-emotional development was observed by any of the participating teachers. Instead, teachers expressed experiencing multiple benefits related to children's social-emotional development, namely: increased self-confidence, helping other children, increased ability to express oneself, increased ability to be patient and listen to others, and curiosity stimulation. Additionally, this chapter provided insights into characteristics of children who might be more susceptible to becoming too attached to the robots, such as children that underachieve on a certain subject and special needs children. Lastly, the in-depth interviews provided best practices for the responsible use of social robots in primary education. Overall, the results of this chapter highlight (1) that social robots seem able to both positively and negatively impact children's social-emotional development, (2) that some children seem more susceptible to becoming (too) attached to robots than most others, and (3) there is a need to examine both the positive and negative impact on children's social-emotional development in more detail.

6.2 IMPLICATIONS TO UNDERSTAND MORAL CHALLENGES RELATED TO SOCIAL ROBOTS IN EDUCATION

The studies presented in this dissertation collectively provide a first step towards guidelines on how educational social robots can be designed and used in such a way that they do not undermine the values and moral considerations of various relevant stakeholders, resulting in important new insights for robot ethics theorising. How (or even if) social robots should be used in primary education has for some time been discussed in conceptual, non-empirical studies (e.g., Sharkey, 2016) and studies focusing on a single-stakeholder perspective (e.g., Serholt et al., 2017). However, an extensive systematic overview that included multiple stakeholder perspectives was missing. Scholars, such as Ljungblad et al. (2011) have advocated for more empirically-grounded studies that focus on the actual environment where social robots are placed, to reveal moral challenges which otherwise may be overlooked or misunderstood. The studies in this dissertation, therefore, utilised a multi-stakeholder approach to examine the moral challenges, by focusing on the values and moral considerations of various stakeholders. Such an approach presupposes that, by focusing on the values and moral considerations of the stakeholders, the moral challenges which are created by the introduction of new technology can be mitigated, which is an accepted standpoint in the robot ethics literature (e.g., Draper & Sorell, 2017; Salem et al., 2015; van Wynsberghe, 2013). We argue that such an approach is needed to provide a better, contextual understanding of the moral challenges related to social robots in education, as opposed to the existing, more general guidelines on AI and robotics (e.g., Prescott et al., 2016). Our approach has led to several main theoretical implications, which are each discussed in the subsections below.

6.2.1 Variation in complex moral challenges

Theoretical implication 1: *Social robots in primary education create complex moral challenges due to the variation in stakeholder values and the at times conflicting moral considerations of relevant stakeholders.*

The results presented in this dissertation have highlighted the complexity of implementing social robots in primary education in a morally justified way by keeping in mind the values and moral considerations of all relevant stakeholders. The complexity is largely due to the considerable number of values that are potentially impacted (Chapter 2), the sometimes conflicting views of stakeholder groups (Chapter 3) and the distinct attitude profiles of individual stakeholders (Chapter 4).

The results of the systematic literature review (Chapter 2) and the focus group sessions (Chapter 3) revealed seventeen values being relevant. These results are in line with other studies on values and educational technology (e.g., Leite et al., 2013; Lemaignan et al., 2021; Pijpers et al., 2020). However, the values that seem to be understudied in earlier research are applicability, usability, freedom from bias, autonomy, and flexibility. Although some studies, such as Pijpers et al. (2020), created sub-domains of values, no study in the extant literature included all seventeen values identified and described in this dissertation. The identified values thereby provide a more complete understanding of which moral issues are relevant in view of the various stakeholders. In line, results imply that the introduction of social robots in primary education is even more morally complex than was expected based on the extant literature at the start of the current research.

The overview of the values identified provides a starting point for embedding values into social robots for education. However, taking into account seventeen values when designing and applying social robots is no easy task, and a situation of *moral overload* (Van den Hoven et al., 2012) seems likely to occur. In such a situation, taking into account all relevant (sometimes conflicting) values and moral considerations cannot be realised (Van den Hoven et al., 2012). For example, in Chapter 3, almost all stakeholder groups reported being concerned about children’s privacy, however, the vast majority of them also reported that they would like access to the data collected by the robot for their own goals. What seems to make it even more complex, besides the sometimes conflicting values between stakeholder groups, are the distinct attitude profiles of individual stakeholders. Whereas results of the focus group sessions (Chapter 3) indicated more similarities than conflicts in attitudes, the quantitative results of Chapter 4 provided five distinct attitude profiles. Hence, taking into account these results in one general code of conduct that satisfies all attitudes is complex and will require trade-offs. Stakeholders may not be able to design and implement social robots in such a way that it satisfies all identified values and considerations. The systematic approach of this dissertation provides them with a better overview of the challenges, and allows for stakeholders to decide on which factors to focus on specifically to maximise benefits and mitigate potential harms for relevant stakeholders, especially for children and teachers.

6.2.2 Distinct attitude profiles related to the moral considerations

Theoretical implication 2: *Five distinct attitude profiles related to the moral considerations of stakeholders exist and multiple socio-demographic characteristics influence the probability of belonging to a specific profile.*

The results of our systematic questionnaire study (Chapter 4) imply that there are five distinct attitude profiles related to the moral considerations of all relevant stakeholders (i.e., Enthusiast, Practical, Troubled, Sceptic, and Mindfully Positive stakeholder perspectives). In earlier research, views on the use of social robots were generally analysed in terms of anxiety (e.g., Nomura et al., 2006b), or negative attitudes (e.g., Nomura et al., 2006a). These studies usually provide a mono-dimensional view of the perspectives of stakeholders. Because of the diversity of relevant values and moral considerations, these mono-dimensional views might be considered too limited for analysing moral considerations. Some have included what stakeholders consider appropriate and inappropriate values in acceptance studies, such as De Graaf & Ben Allouch (2013). They studied the reasons for potential robot users to accept robots in their homes and argued for normative beliefs to be considered as a variable influencing the acceptance of social robots. The attitude profiles based on moral considerations identified in Chapter 4 can be considered a type of normative belief. Hence, these profiles can potentially also explain the acceptance of robots in education by stakeholders. Next to the identified attitude profiles, we have also found socio-demographic characteristics that influence the probability of belonging to a specific profile, such as prior experience with robots and income levels. These characteristics that predict stakeholders' likelihood to belong to a certain attitude profile are each discussed in the sections below.

Experience with social robots as a predicting characteristic. In line with earlier research (e.g., Bartneck et al., 2007; Fong et al., 2003), our results (Chapter 4) show that stakeholders who already had experience with social robots were more likely to have a positive attitude toward the use of social robots in education. Stakeholders with robot experience were significantly more likely to belong to the attitude profile labelled Enthusiast: stakeholders that considered the use of social robots in primary education the most positive compared to the other four attitude profiles. Stakeholders with experience were significantly less likely to belong to the attitude profile labelled Practical. The main thing that set these groups apart was that the Enthusiast profile expresses a positive attitude toward the use of social robots for social interaction and bonding with children, whereas the Practical profile considers social interaction and bonding with robots undesirable.

Letting people get acquainted with robots, both direct and indirect, has been shown to change people's attitudes toward robots (Sarda Gou et al., 2021). Without experience with robots, people's views of robots are often based on media representations, science fiction literature and film (Kriz et al., 2010). It is therefore not surprising that people without experience with social robots are reported to be afraid that they might take over their job, or even associate them with weapons (MacDorman et al., 2009). Our results imply that people without robot experience indeed seem to have unrealistic expectations related to the potential impact of social interaction, whereas the people who do have experience with robots showed to have a more adequate understanding of the robots' capabilities. Hence, our results further underscore the importance of making people acquainted with new technologies before full-scale implementation.

Income levels as a predicting characteristic. People with a low or medium income were more likely to belong to the attitude profile of Sceptic stakeholders, compared to stakeholders with a high income. Earlier research on the acceptance of social robots found that preferences were independent of participants' level of income (Korn et al., 2021). However, in the study of Korn et al. (2021), most participants were students of similar ages and levels of income. Our quantitative study presented in Chapter 4 was more diverse, with participants with more distributed income levels. In line with our results, Liu et al. (2021), who surveyed 1480 Chinese older adults living in rural areas to understand how older Chinese adults perceive social robots, showed that income was a significant predictor of technical and financial concerns. Thus, income levels should be taken into account when studying stakeholders' moral considerations towards social robots, or perhaps even towards other types of technological innovations. Further research could focus on the underlying reasons for stakeholders with low to medium income levels to be less positive about social robots in education compared to high-income income stakeholders. One such underlying reason might be that children from low-income families would not be able to benefit from social robots because robots are often considered costly, which is a concern reported by parents in Chapter 3. The robots being costly is also something that is voiced by the experienced teachers in Chapter 5. Just as reported by the parents (Chapter 3) and teachers (Chapter 4), Natarajan et al. (2022) reported that social robots may not be affordable for all income groups. This might contribute to unequal opportunities in education when schools with more budget (usually in high-income areas) can buy (more/better) robots to support children, compared to schools with less budget (usually in low-income areas). Measures should therefore be taken to not further increase the digital divide (Dondorp & Pijpers, 2020) when social robots are introduced in education.

Gender as a predicting characteristic. In our results, the gender identity of the stakeholders did not affect their views on robots in education. These results are in line with Korn et al. (2021) who found similar results. Also, de Jong et al. (2021) and Spence et al. (2018) found that gender did not significantly predict attitudes toward social robots. However, the literature is still inconclusive on the influence of gender on perceptions of social robots. Some studies suggest that females are more comfortable interacting with social robots and men view social robots more as mechanical artefacts (e.g., Shibata et al., 2009). Others found contradictory results, such as Schermerhorn et al. (2008) who found that males overall considered robots more human-like and accordingly showed more socially desirable responses to a social robot, and found females to view robots as more machine-like and accordingly showed less socially desirable responses. In another study, females reported more anxiety toward social robots compared to males (De Graaf & Ben Allouch, 2013). A recent systematic review on the effect of gender on attitudes towards social robots found similar mixed results (Naneva et al., 2020). They did find that gender affected people's attitudes, however, according to the researchers, "the number of studies was quite small and it was difficult to draw clear conclusions regarding the effect of gender" (Naneva et al., 2020, p. 1195). Our results suggest that, for studying stakeholders' moral considerations on the use of social robots in education, gender is not a significant characteristic. It should be noted that in our study we did only include relevant educational stakeholders, and therefore, results for people in general may differ. Given the mixed results on the impact of gender on the attitudes towards robots, future research might try to isolate the specific robot attributes that cause differences between gender, or focus on other possibly more promising characteristics for predicting stakeholder attitudes, such as income, prior robot experience, and being part of one of the profile groups identified in Chapter 4.

Education level as a predicting characteristic. Our results show that stakeholders with a higher education degree were more likely to have a negative attitude compared to stakeholders with a secondary school or a vocational education degree. Stakeholders with a University of Applied Science (HBO) degree showed a trend of belonging to the Sceptic group and were significantly less likely to belong to the Mindfully positive group. Whereas, stakeholders with a secondary school or a vocational education (MBO) degree were significantly more likely to belong to the Practical group. The existing research on the influence of individuals' education level on attitudes towards social robots is mixed. The Eurobarometer – a survey conducted in 2017 with a total sample size of 27,901 EU citizens from 28 member states – for example, reports a more positive attitude towards robots by those with higher education (European Commission, Directorate-General for Communication, 2017). However, a study conducted with German participants (N=345) found that education level did not influence negative attitudes and anxiety related to education robots (Reich-Stiebert & Eyssel, 2015). In discussing their results, Reich-Stiebert and Eyssel argue that the contradictory results in the literature might be because participants with a higher education level doubt if social robots could effectively assist in the more complex content provided in higher education. Another suggestion is that respondents with higher education could potentially be more knowledgeable about the impact of social robots in education. Further research might focus on identifying the underlying reasons for the sometimes conflicting results regarding the impact of individuals' educational levels on their attitudes.

