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EDUCATIONAL ROBOTS FOR CHILDREN IN PRIMARY SCHOOL

Bachelor's Degree Programme in
Computing and Electrical Engineering
February 2021

TIIVISTELMÄ

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Tampereen yliopisto
Tietotekniikan kandidaatin tutkinto-ohjelma
Helmikuu 2021

Teknologian jatkuva kehittyminen mahdollistaa uusien oppimistapojen luomista. Teknologiaa hyödyntämällä opiskelijoille ja lapsille avautuu uusia mahdollisuuksia oppia entistä nopeammin, jopa pienemmällä vaivalla. Robottien hyödyntäminen opetustilanteissa ei itsessään ole uusi keksintö, mutta niiden hyödyntäminen oppimisen apuna on saanut viime aikana enemmän huomiota. Sosiaalisten robottien käyttö ovat lisääntyneet jatkuvasti ja sitä kautta myös koulutusrobotit ovat lisääntyneet**.** Vaikka robotteja ei koululuokissa vielä paljoa näy, on robottien liittäminen osaksi oppimisympäristöä ollut paljon esillä tutkimusten aiheena.

Tässä tutkimuksessa yritetään selvittää, minkälaisia vaikutuksia robottien käyttämisellä oppimisen apuvälineenä on ala-astekouluikäisiin lapsiin. Tutkimus toteutetaan kirjallisuuskatsauksena ja se on jaettu kahteen osaan. Tutkimuksen ensimmäisessä osassa tuodaan esille jo tehtyjen tutkimusten perusteella löydettyjen koulutusrobottien käyttöön liittyviä etuja sekä haasteita. Tutkimuksia robottien hyödyntämisestä oppimiseen on tutkittu paljon, varsinkin lapsiin, joilla on erityistarpeita, kuten esimerkiksi ADHD. Tutkimuksia koulutusrobottien haitallisista vaikutuksista löytyi hyvin vähän, sillä tehdyt tutkimukset keskittyivät selvästi enemmän hyötyihin kuin haittoihin. Tutkimuksen toinen osa keskittyy koulutusrobottien suunnitteluun. Siinä tuodaan esille minkälaisia ominaisuuksia hyvällä koulutusrobotilla tulisi olla, jotta lapset tuntisivat olonsa turvalliseksi niitä käyttäessä. Minkälaiselta robotin tulisi näyttää ja minkälaisia ominaisuuksia robotilla tulisi olla ovat kysymyksiä, joihin vastataan tutkimuksen toisessa osassa. Tutkimuksen tulokset osoittavat, että koulutusrobottien käytöllä lasten apuna oppimisympäristössä voi olla positiivisia vaikutuksia lasten oppimiseen. Avoimeksi kysymykseksi jää kuitenkin minkälaisia vaikutuksia koulutusrobottien pitkäaikaisesta käytöstä on lapsiin, sillä tehdyt tutkimukset keskittyvät paljolti robottien lyhytaikaisen käytön vaikutuksiin.

ABSTRACT

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Technology is constantly evolving and people are trying to find new techniques to help students and children to learn faster and with less effort. An educational robot is not a new innovation as such, but it is only now becoming more popular as technology evolves. Since social robots are becoming more and more common and therefore educational robots are as well. While the use of educational robots in the classroom is not very common yet, there is an increasing number of research made on the subject. This study is trying to find out what kind of impact an educational robot could have for the children in learning.

The method of this study is literature review based on research in the field and it is divided into two sections. First section is focusing on the benefits and challenges of educational robots. A lot of research has been made about the benefits of the educational robots, especially on children with special needs (e.g. ADHD). Challenges, however, were harder to find since all the studies were solely focusing on the benefits rather than the challenges. The latter section is focusing on the design of the robot. What the robot should look like, how tall it should be and what features it should have in order to have the children feel as secure and comfortable as only possible while interacting with the educational robot. This study shows that educational robots could have a positive influence on the children and their learning. Long-term use, however, is still an open question since the studies are focusing more on the short-term use of educational robots.

