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Child-Robot Interaction in Language Acquisition Through Pepper Humanoid Robot

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Dafina Marku

Abstract

Considering the rapid improvements in science and technology during the last decades, robotics has lately entered the educational sphere as well. Humanoid robots are constantly developing as educational aids with the ability to improve communication and language abilities in young children. Humanoid robots are devices that can replicate human behavior and interaction as well as read human emotions. This new technology is increasingly being employed in helping children in their learning activities, although it is yet to date uncertain how a robot can aid in teaching processes. This master's thesis presents a study in the research field of child-robot interaction. This thesis, in particular, describes a research in which the humanoid robot Pepper is utilized as a learning companion for children aged 8 to 10 years old. Pepper was used to engage and motivate children by having them read a book to the robot and thereafter take a brief quiz about the book they had just read. The experiment is divided into two parts: verbal and tablet-based. As a result, a comparison study was conducted to determine which strategy was more appealing and engaging to the children. Our findings indicate that children in general have a positive attitude toward Pepper as a learning companion. The findings also imply that a humanoid robot with appropriate scaffolding mechanisms might enhance engagement and learning, particularly when adapting to the specific behavior and circumstances of a young learner. Although the humanoid robot Pepper was shown to aid in language acquisition, additional research into child-robot interaction and language acquisition itself in young children is required.

Contents

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Acronyms

AI Artificial Intelligence. 9, 10

ASD Autism Spectrum Disorder. 10

CRI Child-Robot Interaction. ix, 2, 9, 15, 16, 18, 21–23, 26, 33–35, 41, 43, 44

GUI Graphical User Interface. 12

HRI Human-Robot Interaction. 7, 8

LED Light-Emitting Diode. 11, 24

NLP Natural Language Processing. 25, 39, 40

NSD Norsk Senter For Forskningsdata. 17

VR Virtual Reality. 18, 44

Chapter 1

Introduction

This chapter presents the most relevant topics addressed in this master's thesis, accompanied by an overview of the problem encountered thus far, as well as the project's justifications, motivation, and benefits, followed by the research questions.

1.1 Topic

With the rapid advancement of technology over the last decades, the usage of digital devices such as laptops, smartphones, tablets, and so on in our daily lives has evolved. The incorporation of technology into our everyday lifestyle has happened not just in fulfilling ordinary daily tasks, but also in completing more complicated operations [1][2][3].

Given that technology has played a considerably larger role in modern times than it did prior to the digital era, the younger generations have been influenced to have a high degree of technological understanding [4]. The rise in knowledge in today's generations, along with the advancement of digital gadgets, has resulted in the proliferation of technology in the educational area as well [3]. However, laptops, cellphones, tablets, and other gadgets are not the only tools used in teaching. Robotics has recently attracted the interest of researchers. The advancements made in this sector, as well as the creation of humanoid robots, have allowed us to consider how robots may be a valuable asset to instructors in the classroom [2][3].

Current research attempts to build robotic systems which mimic human environments have achieved unprecedented heights [5]. Robots that could previously only focus on doing certain tasks are now designed to accomplish several difficult tasks simultaneously [2][5]. Similar to how the ability of a personal computer to do a job was restricted in its early days, the capacity of robots is still in the establishment stage, therefore their capability is still restricted [2]. However, the development of a new generation of robots has set a new standard for researchers [2]. Humanoid robots are a new type that has increased the interest of experts [5].

Humanoid robots vary from previous generations of robots in such a way that they can not only replicate human behavior and interaction, but can also read human emotions [2][5]. All of these benefits have prompted academics to investigate how these new devices could enhance education [5]. As a result, introducing robots within the field of teaching, especially during the pre-school phase, has had a rapid increase of interest among research studies [2].

The main objective of this master's thesis was utilization of a humanoid robot as a teaching assistant in the process of language acquisition with young children. The main emphasis was shifted towards Child-Robot Interaction, thus it was extensively explored if a sophisticated device such as a robot may assist children in learning easier, faster, and more excitingly.

1.2 Keywords

Child-Robot Interaction; Humanoid Robots; Human-Robot Interaction; Pre-school Children; Language Acquisition; Language Learning;

1.3 Problem Statement

Imposing conventional methods of education on children in an age where nearly everything is digitized is becoming increasingly challenging [2]. Children who are digital natives are expected to be active in their learning process while remaining passive learners and having their technology tools inaccessible [2]. This issue has resulted not only in the necessity to integrate technology into the educational sector, but also in the application of various innovative approaches to make the learning environment interesting, enjoyable, intriguing, and fast [2].

Applying new inventive approaches to the old educational system however, is difficult and time consuming. When attempting to introduce humanoid robots into the classroom, the matter becomes much more difficult.

This research study will attempt to observe several issues. Some of the most important ones include ways in which children interact with humanoid robots in classroom setting, their attitude towards the robot, whether they find this experience enjoyable and the assessment of humanoid robot technology being mature to implement in school systems.

1.4 Justification, Motivation and Benefits

Implementing new modern approaches into the teaching curriculum early on influences children's motivation and attitude toward learning new concepts. Making the learning environment more enjoyable and entertaining encourages kids to participate more actively in their educational growth.

Introducing humanoid robots as a teaching assistant in education also aids in discovering other common patterns. These patterns could be used in transforming the classic education system into something which is perceived as entertaining and engaging while also being instructive and enlightening.

1.5 Research Questions

The introduction of robotics in education has been extensively researched by previous studies, thus, the core of this master's thesis is not the application of humanoid robots in education. Instead, the focus of this study was directed more towards the interaction between child and robot.

In order to have a clear grasp of the project and specify what exactly needs to be investigated, a variety of research questions evolved. In conclusion, after conducting thorough study on the subject, the following research questions were raised:

- R1: How effective is the use of a humanoid robot in language acquisition in young children?
- R2: What is children's attitude and engagement towards Pepper as a learning companion?
- R3: How does children's attitude towards learning with a robot change before and after their interaction with Pepper?

1.6 Contribution

First and most importantly, this research study makes a significant contribution to the area of research by expanding and exposing the lessons learnt from using humanoid robots in language acquisition with young children. The design decisions, technology used, procedures, evaluation methodology, and all other components of this study reflect yet another attempt to include humanoid robots in any way or form into the learning process. As a result, this study has the potential to assist or inspire other researchers working in this field.

1.7 Outline of Chapters

In order to give a brief knowledge about the topic and the field of study, this master's thesis begins by presenting the problem statement, motivation, research questions and contribution to the research area. Chapter 2 dives more into the theoretical as well as technological background on which the work of this study is based upon. Chapter 3 provides a thorough explanation of the methodology including experimental design and implementation, data collection methods, participants, hypothesis and the whole experimental procedure during this study. Chapter 4 goes into detailed analysis of the results obtained, while Chapter 5 provides a discussion on limitations, strengths and weaknesses. Lastly, Chapter 6 concludes our findings and examines potential future work to further improve the field/area of study.

Chapter 2

Background

Note: Part of the content in this chapter is based on my previous reports in courses IMT4205-Research Project Planning and IMT4894-Advanced Project Work. The content, however, has been modified and extended to fulfill the requirements of this master's thesis.

2.1 Related Work

This section examines the already existing related work in the field of robotics, its advancement and application in different areas of our daily life. A special focus in this chapter receives the topic regarding humanoid robots and their application in the educational sphere.

2.1.1 Robotics and Humanoid Robots

With the advancement of science and technology during the last decade, the robotics sphere has become an attraction to the researchers. Different kind of robotics have already been applied in different areas of our lives. A significant number of industrial robots are already in use for replacing or helping employees in performing numerous repetitive and/or risky production activities [6]. Nonetheless, based on current technical capabilities, the robotics industry is constantly expanding to the degree wherein humans not only share the same workplace as robots, but also employ robots as beneficial companions [7].

The industrial robots are largely applied in production systems or used for automating factory activities. The purpose of introducing these machines in the industrial area or in any other aspect of our daily lives, is to make employees' work and generally humans' life easier but at the same time complete any activity faster. On the other hand, a new generation of robotics has currently become an increasingly hot topic of interest for scientists [6] [8].

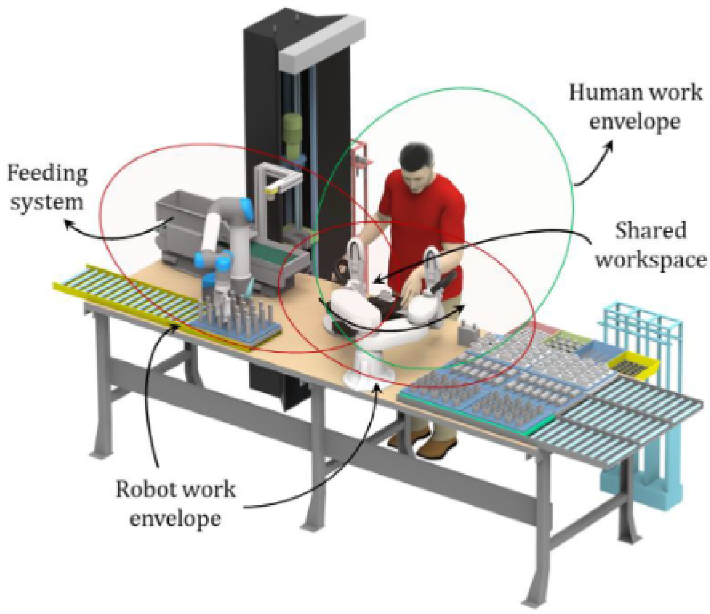
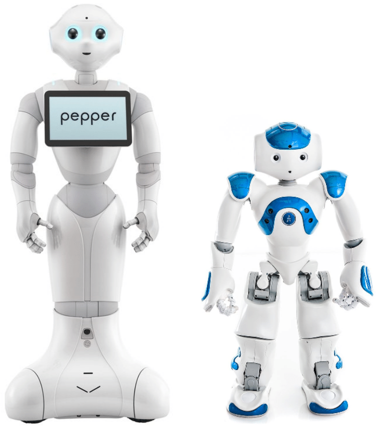


Figure 2.1: Human-robot collaborative workstation (*Source:[9]*)

Humanoid robots are the new experimental "toys" in the robotics field. They are a new type of service robots with the purpose of mimicking human actions and interactions. Humanoid robots are often seen as both an entertainment robot and a human assisting robot to some extent.