Stakeholder roles as a predicting characteristic. It is generally accepted, when studying attitudes on technological innovation, to identify specific stakeholder groups based on their role. For example, in the case of social robots in primary education, current literature is generally focused on specific stakeholder groups, such as the perspectives of teachers (Serholt et al., 2017) or children (Serholt & Barendregt, 2014). Also in other (non-HRI) fields, addressing the moral implications of technologies are often done by focusing on specific stakeholders, such as caregivers and patients (Kowe et al., 2021), teachers (P. Lin & Van Brummelen, 2021) or patients and designers (Nouwen & Zaman, 2018). However, the results presented in Chapter 4 indicated that being part of a specific stakeholder group has a limited effect on the probability of belonging to a specific attitude profile. Factors such as age, robot experience, income, and education level served as stronger predictors than being a specific stakeholder and are important to take into account when studying the moral implications of social robots. Therefore, when addressing the moral implications of robots in education, it is important to not solely focus on stakeholder roles, but also include a broad and diverse group of stakeholders.

6.2.3 Educational social robots impact informational privacy

Theoretical implication 3: *Informational privacy, concerned with data collection and processing capacities that affect users, is the main privacy component argued to be relevant for social robots in education.*

The results of the literature review (Chapter 2) and the focus group sessions (Chapter 3) show that the current literature and the empirical information from the stakeholders are mainly focused on informational privacy, and concerned with the data collection and processing capacities of the robots that might affect its users. This finding is in line with a scoping review that also included interviews with privacy experts on the use of social robots and privacy (Lutz et al., 2019), who showed that most of the privacy issues mentioned in the review and by the experts were related to informational privacy. However, more recently, Lutz and Tamò-Larrieux (2020) also reported on other types of privacy concerns such as social privacy (i.e., issues related to privacy threats that are caused by other users, such as hacking and stalking) and physical privacy (i.e., issues related to the robot's capability to enter physical personal spaces, such as bedrooms and bathrooms), although physical privacy was less prevalent.

The most important open issues related to informational privacy, according to our review (Chapter 2) and the focus group sessions (Chapter 3) are: what data is stored, how is the data used, and who has access to the data. These informational privacy issues are mostly covered in legal frameworks, such as the European General Data Protection Regulation (GDPR) - which is one of the most strict in the world (Wolford, 2018). It is therefore perhaps not surprising that the GDPR covers many of the privacy issues mentioned in our literature review (Chapter 2) and focus group sessions (Chapter 3). Drawing from this legislation, data minimalisation for predefined goals and authorised, consented access to data should be considered key principles when implementing robots in educational settings. However, even when taking into account the strict legislation of the GDPR, some open issues remained such as: how can robots be designed to personalise the learning experience for children with a minimal amount of personal data, and whether the collection of detailed personal data - or even secrets told to the robot in confidence - for a more personalised learning experience justifies the privacy risks involved. These issues seem especially relevant because people's intention to use social robots is not significantly affected by informational (or physical) privacy concerns (Lutz & Tamò-Larrieux, 2020). Hence, the privacy of children and other stakeholders might be undermined, because the privacy concerns do not seem to strongly affect people's intention to start using robots.

The privacy concerns are not only limited to privacy in schools but also extend to children's homes. By letting children bring the robot home, the robot could connect educational experiences at school to that at home, which is valued highly by teachers and promotes beyond the classroom learning for children (Kory Westlund et al., 2016). However, such a robot could then collect data on children at home (Sharkey, 2016). Whereas such data could provide new insights into the learning progress of children beyond what the teacher normally sees (Prentzas, 2013), this would bring the robot directly into the private lives of the children and their caretakers, which potentially leads to new privacy issues. Some, such as Fernandes et al. (2016) have presented technical solutions for privacy-sensitive situations related to social robots in private homes. They argue for giving robots the ability to detect privacy-sensitive, potentially embarrassing situations, such as nakedness during a morning bath, and respond appropriately. Such a technological solution might be useful when educational social robots are also going to enter private homes. However, in a school environment such situations, whereby a robot can detect embarrassing situations based on camera input (such as nakedness) seem limited.

Others have argued for a more interdisciplinary and collaborative approach to privacy issues because of the diverse nature of the issues and privacy being a multi-disciplinary phenomenon (Lutz & Tamò, 2015). They argue for a collective of engineers, legal scholars, sociologists, HRI scholars, and philosophers/ethicists working together to think of privacy-friendly solutions for social robots. Some even go as far as to advocate for privacy-sensitive robotics research as a sub-field because of the complexity of the issues (Rueben et al., 2018). Overall, the privacy issues related to social robots are complex and require further research, especially since these privacy concerns do not seem to influence use intentions (cf., Lutz & Tamò-Larrieux, 2020). This might result in schools starting to use social robots, regardless of their privacy concerns, which could lead to the value of privacy being undermined in classrooms.

6.2.4 Social robots' abilities to impact children's social-emotional development

Theoretical implication 4: *Social robots seem able to impact the social-emotional development of children and some children are argued to be more susceptible to becoming (too) attached to a robot.*

Our results have implications for the ongoing discussion regarding the robots' impact on children's social-emotional development. The systematic literature review (Chapter 2) and the focus group sessions (Chapter 3) indicated that scholars and stakeholders have concerns about the potential negative impact of social robots on children's social-emotional development. In line with earlier research (e.g., Diep et al., 2015; Kanda et al., 2012; Peter et al., 2021), the results presented in Chapter 5 imply that social robots can both benefit and harm children's social-emotional development. However, the interviews with experienced teachers (Chapter 5) indicate that the social robots currently used in education, pose little threat to the social-emotional development of children. However, the results suggest that letting children become too attached to social robots might lead to children's social-emotional development being hurt; it might result in children having less contact with their human peers, and getting upset when the robot is not around.

One of the key characteristics of children that might be susceptible to becoming (too) attached to the robot is shyness, according to the interviewed teachers. However, how shyness affects children's interaction and bonding with robots is one of the individual differences that we know little about. One of the few studies on the effect of shyness and child-robot interaction is Tolksdorf, Viertel, and Rohlfing (2021), who focussed specifically on the role of children's shyness. They compared the CRI of shy children to non-shy children over the course of four successive word-learning sessions. Their findings show that shy children retrieved fewer words than their non-shy peers in the initial post-test, but were able to retrieve a similar level of words as their non-shy peers in a delayed post-test. However, shy children are reported to interact differently with robots compared to other children; shy children in general interacted less expressively with the robot (Tolksdorf, Viertel, & Rohlfing, 2021). Another study by Tolksdorf, Viertel, Crawshaw, et al. (2021) reported that shy children approach both human and robot interaction partners in similar ways: they approach their interaction partners more distantly when compared with their less shy peers. However, in their study, they found that regardless of shyness levels, children spent more time near the robot compared to the human interaction partner (Tolksdorf, Viertel, Crawshaw, et al., 2021). An explanation might be that children experience robots as predictable, which is also considered one of the benefits for children with ASD (Huijnen, Lexis, & de Witte, 2016). Furthermore, children can view robots as friends or peers (Van den Berghe et al., 2021), thereby experiencing the robot not as an authoritative figure but rather as a social equal that might be perceived as being less intimidating than a tutor or teacher (Belpaeme, Kennedy, et al., 2018). Shy and timid children might therefore bond more easily and might get (too) attached to a robot, as indicated by the experienced teachers (Chapter 5).

6.2.5 Dominant utilitarian arguments of stakeholders

Theoretical implication 5: *Most stakeholders seem to argue about the moral challenges in line with utilitarian theory, focusing on the impact robots could have on the well-being of children and teachers.*

When taking into account our results, it seems that most arguments brought forward by the stakeholders fit a utilitarian moral theory (Bentham & Mill, 2003) rather than virtue theory (Aristotle, 1934) or deontological theory (Kant, 2009). That is, the arguments brought forward by the stakeholders (Chapter 3) were primarily focused on the impact robots could have on the well-being of children and teachers. For example, the concerns raised related to children *bonding* with the robot seem grounded in the fear that this would negatively impact their social-emotional development and *friendship* with other children, and consequently their *well-being*. Similar arguments are brought forward for the values of *safety*, *security*, *happiness* and *psychological welfare*; all are focused on the possible outcome of actions rather than on the actions themselves. There are however also considerations that seem to go beyond such outcomes. The robot's ability to interact with children without prejudice, assumptions and *biases* is considered an added value to education according to multiple stakeholder groups. If robot tutors were to be biased (e.g., gender or racial bias), some children could gain an advantage over other children based on their (appearance) characteristics. The underlying principles from stakeholders seem to be that each child should get equal opportunities. Broadly speaking, the arguments provided by the stakeholders can be considered both deontological and utilitarian. The general rule that each child should be treated without prejudice, assumptions or bias, seems to be in line with deontological reasoning, such as Kant's (2009) categorial imperative. However, the argument that each child should get equal opportunities to maximise outcome could be considered in line with utilitarian moral theory (Bentham & Mill, 2003). Thus, more than one moral theory seems to be relevant for some values relevant to social robots in education.

Related, the issue of *deception and sincerity* seems to be in line with deontological theory (Kant, 2009). Deontological theory argues that an action is good or bad, not based on the consequences of the action but on whether the action is in line with a series of rules, such as Kant's categorical imperative (Kant, 2009). For example, the rules that a person should not lie, steal or kill. These deontological rules can be viewed as representing duties that should be followed (Chatterjee et al., 2009). In line with this theory, some scholars seem to hint that it could be considered fundamentally wrong for robots to let children believe that robots are genuinely concerned for children (e.g., Leite et al., 2014). Others have focussed on the outcome such beliefs might have, such as children feeling deceived and unfairly treated, or that deception could lead to aggressive behaviour (Reich-Stiebert & Eyssel, 2016; Serholt et al., 2017), or a situation wherein deception results in an overestimation of a robot's abilities (A. Sharkey & Sharkey, 2021). Our results suggest that the issue is less fundamental than first expected based on such arguments. The stakeholders in our studies have indicated that robots should be honest with children about their goals and uses because this could otherwise leave children feeling not at ease or disappointed. Teachers, however, voiced that they use children's imagination and fantasy already in education with the use of hand puppets and that such robot actions would be a similar form of "deception", appealing to children's imagination, which would not harm the children. These arguments seem in line with utilitarian theory (Bentham &

Mill, 2003). Although it should be noted, as shown in Chapter 4, that teachers have a higher likelihood to view robots as practical tools, which could explain this utilitarian line of reasoning. Overall, no decisive arguments against the simple forms of deception were found, except possible utilitarian arguments. Furthermore, if robots were not allowed to slightly deceive children in similar ways as playing with puppets, this could undermine the whole concept of *social* robots. After all, social robots are designed to follow social behaviours and human communication rules in accordance to specific roles, with the purpose to utilise people's tendency to attribute human characteristics to inanimate objects. This tendency, also known as anthropomorphism, can facilitate the child-robot interaction and can also be used to refine the interaction between robots and children (see, Duffy, 2003). Utilising these tendencies could be considered a form of deception. However, the stakeholders in our studies seem to have a permissible attitude towards such a simple form of deception, comparable to become attached to a stuffed animal or pet, as long as the outcomes do not hurt children.