Keywords: Robot, Educational robots, children, benefits, challenges, design, learning

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ABBREVIATIONS AND MARKINGS

HRI	Human-robot interaction
SAR	Socially Assistive Robotics

1. Introduction

Technology is constantly evolving and people are trying to find new techniques to make students and children learn easier. A social robot is not a new innovation, but the interest towards them has increased when comparing the amount of studies that have been made from the last decade. In general social robots are becoming more and more used in everyday life and it seems that educational robots are following the trend with a small delay. While the use of educational robots in the classroom is not very common yet, however, there is an increasing number of researches made about the subject.

The focus of this study is educational robots and how they are benefiting now and in the future the children's education and how the design should be implemented to the robots to optimally gain the best results on both HRI (Human-Robot Interaction) as well as the children's learning. The appearance is a big part of the HRI, as Woods is writing "Pure machine looking robots were rated by children as being the most aggressive according to adult ratings of robot appearance". It seems that not only the functionality of the robot has an impact on the learning but design is playing a part as well. (Woods, 2015)

The research questions that this study is answering are:

- What are the benefits and challenges to the use of educational robots for children in primary schools?
- What should designers take into consideration when designing the next educational robots for children?

2. Social robots

The purpose of this chapter is to focus on educational robots and defining the differences between social robots and educational robots. First section is focusing on the social robot and educational robots. The last section is focusing on different types of educational robots.

2.1 Definition of a social robot and educational robot

As the words social and robot are more familiar when they are heard separately they do have the same meaning when put together. “Social robots are robots that interact with humans and each other in a socially acceptable fashion, conveying intention in a human-perceptible way and are empowered to resolve goals with fellow agents, be they human or robot” (Shaundra, 2018). In other words, social robots are robots that interact socially with humans or/and other robots.

Belpaeme is stating “Social robots can be used in education as tutors or peer learners“. In other words educational robots are a small section inside the definition of social robots and that are focusing solely on the educational part. (Belpaeme, 2018). Hegel (2019) was analyzing the definition Social robots from four different research and all of them had slightly different names or definitions for social robots. Duffy is stating that Social robots are only interacting with each other and Societal robots are interacting with human beings (Duffy, 1999). Breazael however, stated with the same definition as Duffy but the name is Sociable Robot. Fong (2013) however, stated the name to be Socially interactive robots and Bartneck (2004) stated that a social robot is a robot that is autonomous or semi-autonomous and interacts with humans by following the behavioural norms expected by the people. (Hegel,2019) All of these statements are slightly contradicting each other and to clarify, in this study the term social robots means robots that are interacting with human beings.

2.2 Different types of educational robots

Han is stating ”There are mainly two types of educational robots: hands-on robots, such as LEGO MINDSTORM, and educational service robots, which are intelligent robots deployed into learning environments”. (Han, 2012). In this study we are focusing more on educational robots, even hands-on robots such as Lego Mindstorm (Figure 1) could be beneficial for educational purposes as well.

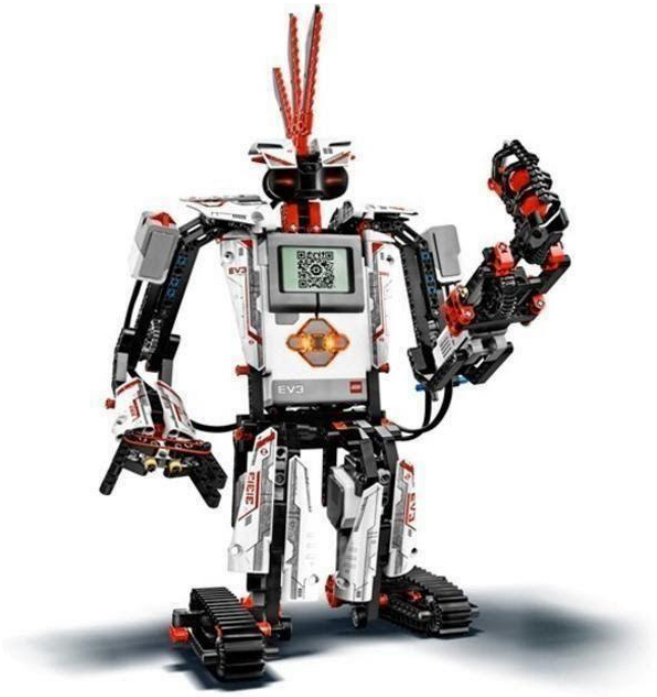

Figure 1: LEGO MINDSTORM

The different types of educational robots are tele-operated type, autonomous type and transformed type, according to the location of their intelligence (Han, 2012). Tele-operated type is functioning, as the name is suggesting with a remote control that the assistant/teacher is using for educational purposes. Autonomous type has its own artificial intelligence. Transformed type is a type that has both of these options, and can switch back and forth from artificial intelligence and remote controlling.