This new generation of robots is lately found its way into the educational field as well. Considering that its appearance resembles to the human appearance to some degree, as well as, having the ability to "sense" people's emotions, researchers believe that a robot of this kind can act as a teaching assistant in schools. The idea behind the robot as a teaching assistant is not replacing the human instructor completely, however, the human may use this machine as an asset for helping both the kids and the teacher with the school activities.

Although the technology is surpassing any of our expectations nowadays, scientists are still facing obstacles in replicating human skills in an artificial humanoid robot [8] [10]. Thus, applying humanoid robots in schools is still in the experimental phase.



(a) Humanoid robots

(b) Industrial robots

Figure 2.2: Comparison between humanoid robots and industrial robots

2.1.2 Human-Robot Interaction

The link between the human and the robot is a very important topic when talking about robotics. Human-robot interaction (HRI) is also a developing study subject that has lately received a lot of attention [11]. As reported in [12], people tend to anthropomorphize robots more than the other technological devices. According to Henschel et al [13], in order to determine the role that robots could play in our social environment, we must assess their similarity to living entities such as humans or pets, as well as, devices like mobile phones, tablets, etc. Answers to these concerns will not only increase our understanding of how humans perceive robots, but will also touch on philosophy, cognitive science, and law, all of which have significant societal impacts [13].

The extensive usage of robots in the recent years has resulted in an explosion of robotic designs and interaction concepts, which is also reflected in HRI research. A considerable number of researches have already been conducted in the area of HRI. However, such diversity makes it difficult to generate reliable conclusions. Many experimental HRI investigations yield significant findings, but whether these conclusions are still true if the setting, the robot, or anything else changes is debatable. Many studies intertwine HRI and anthropomorphism close to one another. Anthropomorphism is a concept that refers to the inclination of assigning human attributes to inanimate things or animals in order to justify their behaviour [14]. Anthropomorphism is predominantly used in social robotics to facilitate meaningful social interactions and the acceptability of the robot in the society [15]. For example, Darling et al. [16] investigated how individuals respond to a small robotic item when asked to hit it in order to determine if anthropomorphic framing alter people's empathy for a robot. They measured people's hesitancy to attack the robot and according to the data gathered, they concluded that people's empathy and commitment to robots were impacted by an anthropomorphic framing of robots.

Despite all the study conducted in the HRI field until now, there are still questions that remain unanswered. Studying the long term relationship between the human and a robot is still lacking. As stated in Henschel et al. [13], future research merging human neurology and social robotics might prepare us for a future where autonomous robots can "co-exist" with humans on a social acceptable level.

Child-Robot Interaction

Within the Human-Robot Interaction topic, the relationship between a child and a robot comes into focus. Given the child's limited cognitive development, they usually tend to not recognize the robot as merely a mechatronic device moving around with the assistance of another software. This feature has prompted several experts to investigate how a humanoid robot may assist young children in their educational process [11][2].

Many kids are timid or apprehensive when they interact with other people, and this is intensified when they interact with a teacher. As a result, children may acquire emotional obstacles that impede their ability to learn a second or third language [2]. Conversations with a robot may be less unpleasant, providing a potentially effective gateway to conversational competence, less anxiety, and more positive attitudes toward learning [2][17][18].

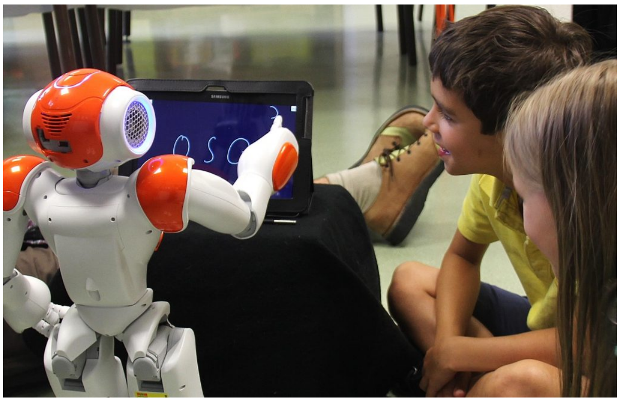


Figure 2.3: Child-robot interaction

Considering that humanoid robots are a newer technology and their application in our daily lives is almost nonexistent, this affects children's behaviour around such a new technology. There is a variety of reasoning why humanoid robots can be appealing to kids. One of the major reasons for the apparent increases in educational outcomes when robots are introduced in education, is that robots are particularly intriguing to kids due to their physical appearance and novelty. As a result, the students are more interested and eager to take part in school activities [19].

Children's Attitude Towards a Robot

Two dominant metrics measured in child-robot interaction (CRI) are motivation and engagement. These two metrics are important to determine children's attitude towards a robot. Studies regarding this aspect have not only evaluated children's self-reports to assess engagement, satisfaction, and enjoyment, but have also analyzed their facial expression to examine whether they enjoy robot's presence or not [20][21][22]. Although parents and educators usually tend to place a greater emphasis on learning outcomes rather than on engagement, engagement is a very important factor that also affects learning outcomes of a student. For a student to be motivated and successful in learning, he/she must enjoy the process of it. The same thing applies to interaction with a robot, children must desire to interact with them in order for robot-assisted teaching to be successful [22].

The majority of pupils embrace learning languages with social robots [22]. A group of fifth-graders in Taiwan, for example, practiced their English skills in a group session led by a human instructor with and without the assistance of a humanoid robot. Children who studied with the robot reported being more motivated and satisfied, as well as being less anxious and having greater self-esteem than their friends who did not have the robot present in their study session [20][22].

Although, recent research shows that children's attitude towards a robot is predominantly positive, novelty is still one of the main factors to be considered while studying attitude.

2.1.3 Collaborative Storytelling

Storytelling is considered to be among the most prominent parent-child interactions. According to current studies, storytelling provides significant benefits to the child, including expanded vocabulary, greater complexity of constructed sentences, improved narrative interpretation, and enhanced learning abilities in general [23] [24][25]. Conversational storytelling, in addition to exposing children to new words, presents an "exercise" for using language to communicate the actual meaning of a word or sentence with analysis and reflection. This way of learning aids in the development of early reading skills for young children [26]. Such an "exercise" has shown to be important for later academic achievements of the child [23] [27].

Regardless of the effort the parents and teachers may put in motivating children to read books, adults do not always have the time or energy to encourage children in cooperative storytelling. Robotics and Artificial Intelligence have lately emerged as potential play-pals for kids [28]. In a mixed-initiative storytelling activity, a computational character such as a robot or virtual characters, collaborates with a kid to compose one or more narratives or even just read a book together [29]. These kind of robots or virtual characters engage with kids in a regimented and minimal manner [30]. Interruptions, inquiries, confirmation, backchanneling actions, and so on are more common in storytelling activities between children and parents or other peers [30].

Nonetheless, the existing capabilities of artificial intelligence (AI) restrict the concept of a collaborative narrative robot. Despite recent advances, AI is still limited in recognizing children's speech and comprehending natural language semantics. Due to limitations in speech recognition and natural language understanding, the robot may not react to children in a semantically consistent manner. With these obstacles, it is still unclear whether fluid collaborative child-robot storytelling is viable or helpful to children.

2.1.4 Application of Humanoid Robots in Education

The number of researches exploring the use of social robots in education is constantly growing during the last years. Many studies have found that using robots in the field of education may improve attention, enjoyment, and engagement [22]. Many research have incorporated robots in traditional learning disciplines like mathematics or language acquisition [19]. There has been evidence of positive impacts from robot-assisted language learning, such as improved vocabulary development, speaking abilities, articulation, etc. [31] [22]. In several studies, both first and second language learners have indeed been examined.

Another form of the social robots application that has shown to have positive outcome is using robots throughout the teaching process of children with Autism Spectrum Disorder (ASD). Many studies have shown positive and favorable impacts on children when applying this way of teaching. Increased participation, good behavior, and social contact are among the documented impacts that have been observed to date [32][33] [34]. Children with ASD have shown to have improved linguistic skills and abilities [22]. It has also been suggested that social robots may be especially good for those with ASD since the robot is less threatening, more predictable, as well as more patient than a human instructor.

Language Learning Through a Humanoid Robot

Most of language learning initiatives through a humanoid robot until now are generally linked to the English language. Nonetheless, studies of learning other languages, such as German, Dutch, Italian, Spanish, Japanese, Korean, and Persian, have also been published [22][31]. However, there are currently no additional studies demonstrating the viability of employing robots for teaching Norwegian language.

While various research papers suggest that using robots for language learning has benefits, much of the research done to date includes a small number of students and is primarily qualitative and exploratory research. There are a lot of unanswered problems due to a lack of long-term inspection of this area [35]. Thus, more research is needed in different aspects, for example, studies on the long-term impacts of utilizing robots, such as whether employing social robots has an advantage over other digital technologies, studies on what characteristics of the robot are significant for vocabulary acquisition, etc. Despite this, there is also a need for more detailed study on ethical issues associated with the usage of social robots, such as the impact and consequences on the emotional and social development of children when applying social robots in education [35].

2.2 Technology and Concepts

This section dives into the technological background on humanoid robots along with explanation of different concepts regarding the topic mentioned previously. The section is divided into two parts. The first part examines the robot used during this study, while the second part talks about the software used to program and control the robot.