Next to utilitarian and deontological arguments, virtue ethics (Aristotle, 1934) could also be used to provide new insights into the moral challenges related to social robots in education. Arguments of all three moral theories can be found when discussing the value of *friendship*. There have been children who report having a kind of *friendship* with social robots. According to the interviewed teachers in Chapter 4, it is not uncommon for children to *bond* with non-human entities such as video characters and hand-puppets. Although most arguments both for and against this kind of "friendship" were utilitarian (e.g., the fear that the bond would harm the children's social-emotional development and the opportunities that the bond would allow for children to stay engaged with the robot and avoid human contact), more fundamental arguments have also been expressed. Some participants voiced that being friends with a non-human entity is just not possible and therefore should not be advocated. This line of reasoning is more in line with deontological theory. Next to utilitarian and deontological reasoning about friendship with social robots, others have used also virtue ethics. Recently, Constantinescu et al. (2021) reflected on child-robot friendship using virtue ethics (Aristotle, 1934). They concluded that "virtue-based friendship cannot arise between children and robots because both parties lack the required moral agency" (Constantinescu et al., 2021, p. 1). However, according to the same authors, children relate to friendship differently than adults; children relate to friendship more as educational play or exploration, rather than to "true" friendship in the sense of a reciprocating virtue-based relationships. They advocate for viewing robots as other fictional entities that could contribute to children's development as virtuous adults by enabling children to exercise affection, moral imagination and reasoning. Constantinescu et al. (2021) are not the only ones advocating for viewing social robots not as “true” human friends but as other entities, such as animals (Darling, 2021). By no longer viewing the bond of children and robots as *human* friendship, but as bonds that children also form with other existing non-human entities (e.g., dolls, animals), complementing those with humans, one might refute the more fundamental arguments against child-robot bonds or friendships.

In all, the findings of this dissertation imply that most arguments brought forward by the stakeholders fit a utilitarian moral theory (Bentham & Mill, 2003) better than virtue theory (Aristotle, 1934) or deontological theory (Kant, 2009). However, arguments along the lines of all three moral theories can be found in the moral considerations of the stakeholders. Using just one theory when considering the moral design and use of social robots in primary education might therefore be too limited. Such an approach could lead to relevant stakeholder values being undermined. The VSD approach followed throughout this dissertation allows for combining multiple moral theories. Therefore, VSD seems especially valuable, not only when studying robots in education, but potentially also robots in other domains, such as healthcare.

6.3 METHODOLOGICAL STRENGTHS AND LIMITATIONS

The studies presented in this dissertation have various strengths and limitations. First, all studies presented build upon each other. We were thereby able to utilise the new insights derived from each study to re-formulate or adapt the research approach of the successive studies. This resulted in each following study systematically contributing to the understanding of the moral challenges related to social robotics in education. For example, our systematic literature review (Chapter 2) provided thematic input for the focus group sessions (Chapter 3), and the qualitative insights of the focus group sessions formed the based for the quantitative study presented in Chapter 4. Second, the combination of these approaches can be considered an overall strength of this dissertation, as a multi-method approach can provide a more comprehensive understanding of how social robots can be applied in a morally justified way (Mingers, 2001). The third and final methodological strength is the broad and diverse range of stakeholders that were included in our studies. In total, we included the perspectives of 642 individual stakeholders with six different roles: teachers, parents, policymakers, robot industry, educational students, and school management. Furthermore, the socio-demographic characteristics such as age, gender, income and education level of the participants were diverse and overall representative of the field. Including such a broad and diverse range of stakeholders is advocated in the literature (e.g., AI HLEG, 2018; BSI, 2016; Spiekermann, 2015) and contributes to a nuanced and thorough understanding of the moral challenges wherein stakeholder groups sometimes have conflicting views (Ligtvoet et al., 2015). Most existing studies on stakeholder perspectives were focused on single stakeholder groups (e.g., Baxter et al., 2015; Reich-Stiebert & Eyssel, 2016; Serholt et al., 2017). Hence, this dissertation provides an important step in understanding the moral challenges from a multi-stakeholder perspective.

The studies presented in this dissertation also have limitations. First, many of the stakeholders involved in the focus group study (Chapter 3) and the questionnaire study (Chapter 4) had no or limited experience with social robots. Participants, therefore, needed to imagine a future scenario and to the best of their abilities reflect on the possible impact of the robots, which might have led to unrealistic expectations. A recent study by Winkle et al. (2020) has demonstrated that such stakeholders might imagine the role and behaviour of a robot differently than when they are actually using the robots in real life. To familiarise participants with social robots in education as much as possible, we used video footage of social robots (Chapters 3 and 4), which is a commonly used method in social robotics studies (Ahmad et al., 2016; Rosanda & Istenič Starčič, 2019). Furthermore, for the focus group study (Chapter 3) we let participants interact with a physically present social robot at the start of the session. Although we tried to familiarise participants as much as possible, further research might include more experienced participants. As time progresses and robots become more widespread in education, this will also be more realistic for future studies.

Second, when assessing the potential impact of social robots on children's social-emotional development, we interviewed experienced teachers (Chapter 5). However, none of the teachers systematically measured the impact of the robot on children's social-emotional development. Therefore, our results are solely based on the experience and perspective of these teachers who observed children in their classrooms using robots for educational purposes. Also, the in-depth interviews were conducted with only a limited number of teachers, although the overall number of children they supervised in child-robot interaction was high. As the goal of this interview study (Chapter 5) was to assess the fears expressed by stakeholders related to the impact social robots could have on the social-emotional development of children, we provided a first step through those experienced teachers. However, the limited sample size implies being cautious in drawing solid conclusions. How social robots would impact the social-emotional development of children, especially with more technologically sophisticated robots, is still an important subject for future research.

Finally, it should be noted that all empirical studies (in Chapters 3, 4 and 5) were solely executed in the Netherlands. Therefore, the results provide insights into a Dutch (and perhaps Western European) perspective on social robots in education. Earlier research has indicated that stakeholder perspectives on social robots differ in other countries. For example, whereas Korean and Japanese stakeholders are reported to view robots as potential friends for children (Choi et al., 2008), European stakeholders report cautious attitudes and concerns about the so-called "friendship" between children and robots (Reich-Stiebert & Eyssel, 2016; Serholt et al., 2017). Future research is needed to be able to compare our results to other countries and cultures.

6.4 PRACTICAL IMPLICATIONS: TOWARDS A CODE OF CONDUCT

The results in this dissertation have highlighted the complexity of implementing social robots in primary education by keeping in mind the values and moral considerations of various relevant stakeholders. This makes creating a code of conduct a daunting task. In this section, we discuss the practical implications that result from this dissertation's theoretical implications. Taken together, these practical implications form the first step towards a code of conduct for the use of social robots in education (summarised in Appendix A).

As argued in Chapter 1, just programming robots with moral reasoning capabilities will probably not suffice. The current state of technology is not sufficiently well developed for robots to autonomously make moral decisions in a complex environment such as a primary school classroom. Technological innovation might, in the long term, solve many of the moral issues identified in this dissertation, such as those related to privacy (Fernandes et al., 2016). However, in the short term, robots seem not able to sufficiently reason about the multiple values and moral considerations of different stakeholders as discussed in this dissertation. Therefore, a code of conduct for the use of social robots in education should, next to providing some technical recommendations, provide clear guidelines for stakeholders on how to build and use social robots for primary education. In the coming sections, we present the code of conduct in terms of practical implications.

6.4.1 Introducing social robots in primary education

In total, this dissertation identified seventeen values relevant when social robots are implemented in education. As discussed above (section 6.2.1. Variation in complex moral challenges), taking into account all values will require trade-offs. Especially, due to the five distinct and sometimes conflicting attitude profiles of stakeholders related to the moral considerations of using social robots in education (Chapter 4). Because the attitude profiles sometimes conflict, schools are likely to also encounter different attitudes of stakeholders that might not be easy to bring in line when introducing social robots. For example, some stakeholders may consider social robots practical tools (e.g., stakeholders belonging to the Practical group; Chapter 4), whilst others consider robots especially useful for social interaction (stakeholders belonging to the Enthusiast group; Chapter 4). Therefore, to ensure schools do not undermine the values of their own specific stakeholders, schools will need to include their stakeholders in the decision process on how social robots are used. However, just including representatives of all stakeholder roles (e.g., teachers, parents, school management) will probably not be sufficient to include all perspectives. Stakeholders' age, previous robot experience, income, and education level served as stronger predictors than a specific stakeholder role. Therefore, when discussing how to integrate robots in education it is important to not solely focus on stakeholder roles, but also include a broad and diverse group of stakeholders. The seventeen values and considerations identified in this dissertation may serve as a checklist for schools to discuss the use of social robots with their stakeholders. It may be unrealistic to expect that schools involve representatives of all stakeholders group in these discussions. For example, governmental policy makers may be hard to involve, because they are not part of the daily educational process of primary schools. Schools might thereby first start to include their direct stakeholders and representatives of children (parents) in these sessions. Thus, **Practical implication 1** is, *schools should involve teachers, parents, school management, and the robot industry, varying in age, robot experience, income, and education level, when implementing social robots and use the values and considerations identified in this dissertation as guidelines to specify the discussion*.

Although stakeholder attitudes can be divided into five distinct attitude profiles (see Chapter 4), there are main values and considerations stakeholder groups agreed on that can be considered as suggestions on how to use social robots in education in such a way that they align with most stakeholder values and considerations. Overall, most stakeholders considered robots useful and fun for children and a potential tool for supporting teachers. Furthermore, stakeholder groups seem to agree that robots should be made widely available in schools. This leads to **Practical implication 2**: *because most stakeholder groups consider social robots a potential valuable educational tool, primary schools should consider starting experimenting with social robots while keeping in mind the impact on stakeholder's values and considerations*. For example, by first setting up a pilot to explore the use of social robots, potentially in collaboration with universities, research institutes, and the robotic industry. By setting up collaborative pilots, schools can on a small-scale conduct experiments with robots. Universities, research institutes, and the robotic industry may be able to facilitate robots for such exploratory pilots. Such collaborations may result in schools not having to allocate a considerable budget for buying new robots; high costs are a concern for several stakeholders.

Stakeholders have indicated (Chapter 3 and 4) that, if robots are being implemented in education, robots should be useful and versatile. Especially for simple, repetitive tasks, social robots are considered by the stakeholders to be of added value. This results in **Practical implication 3**: *rather than aiming to develop a full-fledged all-round robot or trying to emulate a human teacher as a humanoid robot, simply designed, easy-to-use robots need to be designed and programmed for simple (rehearsal) tasks like multiplication, topography and storytelling, in such a way that the robot can execute these tasks as intended, thereby supporting the teacher and not being a burden due to technicalities.* For example, by designing a robot (program) that can interact with children for just teaching multiplication tables or second language learning. Designing such a single-purpose robot tutor would already be a complex task in itself. Robot developers might take into account studies that specifically focused on requirements for such robots tutors, such as Belpaeme, Vogt, et al. (2018) and Konijn et al. (2022) who focussed on a robot for second language learning, or Elloumi et al. (2022) and Konijn & Hoorn, (2020) who studied the requirements for mathematics education. Elloumi et al. (2022) found a comprehensive list of 18 requirements for such a robot tutor for mathematics, based on focus groups with teachers and children. These requirements varied from the 'need for the robot to be adaptive' to the 'robot must have prior knowledge about the children'. This illustrates that designing a robot for just one (simple) teaching task is already challenging; a full-fledged all-around robot seems unrealistic for real-life primary school classrooms given the current state of technology.

Stakeholders expressed that the robots should be able to help building e-portfolios of children and take over administrative tasks of the teacher. However, the current state of technology might not be sufficient for robots to provide reliable data for e-portfolios. For example, interactions between children and robots often break down in real-life environments (Serholt, 2018), and currently used robots have only a limited ability for interpreting complex social environments (see, Chapter 1). These issues may result in the data of the robot being unreliable for e-portfolios. Therefore, multiple stakeholder groups (Chapter 3) consider it important that the data should still be interpreted by a human teacher. This results in **Practical implication 4**: *designers, engineers and programmers of robots should start working towards ways in which the data collected by the robot can be usefully integrated into the school database in such a way that the source data is traceable by the teachers.* For example, by designing a student system that aggregates children's data in such a way that teachers can a) view the children's learning progress on a high level, and b) zoom into the data underlying the aggregated learning progress scores.