Belpaeme made a literature review and analyzed 179 different studies related to the use of educational robots and the most popular educational robot used was Nao (Figure 2), 48%. Nao is 54-cm tall and has arms, legs, a torso, and a head. Nao can walk, move its head, pan, gesture and walk. Based on the research it looks like Nao is considered to be one of most used educational robots for children. The reasons for this Belpaeme is stating that Nao has “wide availability, appealing appearance, accessible price point, technical robustness, and ease of programming”. (Belpaeme, 2018)

Figure 2: Nao (https://www.softbankrobotics.com/emea/en/nao)

The Keepon (Figure 3) robot is a small 25-cm tall snowman-shaped robot. Keepon robot does not have any arms or legs, and it can't walk, it can only roll and pan. The studies made with the Keepon robot according to Belpaeme are showing medium-sized effects in cognitive learning together with Nao robots. However, since these studies of educational robots are made in different environments with different populations, it is not quite right and accurate to compare them. It seems that all of these studies comparing robots should not be taken as a fact but rather as a directional. (Belpaeme, 2018)

Figure 3: Keepon (https://robots.ieee.org/robots/keepon/?gallery=photo1)

Pepper (Figure 4) is a humanoid robot and according to A.K. Pandey and R. Gelin it was launched in June 2014. The purpose of Pepper was first for Business-to-Business which later on moved Business-to-consumer. Pepper has arms, a head and it can roll to different places. Pepper can move with the help of three omnidirectional wheels, change places and has the possibility to gaze, which is an important way to gain the end users attention. Pepper has a height of 121 cm and a weight of 28kg. (A.K.Pandey, 2018)

Figure 4: Pepper (https://robots.ieee.org/robots/pepper/)

It seems that RoboThespian (Figure 5) is a robot that is a bit more sophisticated than the others presented here. It is a web connected device and can be controlled via an online interface. What also is different from the other robots presented here is that from the interface you can see what the robot is seeing in real-time. (https://newatlas.com/robothespian-humanoid-robot/20481/) RobotThespian needs electrical supply, a compressed air supply and an internet connection to be manually controlled. RobotThespian can also interact with humans independently since it can search from the internet for answers. (Belezina, 2011)