2.2.1 The Robot

The robot used for this master's thesis purpose is Pepper robot. Pepper is a humanoid robot manufactured by SoftBank Robotics or formerly known as Aldebaran Robotics. It is 1.21 m in height and it is a wheeled humanoid robot. Pepper has 17 joints and several LED for indicating and helping communication between the robot and a human [36]. It contains four directional microphones in its head that allow Pepper to identify the source of entries (voices speaking to the robot) and, as a result, turn its face to whoever is speaking. The microphones mounted on it help analyze voice tones which allows interpretation of the emotional state of the speaker. Pepper can detect not just faces but also photos and objects with the help of a 3D camera and two HD cameras. The robot has 20 motors that allow it to move its head, torso, and arms [36]. It also comes with six laser sensors, two ultrasonic sensors, and three barrier detectors [36].

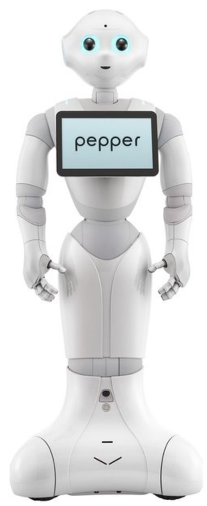


Figure 2.4: Pepper robot

2.2.2 Choregraphe

The program used for programming Pepper robot during this master's thesis is Choregraphe. Choregraphe is a computer software that provides different features such as programming the robot, controlling it, testing it, and creating different animations [37]. This software, furthermore, provides simulation and scripting of complex behaviors such as human interaction, dance, instrument playing, and so on [38][37]. The Choreograph software consists of a graphical user interface which can be used to generate different programming blocks that instruct the robots actions and behavior. In addition to that, for special cases, python code can be written and applied directly on the robot. All of the GUI programming blocks are ultimately python code under the hood.The add-ons include a window to monitor the video, a window to observe the code's behavior, a toolbar, a digital view of the robot for debugging, and a timeline to synchronize the motions at a certain time [37]. When linked to Pepper robot, Choreographe displays the cameras in real time, allowing you to view what the robot's cameras are observing [39][38][37].

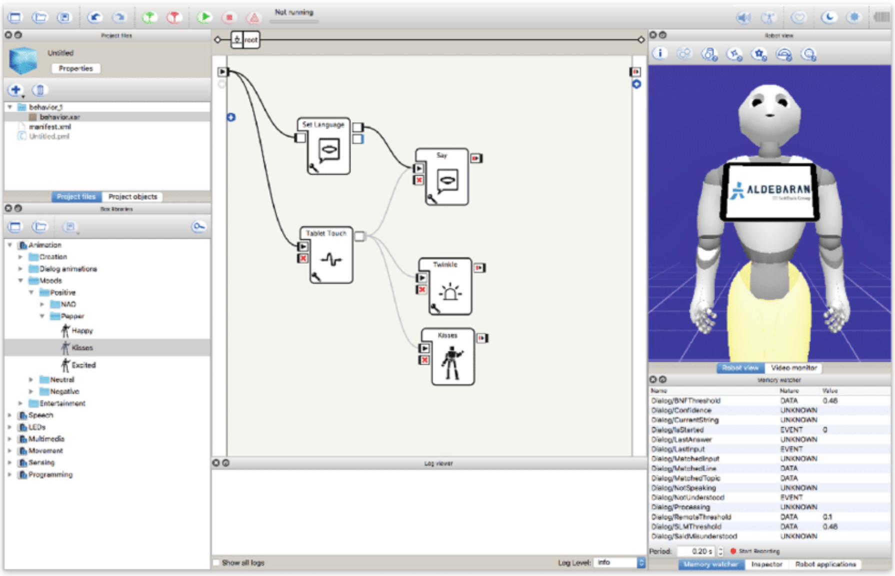


Figure 2.5: Choregraphe software

Chapter 3

Methodology

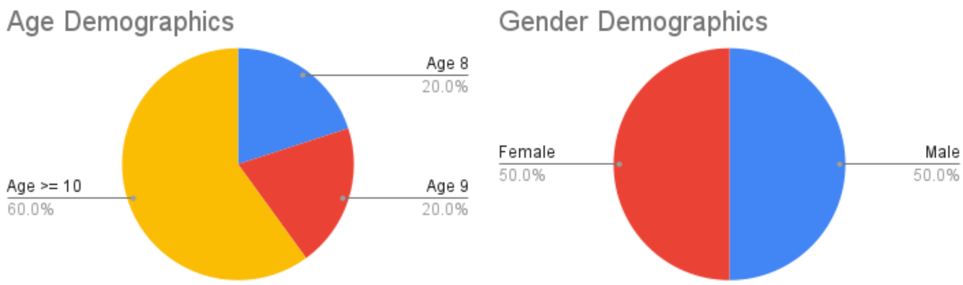
In this section, we present the experimental phase of the study. The chapter is divided into three parts, starting with demographic information, methods of data collection, and ending with the whole procedure of the experiment.

3.1 Participants

For this study, in total 10 children were recruited from 8 to 10 years old. The recruitment process was conducted both at the Norwegian University of Science and Technology - NTNU (children of the staff members working at NTNU) and The International School in Gjøvik. However, it is important to mention that there was no official collaboration between our research group and the International School. All participants were Norwegian children residing in Gjøvik and were somewhat comfortable in reading, writing and communicating in the English language. Among the participants, 2 out of 10 children were eight years of age and currently in the second grade of primary school. The rest of the participants (8 out of 10) were currently in the third grade of primary school, from which 2 out of 8 were 9 years old, and the rest of the group being 10 years old. It is also important to mention that during the recruitment process the balance between genders was a crucial factor, thus, we had an even number of male (5 out of 10) and female (5 out of 10) participants. Prior to starting the task, each child underwent a pre-test in order to collect demographic information. The aim of this pre-test questionnaire was to understand whether they had prior experience with a robot and explore their attitude towards the robot before interacting with it.

Table 3.1: Demographic information of the participants

Age	Male	Female	Total
8 yrs	1	1	2
9 yrs	2	0	2
10 yrs	2	4	6



(a) Age demographics **(b)** Gender demographics

Figure 3.1: Demographic statistics of participating children

To identify acceptable individuals for this study, we investigated a variety of factors.The inclusion and exclusion criteria are as listed below:

- Inclusion criteria:
  - Somewhat comfortable in reading, writing and communicating in English
  - Age between 8 and 12 years
  - Willingness to participate
  - Willingness to come to our lab at NTNU
- Exclusion criteria
  - Unwillingness to participate
  - Non-English speakers
  - Unable to read

Images shown below (figure 3.2 and figure 3.3) are images taken during the experimental sessions of this study, and are used as a representation of the demographic information mentioned previously in this section.

Figure 3.2: Child-Robot Interaction during the experiment

Figure 3.3: Child-Robot Interaction during the experiment

3.2 Data Collection Methods

For this study we captured video recordings of the interaction sessions during the experimental procedure. All ten interaction recordings were transcribed and thoroughly examined, generating in total 5 hours of visual data. Apart from video recordings, each participant was asked to answer three different questionnaires, two of which were in the form of an interview and one of them consisting of 5-point Likert scale as shown in figure 3.4. Considering that the age group of the participants was relatively young, the Likert scale was chosen in a way that it was easy for them to understand but also appealing at the same time.

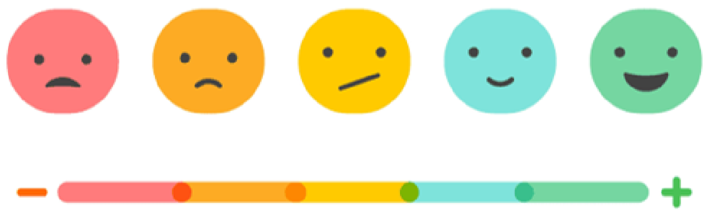


Figure 3.4: 5-point Likert Scale

Before each session, a pre-test questionnaire was collected from each participant. The questionnaires were decided to be conducted in the form of the interview in order to make it simpler and straightforward for the kids. The 5-point Likert scale was used for mid-test questionnaires to compare the two methods of interaction (half digital vs fully digital) between the child and the robot. In the end, after the experiment was finished, again, each participant was asked to answer a post-test questionnaire in the form of an interview for gathering additional data like, their attitude towards the robot after interacting with it, their learning outcome and more.

All data gathered during this study was anonymized and used only for the purpose of this master's thesis.

3.3 Procedure

Taking into account that personal data processing of the participants was involved in our experiment, a digital form was sent to the Norwegian Centre for Research Data (NSD) prior to the start of the study. The experimental phase began only after receiving the approval of the NSD form. In total, we recruited 10 participants ranging from the age of 8 to 10 (average age: 9.4, 50% male, 50% female) throughout university staff members and students.

Considering that the participants were all young children, their parents were asked to fill out a consent form for their child before starting the experiment. After signing the consent form, each participant was instructed on what was expected of them over the course of the experiment. The participants then were asked to answer a couple of interview questions in order to collect demographic information, obtain their attitude towards the robot, as well as understand whether they had interacted with a robot before or not. Subsequently, after the pre-test questionnaire was completed, children started interacting with the robot and accomplish the given tasks. Since the setup of our study was designed for two kids at the same time, in the middle of the experiment, the child who had completed the first part of interaction was led to undertake the mid-test questionnaire. After the completion of mid-test questionnaire followed the second part of CRI, as well as, post-test questionnaire. Additionally, participants were given instructions throughout the whole experiment by the robot and the research group.

The whole experiment, including pre-test and post-test, lasted approximately 35-40 minutes. Moreover, each session of child–robot interaction lasted approximately 20-25 minutes on average. In the end, all participants were rewarded with incentives as a thank you for their participation in the study.

3.3.1 Experimental Setup

The whole design of the experiment was planned to fit the environment of the (Virtual Reality) lab at NTNU in Gjøvik. This was as a result of not having the ability to transport the robot to any other space on campus or outside of it. The experimental flow, as shown in figure 3.5, starts with welcoming the participants together with their parents to the (Virtual Reality) lab, and introducing them to the robot. After familiarizing the kids with the robot, the camera is turned on for video recording the session, thereupon, the experiment begins. The session begins with the pre-test questionnaire, following with CRI along with mid-test questionnaire, and ending with the post-test questionnaire.