According to the stakeholders (Chapter 3 and 4), social robots should be equally accessible to all schools, teachers and children. The robots should therefore also be usable for teachers with limited technical knowledge. In the Netherlands, primary school teachers have indicated a clear need for training to cope with upcoming educational technologies, such as artificial intelligence and robotics (E. Smeets, 2020). Thus, there is a need for learning material and workshops for teachers with low levels of digital literacy to enable them to start working with social robots. However, not only the digital literacy levels of teachers are a potential hurdle, but also the school's budget can be considered a limitation. Stakeholders voiced concerns that schools in lower economic areas could not afford robots as teaching tools, which could potentially result in unequal learning opportunities for children and further the digital divide (Dondorp & Pijpers, 2020). Therefore, **Practical implication 5** is: *governmental policymakers should enable/support schools to experiment with social robots to ensure equal opportunities for children when schools indicate that they would like to use robots but are unable to*. For instance, governmental policymakers can propose policies that enable schools in lower economic areas to experiment with innovative technology.

Furthermore, related to the value of usability (Chapter 3), primary school management must provide each teacher with the opportunity to get acquainted with using social robots when they decide to integrate social robots into their school. Although some children may prefer interacting with robots more than others, stakeholders agreed that each child should get an equal opportunity to use the robot. This results in **Practical implication 6**: *teachers must provide each child with the opportunity to interact and learn with robots when schools decide to integrate robots into their regular education*. Providing each child and teacher with equal opportunities for using robots will likely result in an increase of robots in education.

When robots are increasingly introduced in education, their use may lead to new ways of learning. Teachers in this dissertation voiced concerns about the robot becoming (too) prescriptive to their teaching methods, thereby impacting the teacher's autonomy in the classroom. For example, the teacher needs to follow the pace and learning strategy of the robot. Because the robot is considered beneficial as a supportive tool, this potential prescriptive attribute might be considered undesirable. Therefore, **Practical implication 7** is: *to ensure that social robots do not undermine the autonomy of teachers, robot developers should involve teachers in the design process, thereby ensuring that the robot* *supports the teacher adequately and does not become too prescriptive to the learning process*. For example, by including teachers in multiple stages of the design process. This way teachers could provide important input to the robot's design, not only to respect the teacher's autonomy but also to add other considerations, such as didactical suggestions.

To ensure robots do not become (too) prescriptive, robot platforms should provide teachers with the ability to (re)design the child-robot interaction and the content provided by the robot. For example, by letting teachers create child-robot interactions and dialogues that the robot will follow. **Practical implication 8** therefore is: *robot developers should create robots in such a way that teachers may (re)design the content and interaction of social robots used in the educational process when they consider it beneficial for the pupil's development*. For example, by letting teachers create their own applications that the robot can execute.

Overall, these first eight practical implications provide schools, robot builders and policymakers with new directions for introducing social robots in primary education. The implications highlight that robots can start to be introduced into primary education and the importance of involving stakeholders during the design and introduction phase of this novel technology. However, it is important to consider the different responses schools might encounter from stakeholders when starting to use social robots.

6.4.2 Distinct attitude profiles related to the moral considerations

When schools decide to start using social robots, they are likely to encounter different responses from their stakeholders. The five distinct attitude profiles related to the moral considerations of stakeholders presented in Chapter 4 have shown that multiple socio-demographic characteristics influence the probability of belonging to a specific profile. These influencing characteristics provide grounds for several practical implications. Having experience with robots increases the likelihood of having a more positive attitude towards the moral considerations of using social robots in education. Therefore, **Practical implication 9** is: *it is advisable for schools to first familiarise stakeholders with social robots before implementation*. For example, by first organising workshops where stakeholders can interact with a robot, or by first using robots as tools rather than as social actors, towards which the vast majority of the stakeholder – especially teachers – have an accepting attitude.

Young stakeholders (aged 18 – 35 years) were less likely to belong to the sceptics group. Therefore, **Practical implication 10** is*: schools might turn to their younger employees first for the adoption of social robots, as they are less likely to belong* *to the Sceptic group.* After young employees have introduced the robots into a school, it is likely that the older employees will also start to become more familiar with the robots. Given that having experience with robots increases the likelihood of having a more positive attitude towards the moral considerations of using social robots in education, it is likely that the older employees will then start to have a more accepting attitude towards the robot.

In addition, **Practical implication 11** is: *schools in areas with lower economic status might expect more sceptical stakeholders, given that low income is a strong predictor of belonging to the Sceptic group.* This sceptical attitude might be explained by the concerns related to the financial costs related to the robot. Furthermore, teachers have also been recorded to state that parents of lower socioeconomic status would potentially need additional information to understand the implications of social robots, such as on the subject of privacy (Serholt et al., 2017). Therefore, schools might, for example, provide stakeholders from lower socioeconomic status with additional information on the financial consequences of the robot and the privacy implications during information sessions or workshops.

6.4.3 Directions for informational privacy

According to the stakeholders, parents should always be granted access to the data collected by the robot about their child. This consideration is largely in accord with the European privacy legislation, GDPR (Wolford, 2018). In the Netherlands, the parents (i.e., the legal representatives of a child) do automatically have the right to access their children's school records, until their child turns 16 years of age. Such records consist of data on a child's learning progress, data on their social-emotional development, and results of psychological testing (Autoriteit Persoonsgegevens, 2022). Some schools provide parents with automatic digital access to children's records, however, in general, the access is provided by the school in response to a request of the parents. However, the sensitive nature of the data that a robot is able to collect, such as audio or video recordings of secrets told by a child in confidence, makes this access potentially problematic.

Most stakeholder groups agreed that secrets told by a child in confidence during CRI should not be "passed on" to others. This information might include accounts of child abuse or parents being in a divorce dispute. This information could be misunderstood or even misused by some, such as the parents in the situation of child abuse. Furthermore, "passing on" these secrets that are told in confidence would undermine the values of trust and sincerity and could lead to children feeling deceived.

To mitigate this issue, the data storage of the robot could be designed to separate the access rights to non-secret data of children (e.g., test results) and secret data (e.g., secrets told in confidence). Such a system, however, might be practically unrealistic. Given the technical limitations of the currently used robots, such as limited speech recognition (e.g., Kennedy et al., 2017), detecting what data is "secret" and what data is not, might be problematic. This could lead to undesired situations where sensitive secrets of children are stored by the robot as regular interaction data and are consequently shared with parents. This might be mitigated by, for example, letting parents only access aggregated data on children's learning progress, such as their progress in learning mathematics or language learning. In such a situation, potential sensitive video and audio data of children would be withheld from parents. Legally, however, parents do have the right to access all the data of their children, including audio or video recordings created by the robot. Teachers could serve as a gatekeeper in this situation. Parents could request access to specific data files of their children, which would only be granted after clearance by the teacher. Creating a gatekeeper role for the teacher, however, may contribute to the already relatively high work pressure of teachers. The current workload of teachers seems not to allow for such an extra, potential time-consuming task.

Given the current technological challenges to detect sensitive dialogues during CRI and the gate keeper role for teachers being potentially unrealistic, creating standard educational social robots that collect and store sensitive data seems unwise. However, to utilise robots for simple teaching tasks, supervision, taking exams, and motivating children – the applications most stakeholder groups find acceptable for robots – it seems that not much personal, sensitive data is needed. Robots can execute simple teaching tasks with limited personal data of children (e.g., Konijn et al., 2022; Vogt et al., 2019). Motivating children and keeping children engaged have also been shown possible without sensitive personal data (e.g., Ligthart et al., 2020). Thus, for now, collecting and storing vast amounts of video and audio data seems undesirable and unnecessary. In the future, with improved natural language process capabilities, robots might be able to detect sensitive situations and report potential harmful situations to teachers, but for now, limiting the amount of data seems to be the best way to respect children's privacy and trust and avoided potential harmful situations.

The considerations related to informational privacy mentions above lead to three specific practical implications. **Practical implication 12**: *robot developers should, together with teachers, decide what the minimum amount of data is for a robot to be able to perform its pre-defined function effectively, and design the robot in such a way that it only processes the minimum data required*. For example, when designing a robot that practices multiplication tables with children in a personalised way, teachers and developers should decide what the minimum of data should be for personalisation. A robot might personalise mathematics tasks by just personalising certain questions, such as adding a child's favourite animal or colour to a question. To elicit this information, a robot could ask children what their favourite animal is, process the speech recording and store only the answer to the question. When the answer is sorted in the database, the audio or video file is destroyed. This way the robots are still able to utilise speech recognition capabilities, but do not create complex problems related to secrets. Therefore, **Practical implication 13** is: *the goal of standard educational social robots should not be to uncover sensitive personal secrets of children*.

Please note that this implication applies to "standard" educational social robots.

Practical implication 13 above does not apply to robots that are specifically designed to uncover sensitive data of children, such as for therapeutic aims in special education. For such situations, video and audio recordings might be needed for interpretation reasons. During such sessions, there are usually more resources available and other procedures in place to deal with children's secrets compared to regular primary education. For example, the presence of a specialised health-care professional who has is professionally (better) qualified and has time to listen to the secrets and act accordingly. However, for "standard" primary education classrooms the deployment of social robots to uncover sensitive personal secrets of children stays problematic.

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Given that the later implications related to informational privacy are set into place, parents can be granted access to the data collected by standard educational social robots. Therefore, **Practical implication 14** of this dissertation is: *parents should have access to the educational data collected by the robots, they have this right by law and most stakeholders agree on this issue*. For example, schools could grant parents access to the data in view of the educational progress of the child, just as with the regular records of children.

One of the considerations most stakeholder groups agreed on, is related to the value of privacy. Stakeholder groups, on average, agreed that data collected by the robot should not be shared with third parties such as the government and robot companies to improve policies and products. These considerations lead to **Practical implication 15**: *schools should not share personal data of children collected by the robots with third parties, except 1) for specific purposes when explicit parental consent is provided or 2) when schools are legally obligated to provide the data to specific parties*. This implication is in line with the GDPR privacy legislation; schools may not share privacy-sensitive data with third parties (Wolford, 2018). However, the (Dutch) law also requires schools to provide children's records to some third parties, such as the Inspectorate of Education (Dutch: Inspectie van het Onderwijs) to assess the quality of the education, or in emergency situations such as suspicion of domestic violence (Ministerie van Onderwijs, 2014). However, in general, parents should first provide explicit consent before data may be shared with third parties; the GDPR legislation and the stakeholder views identified in this dissertation are in agreement on this issue.

6.4.4 Social interaction, bonding and social-emotional development

Robots having social interaction with children is central to the definition of educational social robots. As a result of this interaction, children are expected to start to feel attached to robots (Leite et al., 2013) and a kind of social (friendship) bond can start to develop (Sinoo et al., 2018). Stakeholders have expressed concerns related to the potential negative effects of social robots boding with children, especially on children's social-emotional development. However, in Chapter 4 we found no strong dismissive attitude profiles for social interaction and bonding, except for the Sceptics group. This Sceptics group had mainly utilitarian arguments (see section 6.2.5) against social interaction and bonding. However, in Chapter 5, the experienced teachers who had used robots in their day-to-day education did not observe any lasting negative effects on the social-emotional development of children. Therefore, **Practical implication 16** is: *the robot may be designed to form a simple social bond with children, similar to that of hand puppets or dolls.*

However, some children might be more susceptible to getting (too) attached to robots, such as shy children or underachievers (Chapter 5). These children might start to prefer interacting with a robot over their human peers and potentially get upset when the robot is not around. Therefore, **Practical implication 17** is: *teachers should look out for potential signs of strong attachment or friendship issues when social robots are being structurally integrated into their education, especially for children who are considered more susceptible to becoming (over) attached to the robot.* For example, teachers might look out for signs of children getting socially isolated. Although this might seem like an additional burden for teachers, monitoring children's social-emotional development is already part of their daily job. This practical implication, therefore, underscores the importance of having a human teacher present in a classroom to provide children with the attention they need.