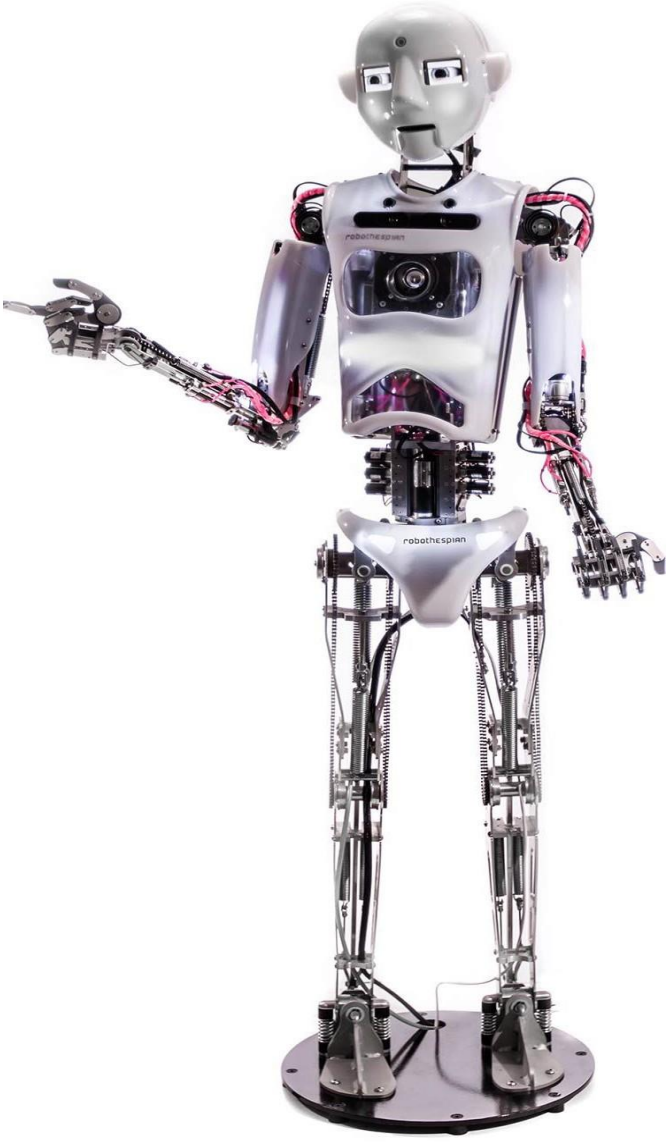

Figure 5: RoboThespian (https://robot-rental.com/robothespian-hire/)

DragonBot is an educational robot that has the shape of a dragon and has a height of 45cm. The only source of power it has comes from an android phone and all the sensors are coming from the phone as well. According to Evan (2015) the difference between DragonBot and some other educational robots is that it is not actively teaching new facts to kids who use it but is rather helping the learning process by encouraging kids to be active with whatever they are learning at the moment.

Figure 6: DragonBot (Evan, 2015)

Robots can have a huge height difference. Keepon's height is at only 25cm when for example RoboThespian is as tall as 175cm. It seems that the choice of the robot depends a lot on the end users, where children are more comfortable with shorter robots and adults are most likely more comfortable with taller ones.

When comparing the educational robots (Table 1) that have been listed, almost all of them have the possibility for remote control and all robots can talk and gaze. It seems evident that between the robots there are big differences on the quality of gazing and level of intelligence. These differences, however, are also reflected in the prices of the robots. Keepon can be bought as low as 50$ (Link 1) when for example RobotThespian costs as much as 93,000$ (Link 2). It appears that from this list Keepon is more used as a private robot, perhaps due to its cost being affordable. RoboThespian on the other hand is so expensive that it does not seem to be a smart choice for an individual person to buy.

Educational robots	Hands moving	Legs to move	Height	Approx. Price	Notes
Nao	X	X	54cm	8.000$	Most used robot based on study by Belpaeme (2014)
Keepon			25cm	50$	Cheapest robot from this Table 1
Pepper	X	* wheel	121cm	30.000$	Use tablet for games
RoboThespian	X	X	175cm	93.000$	The most Expensive robot from Table 1
DragonBot			45cm	1.000$	Using android phone as its face

Table 1: 5 known educational robots differences.

3. Research method and material

This chapter's purpose is to explain the research method that was used and the research material that the study is based on. The first subsection is presenting the method used for this study and the latter subsection is focusing on the process for gathering information and from which sources.

3.1 Research method

In this research the method has been literature review. The data has been gathered from mainly scientific studies, but books have also been a way to gather information. However, robots' information was searched from non-scientific articles and manufacturers websites. As the topic is still relatively new, all the data and research that was used were still quite recent and up to date. As technology is evolving rapidly, some older studies may contain inaccurate results as the intelligence of the robot seems to be a huge factor in improving learning results in classes. There were some studies that were made in the 1990's but these results were not taken into account.

3.2 Research process

Andor (https://andor.tuni.fi) was the main database that was used in this study for searching scientific research. Google Scholar was also used, but to a lesser extent. Almost all the information was found from these two databases and there was actually a lot of research made on the subject. As there was a lot of data provided, Boolean (AND, OR) and

interception (*) were used to specify the data. Some of the more specific searches used were:

- (Social OR Educational) AND Robot
- Education* AND Robot*
- Child* AND Educational Robot
- Social robot AND Design
- Primary school AND robot
- Social robot AND gaze

To obtain the information of the Table1 robots, Google was used with the searches:

- Nao
- Keepon
- Pepper
- RobotThespian
- DragonBot

From all the scientific research that were gathered from the database, titles were the first factor on which articles were picked. Results were narrowed even further after reading the abstracts of the last chosen articles. As already mentioned, technology is evolving fast. Therefore, recently made studies carried a heavier weight than older studies in the choosing. In total 25 articles were chosen to be reviewed.