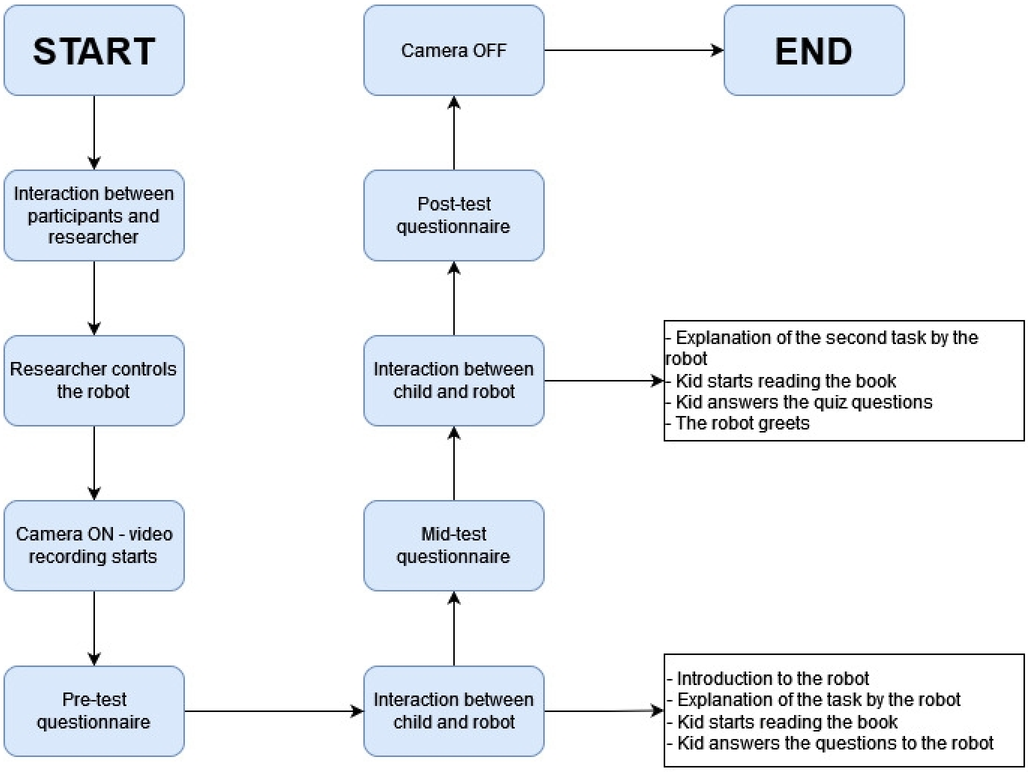


Figure 3.5: Flow diagram of the experiment

The setup of the entire experimental environment is explained in figure 3.6. The left side of the image shows the initial standing positions of the participants and the standing position of the robot, while the right side of the image shows the table where the questionnaires take place. Along with the questionnaire sheets, at the round table is also the book that was used during the experimental session. The participant standing closest to the table is asked by the robot to grab the book from the table.

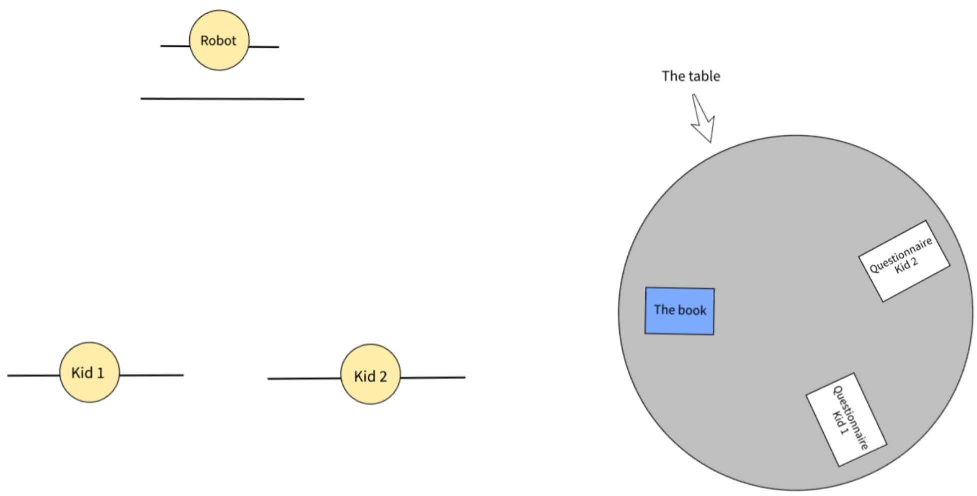
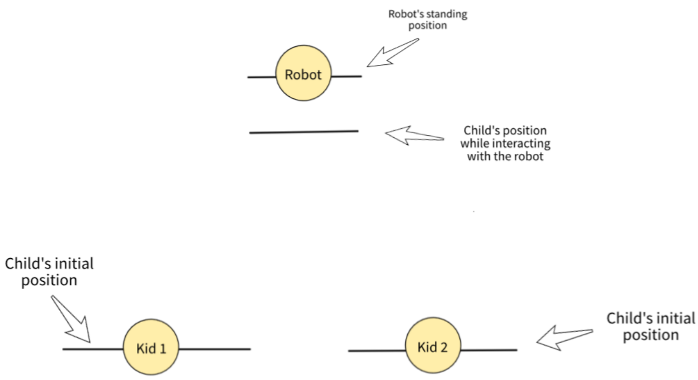
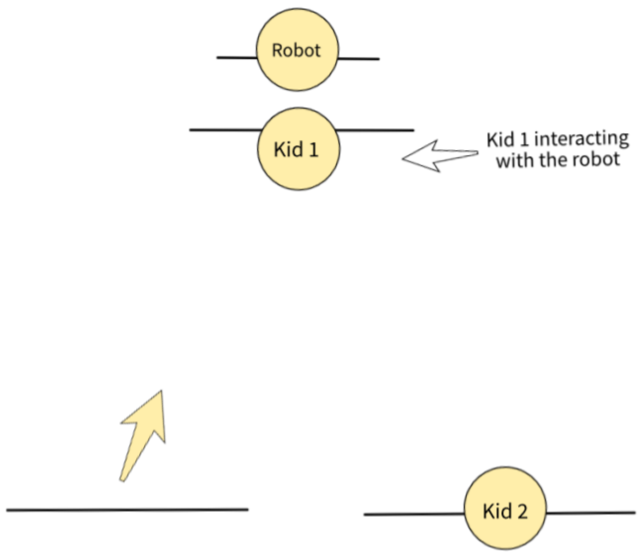


Figure 3.6: The whole setup of the experiment in the VR lab

Figure 3.7 demonstrates child robot interaction during the experiment. As previously explained, figure 3.7a shows the initial positions of all parties participating in the experiment, while figure 3.7 shows the changed position of the child during the interaction. Considering that the hearing ability of the robot is limited, the child interacting with the robot is given instructions to move closer to the robot (figure 3.7b).



(a) Initial positions of the participants



(b) Changed position

Figure 3.7: Child-Robot Interaction setup

Figure 3.8 and figure 3.9 shown below are pictures taken during the experimental sessions, and presented in this section for a better understanding of the Child-Robot Interaction setup.

Figure 3.8: Child-Robot Interaction during the experiment

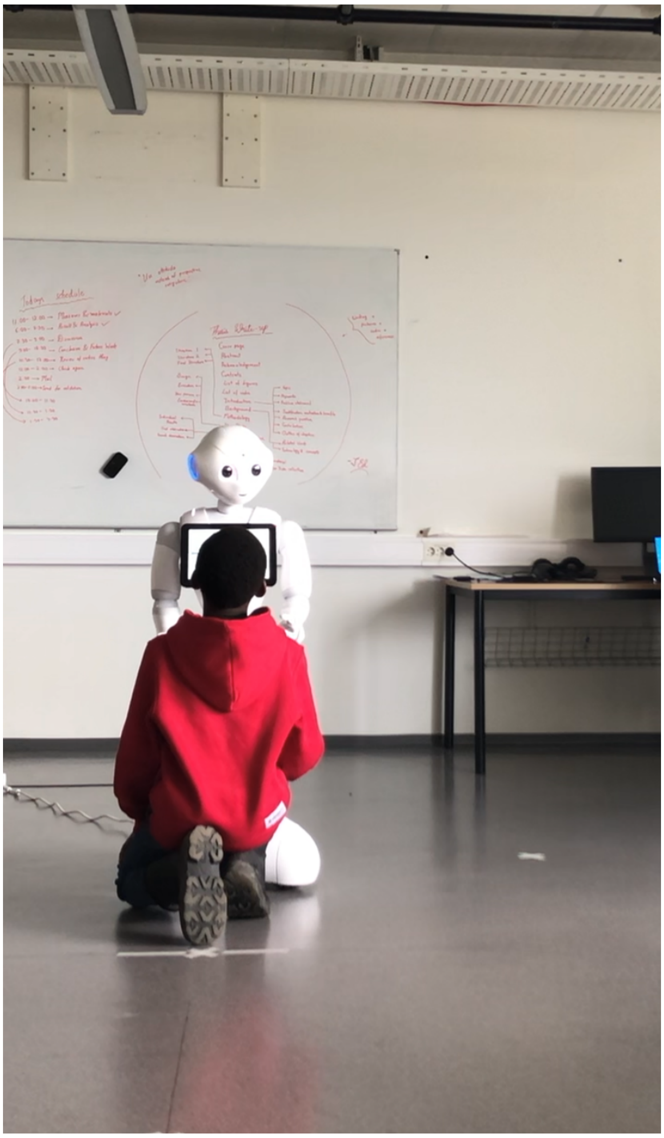


Figure 3.9: Child-Robot Interaction during the experiment

3.3.2 Robot application design and implementation

In this section we explain the application design used to program the robot in preparation for the conducted experiment.