The concerns related to the potential negative effects of child-robot interaction (CRI) on the concept of friendship have not been found in the empirical studies included in the review of Chapter 2 and have not been observed by the interviewed teachers of Chapter 5. However, as this concern is a returning theme, schools might consider explaining to their stakeholders that friendship with a robot is very different to human friendship and that most children know that. Robot friendship for most children will not exceed the bond they have with their pets and stuffed animals. Warnings hold for children that already suffer from attachment issues in other respects and need to be guarded (see Theoretical implication 4).

All stakeholders agree that robots should be considered in addition and assistive to a human teacher, and should not be used to replace human teachers. Therefore, **Practical implication 18** is: *schools should not use robots to replace human teachers but rather see them as potential assistants*. Human contact is perceived as more valuable than robot contact by all stakeholders. Therefore, **Practical implication 19** is: *the robot should be able to free up time for teachers who can then focus more on human contact with the children, and the robot ought to be able to stimulate and promote human contact, for example by encouraging children to work and play together.* A robot could, for example, be programmed for children to work in pairs on an assignment, as presented by Davison et al. (2020). Such an approach would stimulate human contact between children.

6.4.5 Focus on the impact robots could have on children and teachers

Most stakeholders seem to be concerned more with the impact that robots could have on the well-being of children and teachers, rather than with other, more fundamental, moral rules (see, Theoretical implication 5). However, the ambiguity related to who should be held responsible or accountable for any negative consequences of the use of social robots is a concern for policymakers, teachers, parents, and the robotic industry. In the focus group sessions (Chapter 3) stakeholders did not agree on who should be held accountable for the negative outcomes. Although stakeholders could not come to a general consensus on the accountability issue, most stakeholder groups considered the teacher responsible for what happens inside the classroom, and the robot industry responsible for the maintenance, software updates, and security of the robot. For example, the robot industry could be considered responsible for the "My Friend Cayla" case, where the robot failed to safeguard children's security and privacy (see Chapter 1). The teachers could be considered responsible for the potential negative outcomes during the interaction in the classroom, such as, for example, the children molesting the robot. Teachers and the robot industry may both be considered appropriate actors for being responsible for specific tasks. However, when integrating robots on a large scale, the ambiguity related to who is responsible and accountable for negative outcomes must be solved beforehand. Therefore, **Practical implication 20** is: *when schools start* *to experiment with social robots, 1) the teacher is responsible for monitoring the child-robot interaction and signalling signs of attachment issues or other potential negative outcomes, and 2) the robot industry is responsible for ensuring the robots safeguard children's security and privacy and that the robots are up-to-date*. This implication allows schools to start experimenting with social robots on a small scale. However, there is a clear role for school management and governmental policymakers to create more transparency on who is accountable for the impact of social robots, because, currently, the responsibility expectations of stakeholders vary. Because stakeholder expectations vary on who is responsible and accountable, schools should, when starting to introduce social robots, discuss who is responsible and accountable for any negative outcomes caused by the robot with their stakeholders. Until the school management and governmental policymakers come to a clear agreement on who should be responsible and accountable, the two stakeholders discussed above (teachers and the robot industry) may serve as a base for allocating responsibility.

IT security is an important aspect of CRI. The robot (both hardware and software) should be sufficiently secured, thereby limiting the potential of breaking down, collapsing, or being hacked. Some studies have indicated that schools (e.g., Richardson et al., 2020) and social robots (e.g., Miller et al., 2018) are vulnerable to hacking. For example, Miller et al. (2018) demonstrated a scenario wherein an unauthorised user could connect to a social robot and take control of its actions, due to the lack of authentication required for robots that share a wireless network connection. Such a situation might have severe negative effects on children and teachers. Whereas the IT infrastructure of the school is the responsibility of the school management, the security (hackability) of the robot itself is first and foremost the responsibly of the robot industry. Therefore, **Practical implication 21** is: *the robot industry must ensure that the robots are sufficiently secured, before placing, renting or selling their robot to schools*. Stakeholders have indicated (Chapter 4) a relatively positive attitude towards a security certificate that ensures the robot is properly secured. Therefore, the robot industry could consider letting the robots be audited before the robots are placed on the market.

Securing just the robot as a machine, however, will probably not suffice to ensure the safety and privacy of children and teachers. The IT infrastructure of schools is also vulnerable to hacking (e.g., Marinos, 2021; Richardson et al., 2020). Recently, the Dutch government recognised the issues of cybersecurity in education as being urgent and presented a new plan to improve schools' IT security (Dijkgraaf & Wiersma, 2022). In their plan, the Dutch government pledged to invest structurally 6 million euros each year to increase cybersecurity in schools. They argue for a cybersecurity guideline for schools and the obligation for schools to explicitly include cybersecurity in their annual reports. This initiative to improve IT security in schools could help to contribute to a school's infrastructure where social robots can be used safely. However, schools often lack IT security knowledge and skills to assess their IT infrastructure. Therefore, **Practical implication 22** is: *primary school management needs to ensure that their IT infrastructure is sufficiently secured before integrating social robots into their school's processes, by appointing an (internal or external) IT security expert to test their IT infrastructure and to keep it up-to-date*. For example, by letting an IT expert perform vulnerability scans or audits that provide insights into the security state of the school's infrastructure. Such tests will be needed for the secure use of social robots in coalescence with the guidelines the government is setting up to ensure the cybersecurity of primary schools.

Overall, the practical implications presented in the sections above should be considered as a first attempt to embed the multitude of moral considerations and values that accompany the introduction of social robots in education from multiple stakeholder perspectives, into a single code of conduct (see Appendix A). As technological developments continue and we get more insights into the use of social robots over longer periods, this draft code of conduct might need revisions. This code should therefore not be considered an endpoint, but the start of many iterations to ensure that social robots can be applied responsibly, embedded with the values of both direct and indirect stakeholders.

6.5 LESSONS LEARNED AND FUTURE RESEARCH

The extant scientific literature, at the start of this PhD project, discussed mainly conceptual moral concerns, with only limited empirical data on stakeholder perspectives. This dissertation has provided more in-depth and empirically grounded insights into how different stakeholders compare in their values and moral considerations related to the use of social robots in education. We have shown that there are five attitude profiles related to the moral considerations of social robots in education. Against expectations, we concluded that the role of a stakeholder (e.g., being a representative of the robot industry or policymaker) is not a strong predictor of these attitudes. Other, social-demographic variables, such as age, income level, previous robot experience, and education level were shown to be significant predictors of belonging to a specific attitude group (e.g., stakeholders with robot experience were significantly more likely to belong to the attitude profile labelled Enthusiast: stakeholders that considered the use of social robots in primary education the most positive compared to the other four attitude profiles). Future research can include these variables in HRI studies and examine to what extend these variables also influence the attitudes of stakeholders of other domains, such as healthcare or hospitality.

We have also found that the arguments of stakeholders were mainly based on the possible consequences of the robots on the well-being of children and teachers, as opposed to the potential impact on more conceptual concepts, such as friendship. If stakeholders did worry about the potential impact of children bonding with robots, their concerns were more focused on the impact this bond would have on the well-being of children, rather than on the meaning of the concept of friendship itself.

In the existing (conceptual) literature thus far, scholars have voiced concerns that the robot might hurt children's social-emotional development. In our empirical studies, stakeholders also expressed such a concern. However, in our results, we did not find strong indications that robots form a danger to children's social-emotional development. Some children, however, might be likely to bond more easily with a robot than others (e.g., socially isolated children). Consequently, the social-emotional development of these children might be more at risk. Therefore, we encourage future research to include the characteristics of children that might be more susceptible to getting (too) attached to a robot as found in this dissertation (see Chapter 5), such as shyness, in their analyses when studying attachment between children and robots.

Existing guidelines on the responsible (moral) design and use of artificial intelligence (AI) and robots thus far, only provided very general principles that were often hard to apply in "real world" environments. Based on our results, we have provided practical implications as guidelines that are applicable and specified for social robots in primary education (see Appendix A.). Many of these guidelines are concrete and provide suggestions that stakeholders can directly use. These guidelines are more specific and applicable than the existing guidelines (see Chapter 1). However, some of our proposed guidelines are still limited to more general implications, such as the implications regarding IT security, due to the domain-specific knowledge needed to resolve the challenges related to these implications. Future research could focus on specifying the more general guidelines provided by this dissertation. For example, what would be the minimal requirements for a robot or school to be considered adequately secured? Especially technical studies could provide new answers because open issues often require thorough technical IT knowledge. Furthermore, legal and moral scholars may provide new insights into the accountability and responsibility issues still faced. Especially when the AI capabilities of robots improve, questions related to accountability and responsibility become more urgent, as we might enter into a new era wherein technology may also start to be considered an accountable actor.

Finally, looking at the horizon, more knowledge is needed on how children bond and learn with social robots. Very recently, scholars have highlighted the importance of deepening the knowledge of promising elements of child-robot interaction, such as the impact of eye gaze and feedback on engagement (De Haas, 2022), the utilisation of memory-based personalised strategies to foster child-robot relations (Ligthart, 2022) and the specific role of the robot tutor's hand gestures (De Wit, 2022). Although more and more studies are conducted with larger sample sizes, there is still a clear need for more long-term studies with greater sample sizes that take into account didactical knowledge of the education sciences domain, as well as the moral guidelines presented in this dissertation. Such studies will provide new insights into how novel technologies can adequately and responsibly support children and teachers in facing the diverse challenges of modern primary education.

6.6 FINAL CONCLUDING REMARKS

The moral challenges created by the introduction of social robots in primary education are highly complex because they are related to a broad range of values and moral considerations of a wide range of relevant stakeholders such as parents, teachers, students of education, children, school managers and representatives of the robot industry. This dissertation aimed to identify the key values and examine the moral considerations of each of those different stakeholders, relevant to education. In doing so, the results of the studies in this dissertation were integrated into this final chapter to provide a first step towards guidelines, or a so-called code of conduct, on how social robots can be designed and used in such a way that robots do not undermine the values and moral considerations of the various stakeholders in education.

Our empirically based research provides an important first step towards the integration of social robots in primary education in a morally justified manner. When more schools gain experience with social robots, our proposed code of conduct may need finetuning, alterations or extensions. However, for now, we have provided a solid stepping stone for schools, robot designers, programmers and engineers to develop and use social robots in education in a morally justified way. We thereby paved the way for social robots to be explored as an assistive technology for teachers and children in primary education.

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APPENDIX A

CODE OF CONDUCT FOR THE USE OF ROBOT TUTORS IN PRIMARY EDUCATION

Introducing social robots in primary education

1. Schools should involve teachers, parents, school management, and the robot industry, varying in age, robot experience, income, and education level, when implementing social robots, and use the values and considerations identified in this dissertation as guidelines to specify the discussion.
2. Because most stakeholder groups consider social robots a potential valuable educational tool, primary schools should consider starting experimenting with social robots while keeping in mind the impact on stakeholder's values and considerations.
3. Rather than aiming to develop a full-fledged all-round robot or trying to emulate a human teacher as a humanoid robot, simply designed, easy-to-use robots need to be designed and programmed for simple (rehearsal) tasks like multiplication, topography and storytelling, in such a way that the robot can execute these tasks as intended, thereby supporting the teacher and not being a burden due to technicalities.
4. Designers, engineers and programmers of robots should start working towards ways in which the data collected by the robot can be usefully integrated into the school database in such a way that the source data is traceable by the teachers.
5. Governmental policymakers should enable/support schools to experiment with social robots to ensure equal opportunities for children when schools indicate that they would like to use robots but are unable to.
6. Teachers must provide each child with the opportunity to interact and learn with robots when schools decide to integrate robots into their regular education.
7. To ensure that social robots do not undermine the autonomy of teachers, robot developers should involve teachers in the design process, thereby ensuring that the robot supports the teacher adequately and does not become too prescriptive to the learning process.
8. Robot developers should create robots in such a way that teachers may (re) design the content and interaction of social robots used in the educational process when they consider it beneficial for the pupil's development.