4. Results

Purpose of this chapter is to present the benefits and challenges that are related to the use of educational robots in the classroom. The last subsection is focusing on the design of the educational robot's appearance, when taking into consideration the age of the end user. This chapter will also bring forward what kind of features should the robot have in order to have a positive experience for the end user.

4.1 Benefits and challenges of educational robots in primary school

Based on the findings from the literature, multiple possible benefits could be gained from using an educational robot. Perhaps paying attention is one of the most important ways to improve your learning. "The very first step to learning is paying attention" (Link 3) . Kirstein & Risager studied the effects on concentration time and efficiency of educational robots on children with the help of the robot Zeno (Figure 7).

Figure 7: Zeno, robot used in Kirstein & Risager study

The study focused on the effects the educational robot had on the children before the use and while using the robot. The analysis shows clear positive changes in most of the cases, especially on the children that have challenges in concentrating. The Table 2 shows that the children who have normally problems concentrating had a lot greater concentration time as well as concentration efficiency while using the robot. However, the children that had already a medium concentration time were not affected by the robot. What is surprising is that the children that had a lower concentration seemed to obtain better results than others when using the robot. (Kirstein, 2016)

Group / Number of Children	*Concentration time before/after*	*Concentration efficiency before/after*
Zeno Kindergarten		
Weak / 1	7 min / 30 min	70% / 100%
Zeno School		
Medium Strong / 1	10 min / 10 min	50% / 50%
Medium / 1	10 min / 10 min	50% / 50%
Medium Weak / 2	5 min / 15 min	40% / 75%
Weak / 1	2 min / 15 min	20% / 75%

Table 2**:** Business case calculations for zeno in kindergarten and school (Kirstein)

Table 2 is showing the growth of concentration time and efficiency. As stated above the results are surprising and due to the small sample one could argue that the reliability of the results are questionable. Since the teacher is calculating the concentration time and efficiency, one potential issue that the study has, is the way the teacher is calculating these and if the teacher could be biased when doing these calculations. Therefore, similar study should be conducted with a considerably bigger sample and with neutral unbiased observers. However, Fridin came to the same

conclusion in his/hers studies that ADHD/ADD children had more positive interaction with the educational robot, however, the study was only focusing on the level of interaction (Fridin, 2011).

Should the new study have similar conclusions on the way the educational robots increase the concentration time and efficiency of the children with weaker concentration ability. This could be a real “game changer” in efficiency of children's education as the ones today holding back the speed of learning in classes could in future match, if not surpass, the others in concentration.

It remains to be seen if a new study is conducted, whether it confirms the results shown in Table 2. It is however showing that the educational robot is not doing any harm when it comes to concentration time and efficiency, and in some cases concentration time and efficiency can be improved. Perhaps the results could show a different result after using Zeno for a longer period of time and results could show a negative effect? This study however was not examining that.

In the article Belpaeme brings forward three reasons to back up the need of physically embodied robots. First, they can be used for curricula or populations that require engagement with the physical world. Secondly, the users show more social behaviors that are beneficial for learning while engaging with a physically embodied system. Lastly, it seems that users show increased gains when interacting with physically embodied systems over virtual agents. (Belpaeme, 2016)

One of the main challenges that comes with educational robots is how to keep the user interested for a longer period of use. As Kertész & Turunen mentioned “Despite the recent technological advances, long-term experiments with robots have challenges to keep the users interested after the inital excitement dissapears”. Therefore, one of the main challenges with educational robots is related to the difficulty of maintaining the curiosity of the child. According to an article in Nature (Nature 2014) “Curiosity boosts people's ability to learn and retain new information, thanks to key reward and memory centres in the brain”. Again, maintaining curiosity is linked to the ability to learn and therefore the emphasize on keeping the user’s curiosity should be a priority for those who design educational robots.

One challenge related to the use of educational robots is their necessity. Virtual agents, such as tablets, laptops or phones, can be already seen used quite often in a classroom by students. Virtual agents can indeed offer some of the qualities that educational robots do. However, virtual agents do not need as much maintenance, they are cheaper to make, are more easily distributed and installed, and finally are usually smaller overall. Therefore, the need of educational robots needs to be justified. (Belpaeme, 2018)

One other challenge related to educational robots is the cost-benefit balance. Some subjects could be easier taught by virtual agents, but subjects that require direct physical manipulation of the world can be easier done by an educational robot.