According to SoftBanks Robotics, who have created Pepper and developed the software running on it, Pepper is alive and autonomous [40]. It interacts with its surroundings, is aware of actions and understands the environment surrounding it. Based on the context the robot finds itself into, different pre-programmed behaviors and actions will take place. Such actions and awareness are things that Pepper does naturally based on inputs and stimuli coming from the outside. [41]

Therefore, we as developers, need to take into consideration that the application we create to run on Pepper's platform must co-exist with other abilities that Pepper does naturally. Some of these abilities include Pepper blinking, background movement, basic awareness (keeping eye contact with person in front), listening movements on so on. Pepper is able to manage itself using these abilities while feeding with contextual information and running built in activities or activities that we program for it. A generic overview of how Pepper manages its life is shown on figure 3.10.

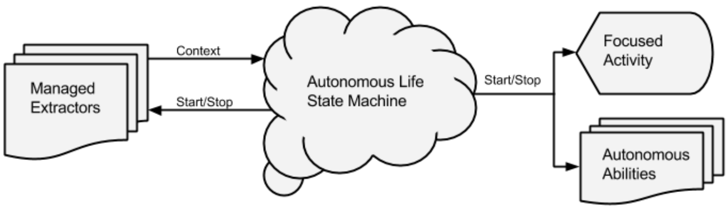


Figure 3.10: Pepper's active life cycle state transitions

During the time period when the robot is active, the Autonomous Life State Machine is the heart of everything the robot does. This state machine makes sure to start and stop activities, autonomous abilities and extractors. In this case, activities are the pieces of code that we have created for the experiment with the intention of allowing Pepper to communicate with children and help them read the book. An activity is ultimately a behaviour that is developed using the Choreograph software provided by Softbanks Robotics. An extractor gives the robot contextual information such as number of people in the room, movement detection, emotion detection. These extractors provide useful contextual information which can be helpful to trigger different activities. Finally, the autonomous abilities make sure the robot seems alive by moving, waving, animating different parts of the body, blinking LED and more [41].

For the purpose of our experiment, Choreograph software has been used to program the robots behavior. Several managed extractors were invoked for helping with contextual information that proved crucial on triggering the right activity based on children's input. Some of the most important managed extractors for our experiment were:

- *ALMood*: Ability to perceive the mood of the person in front of the robot
- *ALPeoplePerception*: Ability to perceive the number of people in front of the robot (limited to the field of view of the front cameras).
- *ALTabletService*: Ability to use the built-in tabled device for showing images and animations during the experiment

Basic awareness together with listening and speaking movements were enabled for our experiment to make the robot behave more lively and human like. This was important so that the children did not perceive the robot as scary or unpredictable. Additionally, the robots built-in Natural Language Processing (NLP) module was used to communicate with children and process keywords while listening to the children speaking. For example, for the quiz session of the experiment, Pepper would ask the questions and process the answers in order to validate them. Using Choreograph, we were able to implement all this functionality, build the complete behavior as a package and upload it to the robot. The complete behavior/system architecture can be seen on figure 3.11.

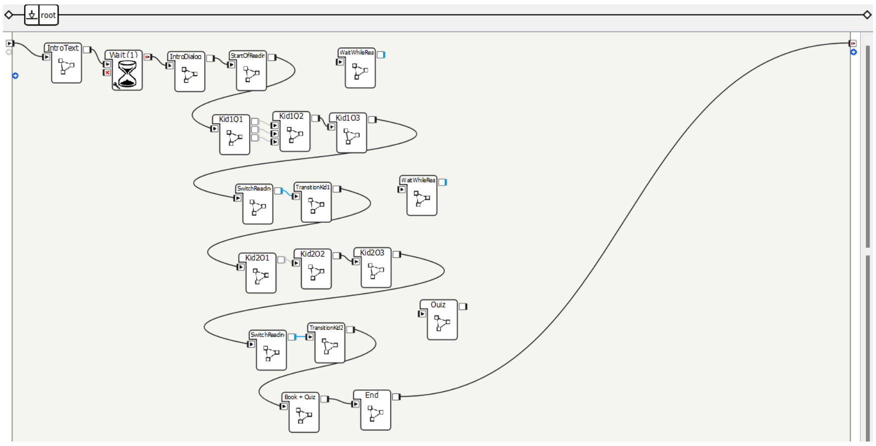


Figure 3.11: Overall choreograph behaviour overview of experiment

Observing figure 3.11 we can see that the behavior flow diagram is composed of several more-complex sub components making up the whole experiment. Each component consists of other sub components which ultimately comes down to single components that do text-to-speech interactions, person detection, speech recognition, emotion detection and so on. The state transition is controlled using logical routes based on context and input from the environment and the participating child.

Figure 3.12 shows one of the components from the root behavior tree in more detail. In this figure we can see that the robot starts by formulating the question which, after completed, is connected with a speech recognition component. The speech recognition component makes sure to parse speech to text and continue to check whether the answer given by the child is correct or wrong. For the case where the kid guesses correct, the flow continues further to the next component in line. The component allows to repeat the question over again in case the parti-

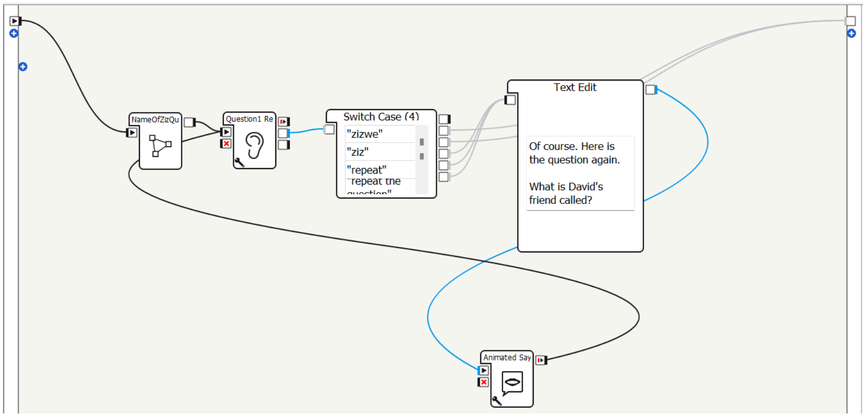


Figure 3.12: A detailed flow diagram showcasing one of the quiz stages

cipant asks to repeat the question. Using this approach, the whole behaviour graph has been compiled together to deliver the interaction which helped us complete the user experiment.

Hypothesis

The Child-Robot Interaction experiment was conducted to either support or deny our claimed hypothesis which we will list below. As mentioned earlier in this chapter, the number of children participating in this experiment was limited. Therefore it is important to note that analysing the results of this experiment and drawing conclusions based on the analysis acquired, the limited number of participants makes it difficult to support or deny our hypotheses with statistical significance. With this very important aspect of the experiment explained we have come up with the following hypothesis:

- *H1*: Children's attitude and engagement towards Pepper as a learning companion will improve after undergoing the experiment.
- *H2*: Children will perceive Pepper and humanoid robots in general as an important learning companion
- *H3*: Humanoid robots technology is still immature in considering them as tools for improving the effectiveness of learning English and other foreign languages in young children

Chapter 4

Results

In this chapter we will disclose the results of the experiment conducted with the children and the humanoid robot Pepper. We report on the demographics of the participants (in this case the participating children), the different attitudes towards behavior, effectiveness and interaction with the humanoid robot. Furthermore, using the pre, mid and post questionnaire technique we attempt to compare and test whether there is a change in attitude, effectiveness in learning English in addition to measuring their attitudes towards Pepper being a good learning companion.

The different statistics, reports and analysis shown in this chapter will try to shed light into our research questions and provide the means of resolving the proposed hypothesis of this research study.

4.0.1 Attitude and engagement with Pepper

During the experiment phase, all the participating children where presented with a pre-questionnaire. The goal of this pre-questionnaire was to assess children's attitude and engagement with the Pepper robot. In order to measure this, children were asked to answer a couple of questions beforehand. Due to the fact that the experiment was conducted with young children between the ages of 8 and 10, we did not use complex scaling questions. Instead we asked the children questions such as:

- What do you think about reading a book with a robot?
- What do you think about using a robot to learn English?
- Could you be friends with a robot?

After collecting the answers to all the participating children on the experiment, we grouped their answers into three different groups depending whether the answer reflected positive, neutral or negative feelings/attitudes on the posed question. An answer was considered to fall into the *Positive* group if the child answered with a positive, assuring and optimistic take when presented with the question. The *Neutral* group consists of answers where children were unsure what to answer, had no experience with robot interaction or refused to answer. Last but not least, an answer fell into the *Negative* group if the child was pessimistic on the presented idea/claim from our side.

On figure 4.1 we present the results of the measured attitudes of children towards having Pepper as a learning companion. As observed on the chart, before conducting the experiment, the measured attitude was split in half between perceived positive and negative/neutral. Which means that half of the participants were either unsure or did not imagine a humanoid robot such as Pepper to be a good learning companion.

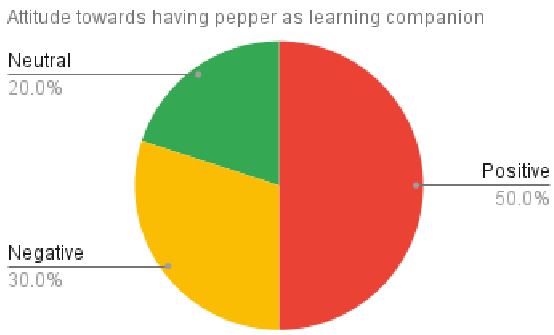


Figure 4.1: Attitude on Pepper as a learning companion

We went further and narrowed down the idea of learning companion into two more specific measures, namely English language acquisition and interpretation of books. Figure 4.3 and 4.2 will help us understand the underlying attitudes of children on the above mentioned measures. We observe that children have a more positive attitude when asked how they feel about reading a book together with Pepper, 70% of them to be more precise. Regarding language acquisition with the help of Pepper, the attitudes were mixed between participants, namely 50% of them having a positive attitude and the rest of them having no opinion or being pessimistic towards that idea.