Distinct attitude profiles related to the moral considerations

9. It is advisable for schools to first familiarise stakeholders with social robots before implementation.

10. Schools might turn to their younger employees first for the adoption of social robots, as they are less likely to have a sceptical attitude towards the use of social robots in education.
11. Schools in areas with lower economic status might expect more sceptical stakeholders, given that low income is a strong predictor of having a sceptical attitude towards the use of social robots in education.

Directions for informational privacy

12. Robot developers should, together with teachers, decide what the minimum amount of data is for a robot to be able to perform its pre-defined function effectively, and design the robot in such a way that it only processes the minimum data required.
13. The goal of standard educational social robots should not be to uncover sensitive personal secrets of children.
14. Parents should have access to the educational data collected by the robots; they have this right by law and most stakeholders agree on this issue.
15. Schools should not share personal data of children collected by the robots with third parties, except 1) for specific purposes when explicit parental consent is provided or 2) when schools are legally obligated to provide the data to specific parties.

Social interaction, bonding, and social-emotional development

16. The robot may be designed to form a simple social bond with children, similar to that of hand puppets or dolls.
17. Teachers should look out for potential signs of strong attachment or friendship issues when social robots are being structurally integrated into their education, especially for children who are considered more susceptible to becoming (over) attached to the robot.
18. Schools should not use robots to replace human teachers but rather see them as potential assistants.
19. The robot should be able to free up time for teachers who can then focus more on human contact with the children, and the robot ought to be able to stimulate and promote human contact, for example by encouraging children to work and play together.

Focus on the impact robots could have on children and teachers

20. When schools start to experiment with social robots, 1) the teacher is responsible for monitoring the child-robot interaction and signalling signs of attachment issues or other potential negative outcomes, and 2) the robot industry is responsible for ensuring the robots safeguard children's security and privacy and that the robots are up-to-date.

21. The robot industry must ensure that the robots are sufficiently secured, before placing, renting or selling their robot to schools.
22. Primary school management needs to ensure that their IT infrastructure is sufficiently secured before integrating social robots into their school's processes, by appointing an (internal or external) IT security expert to test their IT infrastructure and to keep it up-to-date.

SUMMARY

Primary education is fundamental to children's development and a basic human right. However, providing each child with the primary education they need is no easy task. The challenges currently faced in (Dutch) primary education include growing shortages of primary school teachers, relatively high administrative loads that contribute to work-related stress, and a highly diverse population in classrooms, differing in educational ability levels, special needs and cultural backgrounds. A promising new technology that could help support teachers and children in facing these challenges is social robots. These physically embodied robots can interact with children by taking on social roles, such as that of a peer or tutor. In doing so, social robots have been shown to be able to outperform traditional (screen-based) educational technologies in several ways. However, social robots do not only come with new opportunities, they are also reported to potentially undermine values upheld in education and are regularly morally questioned by the scientific and public community.

At the start of this PhD project, the scientific knowledge on the moral implications related to social robots in education was mainly based on conceptual arguments that used moral theories, such as deontology, utilitarianism and virtue ethics, or on single stakeholder perspectives. However, it is generally accepted that conceptual arguments and single-stakeholder perspectives are too limited to serve as a solid foundation for the morally justified design and implementation of technology. To advance the knowledge on the moral concerns related to social robots in primary education, there was a clear need to empirically study what values are impacted by the introduction of these robots and the moral considerations of different groups of stakeholders (e.g., parents, robot industry). Therefore, the PhD project presented in this dissertation systematically studied the relevant values - what people consider important in primary education - and moral considerations of various stakeholders related to social robots in primary education, thereby providing a first step towards guidelines on how social robots can be designed and used in such a way that robots do not undermine these values and moral considerations. In our studies, we used a mixed-method approach, following the Value Sensitive Design (VSD) methodology to offer a comprehensive and nuanced overview of the moral values and considerations of relevant stakeholder groups, and provide new insights into the moral challenges of designing and using social robots for primary education. In doing so, this dissertation adds new knowledge to the intradisciplinary research field of Robot Ethics, which aims to understand the moral implications of robotic technology and to suggest means for achieving improved results for the integration of robots in our everyday world.

Harms and benefits of social robots in education

Chapter 2 presents a systematic literature review ($N = 256$) to identify the potential harms and benefits related to social robots in primary education. Findings indicate that social robots provide five main (potential) benefits for primary education: (1) increased motivation and enjoyment, (2) reduced anxiety, (3) new opportunities for education (e.g., new social interaction and roles), (4) personalised learning, and (5) reduced administrative work. Next to these reported benefits, we found a broad and diverse scheme of eleven potential harms (e.g., downsides, negative impact, concerns), including the disruption of the educational process and the loss of human contact. Most of these harms were argued to be caused by the technological limitations of the social robots that are currently used and studied in classrooms, such as the robot's limited ability to interact autonomously with children and the current state of speech recognition technology. If these technological limitations were to be solved, four key clusters of issues would remain (1) privacy and security, (2) control and accountability, (3) social implications, and (4) loss of human contact. Next to the identified issues, results showed that all reported harms and benefits in the literature were related to the teachers and children. The perspectives of other stakeholder groups, such as parents, governmental policymakers, and the robot industry were overlooked in the reviewed literature.

Including understudied stakeholders: their values and moral considerations

Chapter 3 reports on a focus group study ($N = 118$) that examined the perspectives of stakeholders who were missing in the literature. Results of the focus group sessions with parents of primary school children, representatives of the robot industry, educational policymakers/advisors working for the government, teachers, and primary school children, showed that seventeen values are relevant to social robots in primary education. Many of the identified values were in line with other studies on values and educational technology. However, we also identified values that seem to be understudied in earlier research, such as applicability, usability, freedom from bias, autonomy, and flexibility. Overall, each of the stakeholder groups considered social robots a potentially valuable tool for education, next to their concerns. Many similarities and only a few conflicting views across the various stakeholder groups were found. Particularly among the teachers, parents, and policymakers, there were many similarities in the issues reported and their considerations were often aligned.

Comparing individual stakeholders on moral considerations

In Chapter 4, we present a quantitative study ($N = 515$) that explored the differences in the moral considerations between (and within) stakeholder groups.

This study aimed to gain insights into the various attitude profiles related to the moral considerations and to examine which socio-demographic characteristics influence these attitude types. Based on the results of the literature review (Chapter 2) and the focus group sessions with stakeholders (Chapter 3), a questionnaire was created to systematically identify distinct attitude profiles as well as socio-demographic characteristics that influence the probability of belonging to a specific profile. Findings revealed five distinct attitude profiles: (1) Enthusiast, (2) Practical, (3) Troubled, (4) Sceptic, and (5) Mindfully Positive. Overall, the Enthusiast group represents the most positive attitude towards social robots, whilst the Sceptic group represents the most negative one. The other three clusters show no strong dismissive attitudes towards social robots in education, although they each have their own moral issues that they consider relevant. Next to identifying the distinct attitude profiles, we also identified the socio-demographic characteristics that influence the probability of belonging to a specific profile. In line with earlier research, our results show that people with experience with social robots were more likely to have a positive attitude toward social robots. Furthermore, stakeholders with a low-income level were significantly more likely to belong to the group of stakeholders who are sceptic about social robots in education. Other factors, such as age and educational level also served as strong predictors for the attitude profiles. Against expectations, the socio-demographic characteristics served as stronger predictors for stakeholder attitudes than being a specific stakeholder (e.g., being a representative of the robot industry or policymaker).

Social-emotional development

Throughout the previously mentioned studies, many stakeholders voiced concerns about exposing children to robots over a longer period, which would impact children's social-emotional development. In Chapter 5, we report on a qualitative study with in-depth interviews to examine the impact of this specific concern. Based on in-depth interviews with primary school teachers who used robots in their day-to-day education (N = 9, who supervised the child-robot interaction of >2500 unique children), the results show that social robots can impact children's social-emotional development in multiple ways. However, no lasting negative impact on children's social-emotional development was observed by any of the participating teachers. Instead, teachers expressed to experience multiple benefits related to children's social-emotional development, namely: increased self-confidence, helping other children, increased ability to express oneself, increased ability to be patient and listen to others, and curiosity stimulation. Nevertheless, teachers mentioned that extra caution might be at place for some children. Through the teachers' reports, this chapter also provided characteristics of children who might be more susceptible to becoming too attached to robots, such as children that underachieve on a certain subject and children with special needs. Lastly, Chapter 5 provides best practices for the responsible use of social robots in primary education, according to the interviewed teachers, such as the need to proactively informed parents when social robots are going to be used. Overall, the results of this chapter highlight (1) that social robots seem able to both positively and negatively impact children's social-emotional development, (2) that some children seem more susceptible to becoming over-attached to robots, and (3) that there is a need to examine both the positive and negative impact of robots on children's social-emotional development in more detail.

Theoretical implications

Overall, the results of this dissertation lead to five main theoretical implications (see Chapter 6). **First**, social robots in primary education create complex moral challenges due to the variation in stakeholder values and the - at times - conflicting moral considerations of stakeholders. **Second**, five distinct attitude profiles related to the moral considerations of stakeholders can be identified and multiple socio-demographic characteristics influence the probability of belonging to one of these profiles. Against expectations, we concluded that the role of a stakeholder (e.g., being a representative of the robot industry or policymaker) is not a strong predictor of these attitudes. Other, social-demographic variables, such as age, income level, previous robot experience, and educational level were shown to be significant predictors of belonging to a specific attitude profile. **Third**, Informational Privacy, concerned with the data collection and processing capacities of a robot that affects users, is the main privacy component argued to be relevant for social robots in education. **Fourth**, social robots seem able to impact the social-emotional development of children and some children are more susceptible to over-attachment to robots than most. However, throughout this dissertation, we have found no empirical evidence that implies that social robots are likely to hurt children's social-emotional development. Lastly, the **fifth** theoretical implication of this dissertation is that, when considering the three main moral theories (deontology, utilitarianism and virtue ethics), most stakeholders seem to argue about the moral challenges in line with utilitarian theory, focusing on the impact robots could have on the well-being of children and teachers. However, arguments along the lines of the other main theories can be found in the moral considerations of the stakeholders. Using just one moral theory when considering the moral design and use of social robots in primary education might therefore be too limited. Such an approach could lead to relevant stakeholder values being undermined. The Value Sensitive Design approach followed throughout this dissertation allows for combining multiple moral theories. Therefore, the Value Sensitive Design methodology seems especially valuable, not only when studying robots in education, but also robots in other domains, such as healthcare.

Practical implications

This dissertation has several practical implications, that together form the basis for a code of conduct for the use of social robots in education (see Chapter 6). As technological developments continue and we get more insights into the use of social robots over time, this code of conduct might need to be revised. This code of conduct should therefore not be considered an endpoint, but the start of many iterations to ensure that social robots can be applied responsibly, embedded with the values of both direct and indirect stakeholders.

Concluding remarks

Our empirically based research provides an important first step towards the integration of social robots in primary education in a morally justified manner. When more schools gain experience with social robots, our proposed code of conduct (see Appendix A) may need finetuning, alterations or extensions. However, for now, we have provided a solid stepping stone for schools, robot designers, programmers and engineers to develop and use social robots in education in a morally justified way. We thereby paved the way for social robots to be explored as an assistive technology for teachers and children in primary education.