According to Belpaeme et al. (2018) ''robots can be more engaging and enjoyable than a virtual agent in cooperative tasks and are often perceived more positively.'' Children may perceive an educational robot as something new and exciting and therefore pay more attention to it than to a virtual agent such as a laptop, that they already are familiar with. Again, one of the challenges is to keep the child engaged and curious about the robot.

One major challenge to the use of educational robots is its ability to respond to the child's social cues. Many emotions are transferred through non-verbal behaviors and a significant part of communication between humans is through non-verbal communication. It might be very hard to make an educational robot detect and interact with confusion, attention and engagement. Belpaeme (2018) is stating ''Although automatic speech recognition and social signal processing have improved in recent years, sufficient progress has not been made for all populations. Speech recognition for younger student, for example, is still insufficiently robust for most interactions.'' This could also be a bigger issue for obtaining the interest of the children if the robot is not recognizing the speech accurately. ''Over the last decade, much research effort has been dedicated to improving robots' capabilities regarding perceiving, interacting and cooperating with humans.'' This shows again that there is an emphasis on the importance of detecting social cues.

Without understanding the child's state it can be difficult for an educational robot to choose between whether it should advance to a more complex exercise, give a hint, go back to an easier exercise or just repeat the question. These are very important steps in learning as according to Belpaeme et al. (2018) ''Choosing an appropriate emotional support strategy based on the affective state of the child, assisting with a meta-cognitive learning strategy, deciding when to take a break, and encouraging appropriate help-seeking behavior have all been shown to increase student learning gains.''

One challenge which seems to be evident as well, is the possible extra cost of the use of robots. Firstly not all of the primary schools have a budget for the robots. Secondly, the possibility that in heavy use the robot can break, which again is an extra cost to consider. Eventho, this was not in the studies, this is a possible cost that should be taken into consideration.

To conclude Table 3 shows the potential benefits and potential challenges that educational robots might bring in education in primary schools.

Benefits	Challenges
Concentration time, especially for children with ADHD/ADD	Budget
Concentration efficiency, especially for children with ADHD/ADD	Necessity
Attention level	Cost-benefit
Curiosity of the children	Long-term effects which have not been studied enough
	Robot intelligence

Table 3: Potential benefits and potential challenges that educational robots might bring in primary schools.

4.2 Design of educational robots

This subsection is going through the differences between the designs that could be implemented when considering end-users. Purpose of the first sub-subsection is to compare the educational robot's designs likeability between children and adults. Second sub-subsection is focusing on the features that could be implemented to obtain the best possible educational robot for children.

4.2.1 The likeability of robots appearance

When designing an educational robot, the end users are the ones that need to be taken into consideration. For example there are many ways to design an educational robot for children. One way to design is by involving the children in the design process. According to Obaid (2018) there are not many studies that have actively involved children when it comes to designing the robot. Before the age of nine, children pay more attention to a human-like robot appearance; older children and adults are inclined to think more of its skills and functions (Obaid, 2018). It seems that even at the age under nine, human-like robots are more likeable. Woods is stating as well that " Pure machine looking robots were rated by children as being the most aggressive according to adult ratings of robot appearance"(Woods, 2015). Based on studies By Woods (2018) and Obaid (2018), it seems that children do not like if the appearance of the educational robot is completely machine-like but instead prefer the ones that have similarities with humans.

4.2.2 Features of robots

This subsection presents features based on the reviewed literature and also focuses on what designers should take into consideration when designing an educational robot.

Building a positive relationship

When it comes to designing a social robot, not only the robot's appearance should be taken into consideration. In his studies Davison (2019) was focusing on the design guidelines for when and how a social robot could bring a positive contribution towards the learning process. One recommendation that Davison is stating is that " The robot should work towards building and maintaining a positive social relationship with the child''. One of the ways that Daniel is suggesting to build a positive social relationship is for the robot to offer emotional support. It appears that for the child to stay attracted towards the robot, it should maintain a positive social relationship so that the child would feel needed for a longer period.