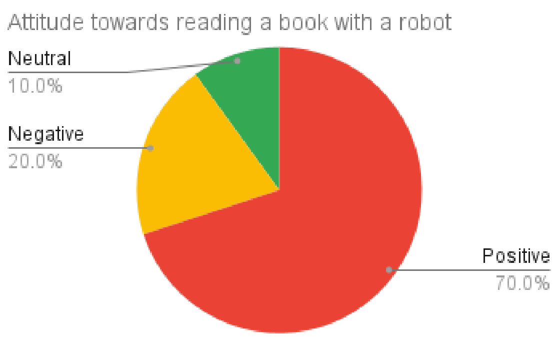


Figure 4.2: Attitude on reading and understanding books the help of Pepper

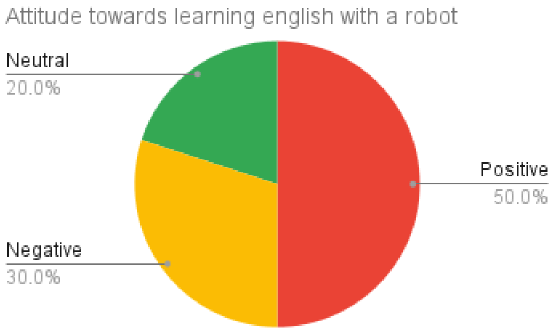
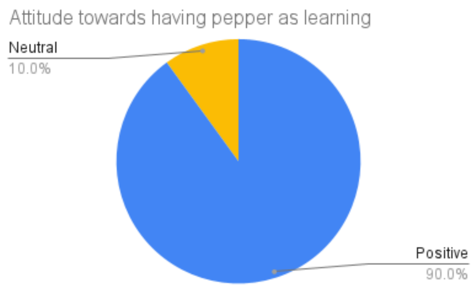
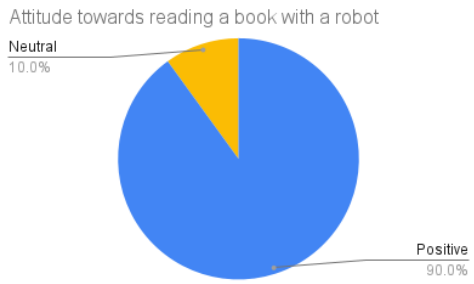


Figure 4.3: Attitude on language acquisition with the help of Pepper

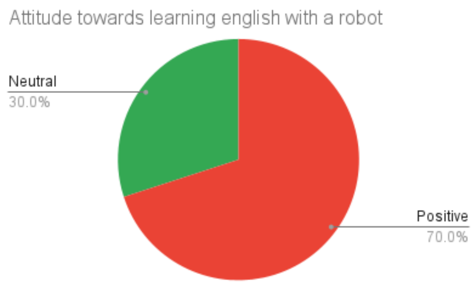
It is worth mentioning that we have used the same metric to measure again the children's attitudes after having interacted with Pepper during the experiment. The post-questionnaire was conducted at the end of the experiment after all interactions with Pepper were completed. Results of the post-questionnaire analysis on children's attitude towards learning and engagement with Pepper are presented on figure 4.4. It can be observed that there is a significant change on the measured attitude of children. When it comes to having Pepper as a learning companion, the attitude has significantly increased among the participating children, namely from 50% to 90% (figure 4.10a). A similar increase on the positive attitude can also be observed on figure 4.4c. We observe a 40% increase on positive attitude towards language acquisition with the help of Pepper. The smallest change on positive attitude before and after the experiment was observed on the attitude towards reading and interpreting a book with the robot. On this metric we only observe a 20% increase on the positive attitude. It is worth mentioning that after the experiment, no negative attitudes were observed on book interpretation between the child and the robot.



(a) Attitude on having pepper as learning companion



(b) Attitude on reading a book with Pepper



(c) Attitude on language acquisition with Pepper

Figure 4.4: Measured attitude during the post questionnaire stage

Based on the results observed above we can answer our second research question stated in section 1.5 by claiming that children's attitude and engagement towards Pepper as a learning companion is positive. With the help of our conducted analysis the first research hypothesis (H1) is supported. Children's attitude and engagement with the robot does indeed improve after having undergone our experiment. Furthermore we believe that our research study can be used as a base for continuation of further exploration of child-robot engagement and further explore humanoid robots as learning companions.

4.0.2 Humanoid robots as learning companions

The classic school classroom with teachers and fellow pupils has been around for centuries. From experience we know that such environments have proved to be fruitful for the continuation of education for kids but we also know from previous research studies that the one-size-fits-all is not always the best way to go. The goal of this research study was to investigate the possibility of introducing humanoid robots as learning companion to help further improve the children's learning experience.

Humanoid robots are a relatively new technology and has not been employed all that much on the educational curriculum of small kids. This is partially as a result to the immaturity of the technology itself to cope with the kids' needs but also due to the lack of research studies proving the success of it on the education field. Therefore, the aim of our research study is to contribute with research analysis on the subject of humanoid robots as learning companion.

The experiment started by gathering information on previous experiences with robots in general for the participating children. When asked whether they have interacted with some type of robotic technology before, 70% of them responded that they haven't whereas the rest had done so (see figure 4.5).

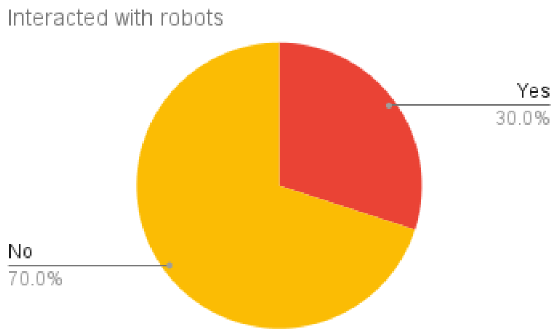


Figure 4.5: Statistics on children having interacted with a robot before

It is important to note here that such results were expected by the research group. This is partially because of the relatively new age of participating children and also due to the fact that humanoid robots are costly and require professional maintenance and operation. Familiarity with the concept of a humanoid robot was measured also by asking the participating children whether they have previously seen a robot of this type. Having a rough idea of what a humanoid robot looks like and what it does, was a positive indicator that children would not be scared upon encountering Pepper. The results show that a total of 80% of participating children have seen a humanoid before either on TV, YouTube or some other form of entertainment (figure 4.6).

Nevertheless, during the experiment we observed that among 10 participating kids, one of them did perceive Pepper as scary and inappropriate and as a result

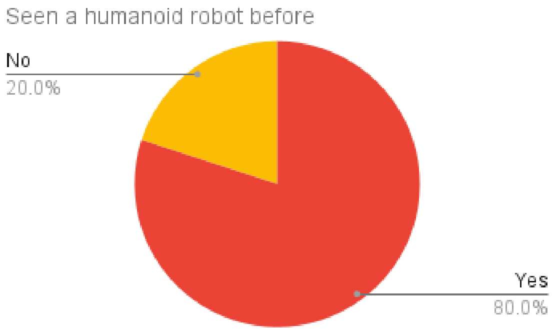


Figure 4.6: Statistics on children having seen a robot before

the child did not proceed with undergoing the experiment. Despite our believes that Pepper does look and act friendly most of the time, we observed that 50% of participating children said that the robot was not nice when being silent, whereas 90% of them responded that the robot was nice when speaking (figure 4.7).

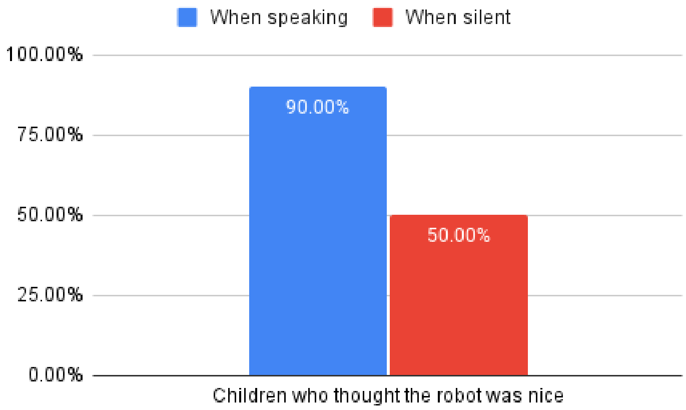


Figure 4.7: Perceived niceness

An important thing to note here is that all questionnaires together with the experiment were conducted in the same room. At the time when children were completing the pre-questionnaire, the Pepper robot was in "Idle" state (figure 4.8) and activated after the pre-questionnaire was completed by the participating child.

The posture of Pepper while being idle could have had a negative impact on the perceived niceness of the robot among the participating children. We have to keep in mind that the age group is between 8 and 10 years old and therefore unfamiliar positions on a robot that looks similar to a human being can be considered scary or unsettling to them. The reasoning behind exposing the kids to seeing Pepper on idle state is to simulate those scenarios where the software running on the robot crashes or battery goes out. In such scenarios, the default fallback position of the Pepper robot is the one seen in figure 4.8. This is a strong indicator to the results we see on the bar chart on figure 4.7 where only 50% of participants thought the robot was nice while being silent. This assumption is based on observations of children's emotions when the robot transitions from idle to activated (robot is not speaking but is listening and interacting with the environment non-verbally). Figure 4.9 shows the different positions that Pepper can take while listening to the kids reading the book during the experiment.