NEDERLANDSE SAMENVATTING (DUTCH SUMMARY)

Basisonderwijs is een fundamenteel mensenrecht en van groot belang voor de ontwikkeling van kinderen. Het is echter geen gemakkelijke taak om elk kind het basisonderwijs te bieden dat het nodig heeft. De uitdagingen waarmee het (Nederlandse) basisonderwijs momenteel wordt geconfronteerd zijn, onder meer, een groeiend tekort aan leraren, relatief hoge administratieve lasten die bijdragen aan werkgerelateerde stress. Tevens is de populatie kinderen in klaslokalen in toenemende mate divers, varieert in onderwijsniveaus, speciale behoeften en culturele achtergronden. Een veelbelovende nieuwe technologie die leerkrachten en kinderen kan helpen bij deze uitdagingen is de sociale robot. Deze fysiek belichaamde robots kunnen communiceren met kinderen door sociale rollen op zich te nemen, zoals die van medeklasgenoot of onderwijsassistent. Eerder onderzoek toont aan dat de inzet van sociale robots op verschillende manieren kan leiden tot betere resultaten dan traditionele (scherm gebaseerde) onderwijstechnologieën. Sociale robots bieden echter niet alleen nieuwe kansen. Ze ondermijnen naar verluidt ook waarden die in het onderwijs worden nageleefd. Daarnaast wordt de toepassing van sociale robots in het onderwijs regelmatig moreel in twijfel getrokken door de wetenschappelijke en publieke gemeenschap.

Bij de start van dit promotieproject was de wetenschappelijke kennis over de morele implicaties van sociale robots in het onderwijs voornamelijk gebaseerd op conceptuele argumenten die gebruik maakten van morele theorieën, zoals deontologie, utilitarisme en deugdethiek, of op single-stakeholderperspectieven. Het is echter algemeen aanvaard dat conceptuele argumenten en single-stakeholderperspectieven te beperkt zijn om als solide basis te dienen voor het moreel verantwoord ontwerpen en implementeren van technologie. Om de kennis over de morele zorgen met betrekking tot sociale robots in het basisonderwijs te vergroten, was er een duidelijke behoefte om empirisch te onderzoeken welke waarden worden beïnvloed door de introductie van deze robots en wat de morele overwegingen zijn van verschillende groepen belanghebbenden (bijvoorbeeld ouders, leerkrachten en robotindustrie). Om deze reden heeft het promotieproject dat in dit proefschrift wordt gepresenteerd systematisch de relevante waarden - wat mensen belangrijk vinden in het basisonderwijs - en de morele overwegingen van verschillende belanghebbenden met betrekking tot sociale robots in het basisonderwijs bestudeerd, om zo de eerste richtlijn te creëren voor het ontwerp en gebruik van robots die de waarden en morele overwegingen van belanghebbenden respecteren. In onze studies is een "mixed-method"-benadering gebruikt, waarbij we de Value Sensitive Design (VSD)-methodiek volgden om een uitgebreid en genuanceerd overzicht te bieden van de morele waarden en overwegingen van relevante stakeholdergroepen en om nieuwe inzichten te verschaffen in de morele uitdagingen van het ontwerpen en inzetten van sociale robots voor het basisonderwijs. Daarmee voegt dit proefschrift nieuwe kennis toe aan het interdisciplinaire onderzoeksveld van Robot Ethics, dat tot doel heeft de morele implicaties van robottechnologie te begrijpen en manieren aan te reiken om betere resultaten te bereiken voor de integratie van robots in onze dagelijkse wereld.

Voor- en nadelen van sociale robots in het onderwijs

Hoofdstuk 2 presenteert een systematisch literatuuroverzicht ($N = 256$) om de mogelijke voor- en nadelen van sociale robots in het basisonderwijs te identificeren. Uit de bevindingen blijkt dat sociale robots vijf belangrijke (potentiële) voordelen bieden voor het basisonderwijs: (1) meer motivatie en plezier, (2) minder angst, (3) nieuwe kansen voor onderwijs (zoals nieuwe sociale interactie en rollen), (4) gepersonaliseerd leren en (5) minder administratief werk. Naast deze gerapporteerde voordelen vonden we een breed en divers palet van elf mogelijke nadelen (potentiële schade, negatieve impact, zorgen), waaronder de verstoring van het onderwijsproces en het verlies van menselijk contact. Het merendeel van deze nadelen zou worden veroorzaakt door de technologische beperkingen van de sociale robots die momenteel worden gebruikt en bestudeerd in klaslokalen, zoals het beperkte vermogen van de robot om autonoom met kinderen om te gaan en de huidige mogelijkheden van de spraakherkenningstechnologie. Als deze technologische beperkingen worden opgelost, zouden er vier belangrijke clusters van nadelen overblijven (1) privacy en veiligheid, (2) controle en verantwoording, (3) sociale implicaties en (4) verlies van menselijk contact. Naast de geïdentificeerde problemen tonen de resultaten aan dat alle gerapporteerde voor- en nadelen in de literatuur verband hielden met de leerkrachten en kinderen. De perspectieven van andere groepen belanghebbenden, zoals ouders, onderwijsbeleidsmakers/-adviseurs werkzaam bij de overheid, en de robotindustrie, werden in de beoordeelde literatuur over het hoofd gezien.

Onderbelichte stakeholdergroepen: hun waarden en morele overwegingen

Hoofdstuk 3 doet verslag van een focusgroep-onderzoek ($N = 118$) waarin de perspectieven van belanghebbenden werden onderzocht die in de literatuur ontbraken. Resultaten van de focusgroepsessies met ouders van basisschoolkinderen, vertegenwoordigers van de robotindustrie, onderwijsbeleidsmakers/-adviseurs werkzaam bij de overheid, leerkrachten en basisschoolkinderen lieten zien dat zeventien waarden relevant zijn voor sociale robots in het basisonderwijs. Veel van de geïdentificeerde waarden kwamen overeen met andere studies over waarden en onderwijstechnologie. We hebben echter ook waarden geïdentificeerd die in eerder onderzoek onderbelicht lijken te zijn, zoals toepasbaarheid, bruikbaarheid, vrijheid van vooringenomenheid, autonomie en flexibiliteit. Over het algemeen beschouwden alle groepen belanghebbenden sociale robots, ondanks hun zorgen, als een potentieel waardevol hulpmiddel voor het onderwijs. Er werden veel overeenkomsten en slechts enkele tegenstrijdige opvattingen gevonden tussen de verschillende groepen belanghebbenden. Met name onder de leerkrachten, ouders en beleidsmakers waren er veel overeenkomsten en waren hun overwegingen vaak van gelijke strekking.

Vergelijking van individuele stakeholders op morele overwegingen

In hoofdstuk 4 presenteren we een kwantitatief onderzoek (N = 515) waarin de verschillen in morele overwegingen tussen (en binnen) groepen belanghebbenden zijn onderzocht. Dit onderzoek had tot doel om inzicht te krijgen in de verschillende attitudeprofielen die verband houden met de morele overwegingen en om na te gaan welke sociaal-demografische kenmerken deze attitudetypen beïnvloeden. Op basis van de resultaten van het literatuuronderzoek (hoofdstuk 2) en de focusgroepsessies met belanghebbenden (hoofdstuk 3) werd een vragenlijst opgesteld om systematisch verschillende attitudeprofielen te identificeren en om sociaal-demografische kenmerken te onderscheiden die van invloed zijn op de waarschijnlijkheid om tot een specifiek profiel te behoren. Uit de bevindingen kwamen vijf verschillende attitudeprofielen naar voren: (1) Enthousiast, (2) Praktisch, (3) Onrustig, (4) Sceptisch en (5) Bedachtzaam positief. Over het algemeen vertegenwoordigt de Enthousiast-groep de meest positieve houding ten opzichte van sociale robots, terwijl de Sceptisch-groep de meest negatieve vertegenwoordigt. De andere drie clusters staan niet sterk afwijzend tegenover sociale robots in het onderwijs, hoewel ze elk hun eigen morele kwesties hebben die ze relevant achten. Naast het identificeren van de verschillende attitudeprofielen, identificeerden we ook de sociaal-demografische kenmerken die van invloed zijn op de kans om tot een specifiek profiel te behoren. In lijn met eerder onderzoek laten onze resultaten zien dat mensen met ervaring met sociale robots vaker een positieve houding hebben ten opzichte van sociale robots. Bovendien behoorden stakeholders met een laag inkomen significant vaker tot de groep stakeholders die sceptisch staan tegenover sociale robots in het onderwijs. Ook andere factoren, zoals leeftijd en opleidingsniveau, waren sterke voorspellers voor de attitudeprofielen. Tegen de verwachting in bleken sociaal-demografische kenmerken sterkere voorspellers voor de attitudeprofielen dan de specifieke rol van belanghebbenden.

Sociaal-emotionele ontwikkeling

In de eerder genoemde studies hebben veel belanghebbenden hun bezorgdheid geuit over het gedurende een langere periode blootstellen van kinderen aan robots, wat gevolgen zou hebben voor de sociaal-emotionele ontwikkeling van kinderen. In hoofdstuk 5 doen we verslag van een kwalitatief onderzoek met diepte-interviews om de impact van deze specifieke zorg te bestuderen. Op basis van diepte-interviews met leerkrachten (N = 9) die robots gebruikten in hun dagelijks onderwijs en de kind-robot interactie van >2500 unieke kinderen begeleidde, laten de resultaten zien dat sociale robots op meerdere manieren invloed kunnen hebben op de sociaal-emotionele ontwikkeling van kinderen. Geen van de deelnemende leerkrachten constateerde echter een blijvend negatief effect op de sociaal-emotionele ontwikkeling van kinderen. In plaats daarvan gaven leraren aan meerdere voordelen te ervaren die verband houden met de sociaal-emotionele ontwikkeling van kinderen, namelijk: meer zelfvertrouwen, andere kinderen helpen, meer vermogen om zichzelf uit te drukken, meer geduld hebben, naar anderen luisteren en nieuwsgierigheid stimuleren. Desalniettemin merkten leerkrachten op dat voor sommige kinderen extra voorzichtigheid benodigd is. Op basis van de interviews met leerkrachten worden in dit hoofdstuk ook kenmerken gepresenteerd van kinderen die vatbaarder kunnen zijn om te gehecht te raken aan robots, zoals kinderen die ondermaats presteren op een bepaald onderwerp en kinderen met speciale behoeften. Tot slot geeft hoofdstuk 5 best practices voor het verantwoord gebruik van sociale robots in het basisonderwijs, zoals de noodzaak om ouders proactief te informeren wanneer sociale robots ingezet gaan worden. Over het algemeen benadrukken de resultaten van dit hoofdstuk (1) dat sociale robots zowel een positieve als een negatieve invloed kunnen hebben op de sociaal-emotionele ontwikkeling van kinderen, (2) dat sommige kinderen gevoeliger lijken te zijn voor overmatige gehechtheid aan robots en (3) dat zowel de positieve als de negatieve impact van robots op de sociaal-emotionele ontwikkeling van kinderen nader onderzocht moet worden.

Theoretische implicaties

Over het algemeen leiden de resultaten van dit proefschrift tot vijf belangrijke theoretische implicaties (zie hoofdstuk 6). Ten **eerste** creëren sociale robots in het basisonderwijs complexe morele uitdagingen vanwege de variatie in de waarden van belanghebbenden en de soms tegenstrijdige morele overwegingen van belanghebbenden. Ten **tweede** kunnen vijf verschillende attitudeprofielen worden geïdentificeerd die verband houden met de morele overwegingen van belanghebbenden. Meerdere sociaal-demografische kenmerken beïnvloeden de waarschijnlijkheid om tot een van deze profielen te behoren. Tegen de verwachting in concludeerden we dat de rol van een belanghebbende (bijvoorbeeld een vertegenwoordiger van de robotindustrie of beleidsmaker) geen sterke voorspeller is van deze attitudes. Andere sociaal-demografische variabelen, zoals leeftijd, inkomensniveau, eerdere robotervaring en opleidingsniveau bleken significante voorspellers te zijn van het behoren tot een bepaald attitudeprofiel. Ten **derde** is informatieprivacy - dat zich bezighoudt met de gegevensverzameling en verwerkingscapaciteiten van een robot - de belangrijkste privacy component die relevant wordt geacht voor sociale robots in het onderwijs. Ten **vierde** lijken sociale robots invloed te kunnen hebben op de sociaal-emotionele ontwikkeling van kinderen en lijken specifieke kinderen vatbaarder voor overmatige gehechtheid aan robots. In dit proefschrift hebben we echter geen sterk empirisch bewijs gevonden dat suggereert dat sociale robots de sociaal-emotionele ontwikkeling van kinderen kunnen schaden. Ten slotte is de **vijfde** theoretische implicatie van dit proefschrift dat, wanneer we de drie belangrijkste morele theorieën (deontologie, utilitarisme en deugdethiek) beschouwen, de meeste belanghebbenden lijken te discussiëren over de morele uitdagingen in lijn met de utilitaristische theorie. De nadruk ligt hierbij op de impact die robots zouden hebben op het welzijn van kinderen en leerkrachten. Argumenten in de lijn van de andere hoofdtheorieën zijn echter terug te vinden in de morele overwegingen van de betrokkenen. Het hanteren van slechts één moraaltheorie bij het beschouwen van de morele inzet van sociale robots in het basisonderwijs zou daarom te beperkt kunnen zijn. Een dergelijke benadering zou ertoe kunnen leiden dat relevante waarden van belanghebbenden worden ondermijnd. De Value Sensitive Design benadering die in dit proefschrift wordt gevolgd maakt het mogelijk om meerdere morele theorieën te combineren. Daarom lijkt de Value Sensitive Design methodiek bijzonder waardevol, niet alleen voor het bestuderen van robots in het onderwijs, maar ook voor robots in andere domeinen zoals de gezondheidszorg.