Gaze and gestures

One of the ways to build a positive relationship is by the help of gaze and gestures. As Ham is stating "When the robot looked at the persuadee, this research replicated earlier studies that gazing behavior by a robot can have persuasive effects''. Ham focused also on his studies on gestures which had a negative effect if gazing did not occur, however it had a positive impact when gazing was involved. (Ham, 2015)

4.2.3 Conclusion of design

It looks like one of the most effective ways to gain the attention of all the end users is to implement a gazing feature as well as a gesture feature to the robot. However when it comes to the appearance of the design, it has some mixing results. Children and adults have different ways of interpreting the design of the robot. Children like more human-like robots and adults are focusing more on the availability of functions. (Obaid, 2018) Therefore it might be hard to design a robot that can serve both children and adults in a learning situation. When designing an educational robot for children this should be taken into consideration and focusing on who are the end users before starting to design. Belpaeme is also stating " Because the positive learning outcomes are driven by the physical presence of the robot, the question remains of what exactly it is about the robot's appearance that promotes learning."

5. Conclusion

This study was focusing on the benefits and challenges to the use of educational robots for children in primary schools and what designers should take into consideration when designing the next educational robots for children. It seems evident that educational robots can have a positive influence on learning. Nevertheless, Belpaeme (2018) stated that most of the studies are made under different environments and different people are conducting them. End users as well are not likely to be the same ones which again gives less credit to compare these. So it seems difficult to compare robots between each other when all of the tests are different, and the results can vary on a lot of different things.

As already mentioned in the benefit section (4.1) the possible benefits were:

- Concentration time
- Concentration efficiency
- Children's level of paying attention

All of these are important for learning. There are however also challenges and limits on the possibilities of different tests. One of the questions that was not answered was what are the negative effects of using an educational robot over a longer period. Most of the studies made were only focusing on a one or two tests and some of the tests were done for a short period. In the start, the robot is something new to the children and it will increase the attention and the level of focus needed which can in return give false results for the study. In the author's opinion this is shown on Table 2. Children that had better concentration before the robot, did not “succeed” as well as the ones that had problems with concentrations when using the robot. This again brings more questions to the reliability of the test. Possible issues with the reliability is that if the teacher was biased or were the measurements done correctly? Even though Table 2 shows the robot to have a positive effect, it does not answer the question on the use of a longer period, it only shows at that right moment the level of concentration. Children could have different concentration efficiency on different days, which could also affect the results. In the author's opinion the studies that have been made are enough to determine that educational robots are clearly beneficial, even though this Kirstein (2016) was stating this was a longer period but in author’s opinion 14-16 weeks is still too short.

If hypothetically the educational robot gives only positive effects while using it and the children's concentration remains stable for a longer period, that again brings more questions. One interesting question that remains unanswered is what happens with the children’s mentality after a longer period of use if suddenly the child is not interacting with the robot anymore. Does the level of concentration drop dramatically? And what kind of “side-effects” does this bring in daily life or are there any? Could the children also create

such a relation to the robot in the longer term that it would bring negative effects? Unfortunately, to get answers on these questions is close to impossible. There will be many different variables that will be limited to obtain an absolute truth:

- Sample size issues
- Children are different and react differently
- Ways to measure

Not to forget, conducting an empirical study for a longer period is time consuming and demands a lot of dedication from the children and the ones making the study as well as teachers. Perhaps the main question remains still, if in the future the educational robot could surpass the teacher in terms of motivation and learning.

Although this conclusion is focusing more on the negative effects, the author's opinion is that educational robots would be beneficial for the children in primary schools. Maybe somewhere in the future it could even take the place of the teacher but right now the technology needs to be improved even further to obtain this effect and even then it might take a long time before people will get used to this.

In this study there was one major limit. Due to the ongoing pandemic, it was not possible to go to primary schools and create an opinion, so this study was limited to literature review. For the future studies it would be beneficial to interview teachers and get their opinion. And ideally it would be beneficial to make a longer period study of the use of the robot, however, there are reasons why this has not been done yet as discussed in this candidate thesis.

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Link 2: Got $93,000 to spare? Robots getting cheaper https://www.cnbc.com/2014/05/01/got-93000-to-spare-robots-getting-cheaper.html (visited 12.08.2020)

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