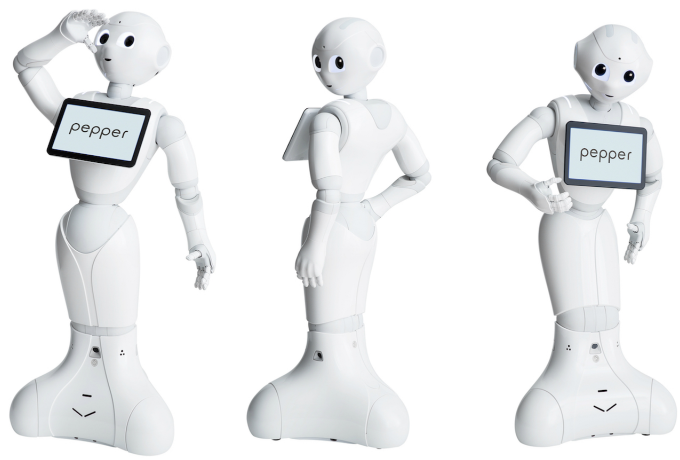


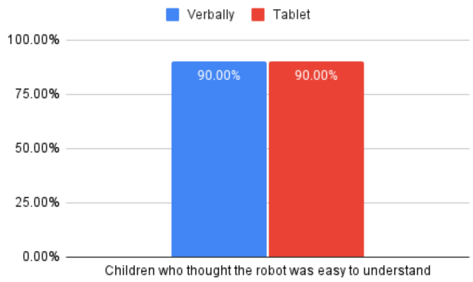
Figure 4.9: Pepper robot positions/postures when in active state

The second hypothesis of this reasearch study (H2) claims that the children will perceive Pepper and humanoid robots as an important learning companion. To verify our claims, participating children interacted with Pepper verbally and also using the built-in tablet on Pepepr. The ease of interaction and understanding between child-robot was measured after the experiment was completed. The following questions were presented to the participating children:

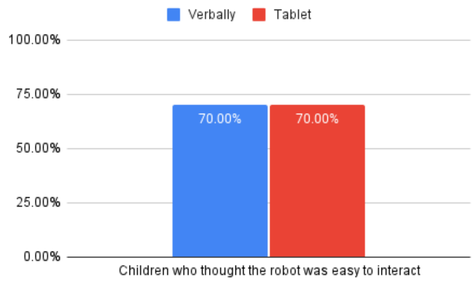
- Was it easy to understand the robot when it was giving instructions through speaking/tablet?
- Was it easy to interact with the robot through speaking/tablet?

Figure 4.8: Pepper in Idle position

The results are presented on figure 4.10. Observing the results presented on the left graph (sub-figure 4.10b), the children responded that it was easy to understand the robot both verbally and when using the tablet, namely, 90% of participants. The other 10% (in our experimental group it corresponds to 1 participant) did not undergo the experiment and therefore not completed the post-questionnaire. Additionally, we present the results of CRI on the sub-figure to the right (sub-figure 4.10b). The results indicate slight challenges



(a) Measured ease of understanding



(b) Measured ease of interaction

Figure 4.10: Child-Robot Interaction

when it comes to interaction between the participating children and Pepper. 70% of children rated the interaction with the robot as positive whilst the rest of them, 30% either perceived it as negative or did not respond at all.

Interaction challenges come as a result of technology immaturity on language processing running on the robot. Previous research studies show that there are limitations on the current language processing algorithms on children's language and jargon [42]. This has been observed and further backed by our research study. One might argue however that tablet interaction should have scored better compared to verbal interaction due to the significant exposure of children to tablets on everyday life. Our hypothesis is that children are affected by the presence of the robot even when only using the built in tablet which affects the overall results when compared to the verbal version of interaction during the experiment. This however is just a theory which unfortunately we were not able to quantify and measure accordingly. Additionally, due to the limiting period on which this research study had to be completed, the quality of the application deployed to Pepper for completing the experiment was not optimal.

With 90% of participants considering the robot as nice and engaging during interaction and 70% of them rating their interaction with the robot as easy, we claim that our second hypothesis is supported. On the other hand, to answer our third research question, results revealed in this section indicate that children's attitude towards learning with a robot has undergone a slightly significant change (fig. 4.11). Most significant change has been observed on the positive side of the attitude. None of the participant's attitude was measured as negative after they have completed the experiment. We believe that these results are a good indication that children have an overall positive attitude towards having Pepper as a learning companion on their everyday school classes. We emphasise that such ways of using robotic technology is still immature and that they should be considered only as supplemental helping material for improving learning experience for children.

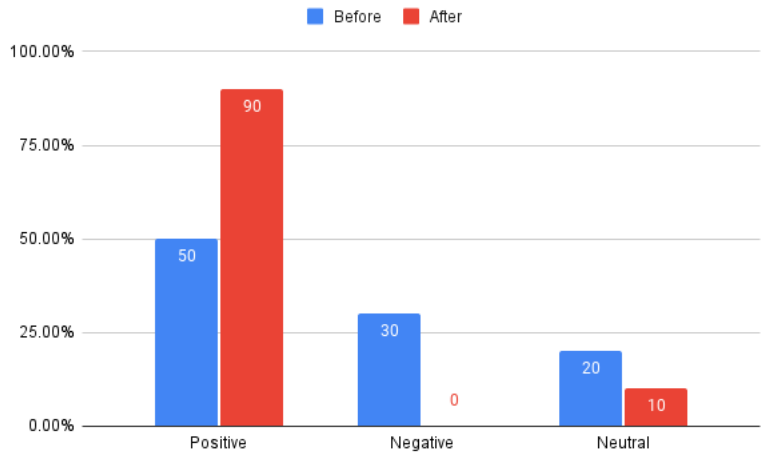


Figure 4.11: Children attitude towards having Pepper as learning companion (before and after the experiment)

4.0.3 Language acquisition with Pepper

Among investigating Child-Robot Interaction and the children's attitude on having robots as learning companions we also investigated the possibility of improving language acquisition on the same experiment. A children's book with a language difficulty between easy and moderate and with content appropriate with the age of target group was used to assess improvement of English language acquisition.

In order to answer our research question on how effective the use of humanoid robot in language acquisition is, two metrics/approaches were used. The first approach was to ask the children during the post questionnaire stage to recall as many words and characters as they can from the book and during the quiz. This approach would tell us approximately the level of understanding that the children have after reading the book with Pepper. Furthermore, distraction levels could also be measured to make sure that the robot does not act as a distracting object but rather as a helping aid towards better understanding the topic at hand. Results are presented on figure 4.12. We observe that the children are much better at recalling the characters compared to recalling the words from the quiz. We would argue that the good results on recalling the characters from the book is a result of having rather easy names to recall from (expect the one character with a more difficult name "Afiya"). The quiz words on the other hand were somewhat more challenging to remember for the target age group. One of the hypothesis was that interaction with the robot through speaking and using the tablets with visual cues on the specific words would help the children recall most of them. Results however prove us wrong on such claim. Before we can answer our first posed research question and conclude on our third research hypothesis, we need to analyse the results of the second approach.

The second approach was to show a list of words which occurred whilst read-

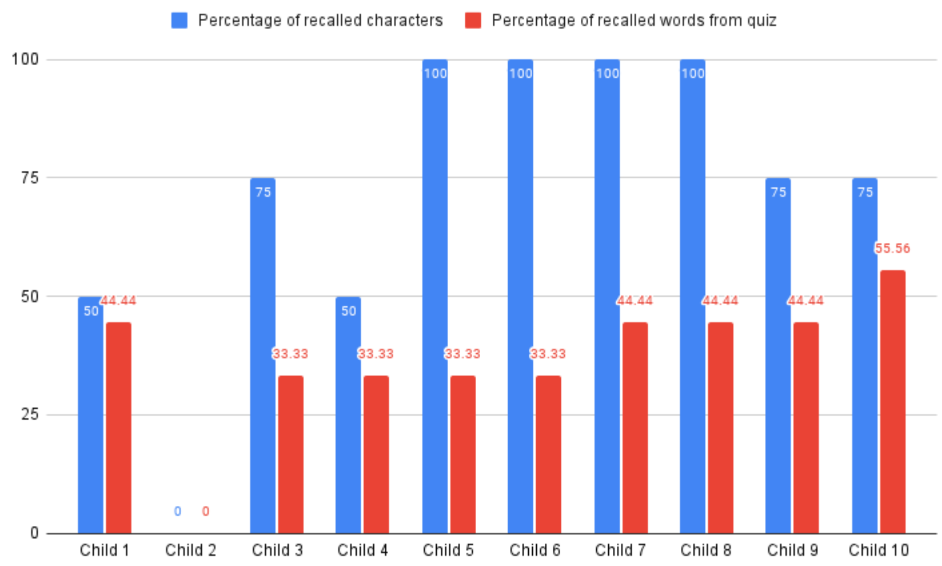


Figure 4.12: Children's ability to recall the book characters vs quiz words in English

ing the book. For each word shown, the child had to choose between one that was spelled correct and another that was spelled wrong. The list of words is shown on figure 4.13. The ones with wrong spelling were chosen deliberately to be very close to the correct spelling. It is our believe that using such approach would further support our claims on improved language acquisition using robots if such improvements are observed in the first place.

In order to measure how good the children were able to recall the quiz words, they were asked to circle the correct spelling of the word. The results are presented on the pie chart on figure 4.15. We report that among the 10 participating children, 40% of them were able to recall more than 8 words from the quiz. 30% of them were able to recall 6 to 7 words whereas the rest of them recalled less than 6 words. There were 9 words in total presented to the participating children. Furthermore, children's responses when asked "What do you think the book was about?" were analysed. Their responses were grouped into two groups, namely those who did understand the plot of the book and those who didn't. An example of answers that did fall on the first group include:

- *The book was about the Tooth Fairy and David and Ziz.*
- *It was about a kid loosing a teeth. And then his grandad found it.*
- *Tooth fairy.*
- *It was about Dave sneezing out his teeth. He found his tooth in the end.*

Results of this analysis are presented in figure 4.14. Per our expectations, we observed that 90% of the participating children were able to understand the mean-

Circle the correct spelling of the following words:

Cloudds	**Clouds**
Comb	**Commb**
Hills	**Hils**
Journey	**Jornay**
Kyte	**Kite**
Owl	**Owel**
Sneze	**Sneeze**
Tre	**Tree**
Whisper	**Wisper**

Figure 4.13: List of words presented to participants after the experiment

ing and plot of the book. The remaining 10% (in our case 1 child) is a consequence of participant(s) not proceeding with the experiment and opting out of it. The results presented on figure 4.14 indicate that the help of humanoid robots is effective in language acquisition on young children (R1 1.5). However, the lacking of good results on choosing the correct spelling of the quiz words (only 40% guessing more than 8 words correct) does pale the claims proposed. It shows, however, that these words were indeed difficult for the children to comprehend which also explains the relatively low numbers on recalling words from the quiz presented on figure 4.12.