Praktische implicaties

Dit proefschrift heeft een aantal praktische implicaties, die samen de basis vormen voor een richtlijn voor de verantwoorde inzet van sociale robots in het onderwijs (zie hoofdstuk 6). Naarmate de technologische ontwikkelingen doorgaan en we in de loop van de tijd meer inzicht krijgen in het gebruik van sociale robots, moet deze richtlijn mogelijk worden herzien. Deze richtlijn moet daarom niet worden beschouwd als een eindpunt, maar als het begin van vele iteraties om ervoor te zorgen dat sociale robots verantwoord kunnen worden toegepast en worden ingebed in de waarden van zowel directe als indirecte belanghebbenden.

Afsluitende opmerkingen

Ons empirisch onderbouwde onderzoek is een belangrijke eerste stap naar een moreel verantwoorde integratie van sociale robots in het basisonderwijs. Wanneer meer scholen ervaring opdoen met sociale robots, kan het zijn dat onze voorgestelde richtlijn (zie bijlage A) moet worden bijgesteld, aangepast of uitgebreid. Voorlopig hebben we echter gezorgd voor een solide opstap voor scholen, robotontwerpers, programmeurs en ingenieurs om op een moreel verantwoorde manier sociale robots te ontwikkelen en in het onderwijs te gebruiken. Daarmee hebben we de weg geëffend voor onderzoek naar sociale robots als ondersteunende technologie voor leerkrachten en kinderen in het basisonderwijs.

DANKWOORD

Een promotietraject is een grotendeels individuele *tour de force*. Maar dit proefschrift was er nooit gekomen zonder de hulp van vele vrienden, collega's, kennissen, mede-onderzoekers en tal van anderen die op mijn pad kwamen tijdens deze leerzame marathon. Want dat is een promotietraject – een marathon. Met prachtige high's, zoals het bezoek aan symposia en conferenties (RIE, IDC, AIES, RO-MAN), het moment dat publicaties geaccepteerd werden, en tal van andere momenten. Echter, ben ik de spreekwoordelijke 'man met de hamer' tijdens dit traject ook tegen gekomen. Op deze momenten waren de mensen die om mij heen stonden cruciaal. Nu de finish in zicht is, kan ik de mensen die met mij mee liepen en langs de kant stonden eindelijk bedanken voor hun steun, liefde en geduld. Zij hebben allemaal een belangrijke rol gespeeld bij het tot stand komen van dit proefschrift.

Allereerst **Elly**, bedankt voor de begeleiding en het vertrouwen tijdens de afgelopen vijf jaar. Ik heb onwijs veel van je geleerd. Vanaf onze allereerste ontmoeting, geheel per toeval tijdens het jaarlijkse onderwijsfestival van de HU, heb je me gestimuleerd om het beste uit mezelf te halen. Zoals tijdens het schrijven van het voorstel voor de NWO promotiebeurs voor leraren – wat volgens sommigen nooit haalbaar was in enkele weken. Het heeft wat nachten gekost, maar niet zonder resultaat. Met de beurs in de pocket begon het werk pas echt. Het was een hele omschakeling van een master Filosofie naar een promotie bij Communicatie Wetenschap. Met jouw begeleiding heb ik echter nooit het gevoel gehad helemaal lost te zijn in dit voor mij toch wel nieuwe domein. Met veel plezier denk ik terug aan onze koffies en lunches bij Dauphine, Brazuca en De Plantage. Je hebt me altijd uitgedaagd bij het opzetten en uitvoeren van de studies en vervolgens bij het schrijven van de papers. Bedankt voor de vele feedback die hierbij een cruciale rol heeft gespeeld. Uit de grond van mijn hart, bedankt voor de mogelijkheid en wat ben ik blij met jou als promotor.

Paul, halverwege dit traject werd jij copromotor. Maar daarvoor hadden we elkaar al wel ontmoet: in Istanbul tijdens het slot symposium van het L2TOR project. Bedankt voor de ontspannen en fijne gesprekken die we hebben gehad. Helaas veelal op afstand vanwege COVID19, maar toch heb ik ze als prettig en leerzaam ervaren. Bedankt voor je support en begeleiding.

Tijdens het schrijven van mijn master thesis over robots en morele concepten aan Tilburg University, attendeerde mijn toenmalige begeleider mij erop dat sommige hoofdstukken mogelijk interessant waren om te presenteren op een wetenschappelijke conferentie. Dit zette mij op het academische pad wat ik de

afgelopen vijf jaar heb gevolgd en de komende jaren met passie en toewijding zal blijven volgen. **Alfred**, bedankt voor dit eerste duwtje in deze richting.

Als parttime buiten-promovendus heb je, naast de werkzaamheden als promovendus, ook nog een 'normale' baan. Ik heb onwijs veel geluk gehad: ik had me geen betere plek kunnen wensen dan het Insituut for ICT en het Lectoraat Betekenisvol Digitaal Innoveren aan de Hogeschool Utrecht. Niet alleen omdat zij mij de mogelijkheid gaven om de minor/specialisatie Social Robotics op te richten, maar ook vanwege de steun en het vertrouwen van alle collega's. In het bijzonder wil ik **Stella**, **Anita, Serge, Regine** en **Johan** bedanken voor de ruimte die ze me hebben gegeven om dit onderzoek in deeltijd te kunnen uitvoeren. En ook **Marlies**, bedankt dat je me attendeerde en daarna meenam naar de eerste AIES conferentie in Nice, waar we kennismaakte met VSD—de methode die als een rode draad door dit proefschrift loopt. Alle BIM collega's die dit traject met alle up's en down's van dichtbij hebben meegemaakt, bedankt. En in het bijzonder wil ik ook de collega's van de minor/specialisatie Social Robotics bedanken: **Marieke**, **Koen**, **Matthijs**, **Sam**, **John**, **Mirjam, Jeffrey** en ook **Anita**, **Lianne** en **Mireille**.

Maar niet alleen collega's hebben een belangrijke rol gespeeld. Bachelor en master studenten van de HU en VU Amsterdam, bedankt voor jullie hulp, toewijding en energie die hebben bijgedragen aan dit proefschrift. Jullie hulp is van onschatbare waarde geweest. In het bijzonder dank aan: **Gijs**, **Michael**, **Jordi, Kim Jimmy**, **Dorien** en **Stefan** voor jullie hulp bij het organiseren en analyseren van de focusgroepen. Daarnaast **John**, **Robin** en **Coen**, dank voor jullie hulp bij het opzetten en de dataverzameling van de questionnaire studie. Zeker met de toen heersende COVID19 restricties was dit een hele klus.

Paulina, bedankt dat je me de statistische vaardigheden hebt geleerd die nodig zijn voor de analyse in het kwantitatieve onderzoek**. Kelly, Huib, Simone** en **Britt,** bedankt voor het nalezen van sommige hoofdstukken. En dank aan de vele mensen die niet bij naam zijn genoemd maar toch betrokken zijn geweest bij dit traject.

Ook mijn (schoon)familie wil ik graag bedanken voor de getoonde interesse, stimulans en ondersteuning. Ondanks dat een deel van jullie geen idee had wat ik precies aan het doen was, waren en zijn jullie er altijd voor mij. In het bijzonder mijn moeder. **Mam**, bedankt dat je me altijd hebt geleerd door te zetten, een eigen plan te trekken en onafhankelijk te blijven.

Ook dank aan alle vrienden en kennissen die zo vaak wat hebben moeten aanhoren over robots. In het bijzonder **Frank**, **Bram**, **Sylvester**, en **Arjan,** bedankt voor alle momenten waarop jullie wéér iets moesten aanhoren over papers en over het eindeloze wachten op reviews, waarbij jullie toch geïnteresseerd bleven (of in ieder geval deden alsof). En uiteraard ook voor onze mannenweekenden, dat waren echte oplaadmomenten.

Zoals gezegd, een parttime promotietraject is iets prachtigs. Met veel up's, maar ook zeker down's. Niet alleen voor mij als promovendus was dit een intensieve tijd, maar ook voor mijn omgeving. Het kopen van een huis en het krijgen van twee prachtige kinderen maakte deze tijd des te mooier, maar gaf ook extra uitdagingen. Er is één iemand in het bijzonder die deze periode van dichtbij heeft meegemaakt en wiens steun en liefde hét verschil hebben gemaakt. Mijn verloofde, de moeder van onze twee prachtige kinderen, **Willemijn**. Liefje, zonder jouw steun had dit proefschrift er nooit gekomen. Jij maakte mogelijk dat ik dit proefschrift in deeltijd kon schrijven. Je bent de liefde van mijn leven.

Als laatste wil ik graag alle participanten die aan de onderzoeken in dit proefschrift hebben meegedaan bedanken. Bedankt, **ouders**, **kinderen**, **leerkrachten**, **schoolleider, studenten, robotbouwers** en **beleidsmakers**, jullie deelname heeft tot veel nieuwe inzichten geleid.

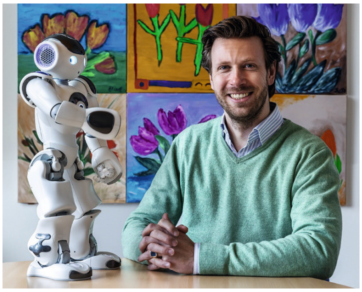

Foto: Angeliek de Jonge

After personally seeing the disturbing impact technology can have as an IT consultant, Matthijs decided to focus on the ethical use of innovative technology, such as robotics and AI. The Institute for ICT at HU University of Applied Sciences Utrecht (HU) allowed him to obtain a master's degree in philosophy from Tilburg University. He completed his master's in 2017 with a thesis on programming robots with moral concepts. Thereafter, Matthijs worked on a part-time PhD project studying the responsible use of social robots in primary education at the Faculty of Social Sciences, Vrije Universiteit (VU) Amsterdam, where he completed his PhD in 2023. During his time as a PhD candidate, he co-founded the Social Robotics programme at the Institute for ICT at HU. Since the start, the Social Robotics programme has been nominated for several awards and has won the Computable Award 2021 for SAMbuddy, a social robot for supporting children's emotional well-being. Matthijs is also co-founder and chairman of the National Social Robotics Contest, a competition in which students from five universities of applied sciences (Hanze, Saxion, HvA, Windesheim and HU) build social robots to solve social issues. Currently, Matthijs is a principal lecturer at the Institute for ICT (HU), a member of the research group Digital Ethics (HU) and a lecturer in human-robot interaction at VU. With his research, Matthijs aims to contribute to the responsible development of technology that improves the lives of all stakeholders involved. His main focus is on how technology can support people in healthcare and education, working closely together with academic and societal partners.