Based on the analysis presented while taking into consideration the limiting number of participating children we conclude that our third research hypothesis (H3) is not supported.

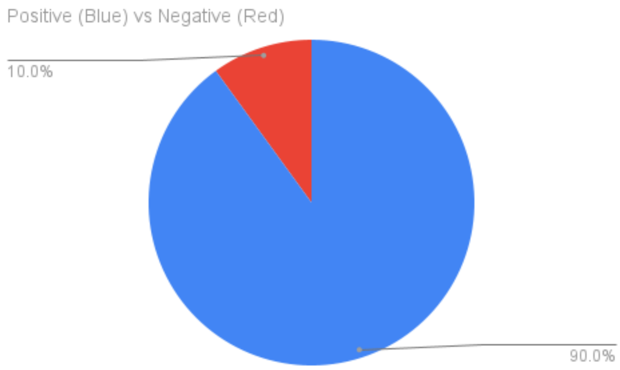


Figure 4.14: Effectiveness of understanding the plot of the book

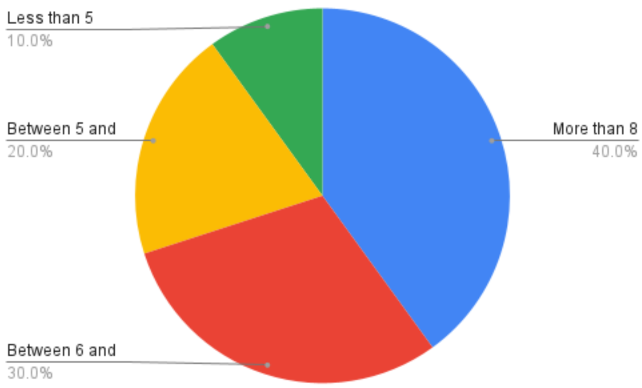


Figure 4.15: Precision of correct guessed English words

Chapter 5

Discussion

Humanoid robots are in the verge of increased popularity and are being applied in several fields such as education, industry, games, storytelling, psychology and other social fields [3, 7, 11, 22, 25, 33, 39]. The deliberate design of a robot with anthropological features contributes in improved sense of affection and relatedness from a human perspective [15]. Such design decision is crucial to the success of humanoid robots despite the very complicated hardware and software design needed to make it functional. In industry, for the majority of tasks where robots are used, anthropological features are not effective and therefore avoided [15]. For this research study, special focus was put on ways of applying humanoid robots for aiding the process of learning in classical school setting for small children.

Thorough analysis, experimentation and development was carried out to further support or deny the claim that humanoid robots can improve learning experience for young children. Designing, developing and implementing a complete behaviour activity with Pepper to interact with children is among the most valuable contribution of this research study. An overall positive attitude towards Pepper as a learning companion was observed among participating children. Our analysis show promising results supporting the theory that humanoid robots transform the traditional classroom to to be more interactive, fun and a pleasant learning experience.

5.1 A robot that helps improve language acquisition

During the time when this research study was carried out, the robot Pepper was running the latest and greatest software version provided by Softbank Robotics. The robot itself consist of a plethora of features useful for educational purposes. Natural language processing (NLP) is the one which was used to help us understand children speaking and provide with contextual answers and feedback. Per the time of writing, Pepper supported the following language for conversations: English, Japanese and French [41]. In our case, English was the primary target for carrying out conversations between the robot and participating children.

We observe that despite the significant improvements on natural language processing in general, it is still challenging for the algorithms top properly detect and process children's way of speaking and expressing. As a result, no significant improvements were found when it comes to language acquisition with Pepper (see section 4.0.3). Meanwhile, analysis on the experiment show that a total of 90% of the children were able to fully understand the plot of the book. Recruited children were however rather good at speaking and understanding English. The technique of measuring language acquisition improvements was to present some rather unfamiliar words found whilst reading the book. The number of children who reported unfamiliarity with some of the presented words from before and consequently choose the correct spelling (see fig 4.13) was rather small. We argue that the lack of significant improvements on this aspect is partially due to the short experiment time of 40 minutes. Improvements on language acquisition is a complex measure, and therefore, a significantly longer period must be reserved for the experimentation phase in order to get trustful and significant analysis. Nevertheless, we do argue that our approach could still prove beneficial when implemented in future experiments of the same kind but for longer periods.

5.2 An all knowledgeable learning companion

Essentially, the robot itself could be considered as a Wikipedia source. The software running on it is capable of accessing various encyclopedia sources on the internet by using it's network access capabilities built-in. With the proper implementation and restrictions in place, one could develop behaviours for the robot that the child could interact with for interpreting various literature sources. Ultimately, one might consider the robot as an all knowledgeable learning companion which could theoretically provide insights to various problems in seconds. Our contribution on this aspect was to provide with analysis on children's attitude on considering Pepper as a learning companion. Analysis show that children perceive Pepper as a friendly, fun and nice robot in addition to being positive on having it as a learning companion (see section 4.0.2).

Despite the positive attitudes observed from the participants, ability to effectively understand a child's request from Pepper was proving challenging. As we have mentioned before, NLP capabilities build-in on Pepper are not as mature in processing an English speaking child's language as they are for processing an average English speaking adult's language. We believe that improvements on this aspect of NLP would further strengthen our claims of humanoid robot's being a useful learning companion for small children.

Another important aspect worth mentioning is the presence of the teacher or instructor during these robot-child interaction activities. Regulations, rules and restrictions must be required when employing Robots on education setting. The presence of the teacher or instructor plays a crucial role in making sure the learning process proceeds within predefined boundaries and makes sure robot interactions are aborted in case of malfunctions. The maturity of robotic technology plays the most important role when it comes to applying such technology in education and especially with small children. Maturity of and compatibility of humanoid robots in education system is discussed in further detail on the next following section.

5.3 Compatibility and maturity of humanoid robots in education system

The education system is slowly picking up with the technology trends. In the Nordic countries, especially during COVID pandemic, schools have become almost fully digital with the help of computers, laptops, smartphones and tablets [43]. This is a good indication that skepticism around using technology to help and improve ways of learning is disappearing. We argue that deploying robots, regardless whether they are built with anthropological features or not, in schools and other educational institutions has never been easier than now. Harvesting the enthusiasm, energy and willingness of children in exploring new technologies could prove valuable and useful in the journey of making robots the next learning companion.

Despite the obvious obstacles and challenges that this application brings, we believe that the positive outcomes justify all the hard work and commitment of researchers and teachers in making it happen. The results presented in section 4 show positive enthusiasm and attitude of children towards the idea of applying robots in their everyday learning process. Furthermore, some of the participants went as far as stating that learning with the robot through speaking and interacting with the tablet would be their preferred approach if available in classroom setting. It must be stated that the positive feedback from participants could be a result of the novelty effect. Having the children exposed to cutting-edge robotic technology with a sneak peak at the potential future of education might have impaired their judgement and critical thinking.

However, although children showed positive attitude towards Pepper as a learning companion, taking into account the current state and technical constraints of humanoid robots, they (robots) are still not ready for mass implementation in education systems to supplement learning activities [44].

5.4 Practical and theoretical implications

Results and analysis of this research study indicate that there is a potential and promising future in the area of CRI. To the best of our knowledge, no other research study of this design and nature has been conducted before with the humanoid robot Pepper. Therefore, this thesis will contribute to the field with the novelty effect and hopefully inspire future researchers in conducting a more thorough experiment over a longer period of time. During the process of conducting this research, several practical and theoretical implications were discovered. Some of the limitations were discovered along the way whilst others were known from the start by the research study. Before commencing with the work on this thesis, a thorough planning phase had been conducted by the research group.

During the planning phase, the following implications and limitations were identified: the inability of transporting the robot to other locations than the research lab, which could lead in limited number of participants taking part in the experiment. This proved later on to be the case. Expert knowledge in operating and programming robots was a limited skill possessed by the main research group. Despite the very well designed application for programming the robot's behavior (Choreograph), the complex nature of operating the robot proved to be an obstacle. The design and development of the interactions and behaviours to be performed by the robot during the experiment took a significant amount of time which affected the deliverables and delay of experiment due date. It is important to mention that in several scenarios, the robot's behavior proved unpredictable contradicting the given instructions to do otherwise. Thorough consultation and training on robot design and programming must be considered next time a project of similar nature is to be carried out with promising results.

Most of the limitations and other implications were unfortunately discovered during the research phase. The limited number of participants signing up and conducting the experiments is potentially the one with the biggest impact to our results and analysis. As mentioned before, the inability to transport the robot in other facilities, with easier access to participants, did negatively impact the total number of participants. Another unforeseen issue discovered during the experimentation was the fear and anxiety observed on the participants when encountering Pepper. This limitation reduced our participant pool by 20%. Such observations are rather important and could lead towards affecting the progress and work on introducing robot technology in education.

Several questions were raised as a result of these observations. One could argue that robots could potentially act as a distraction in the classroom. Distractions could vary from fear, anxiety, perceiving the robot as a toy to play with and more. During the experiment, however, 80% of participating children perceived the robot as a learning companion and not a mere toy. On the other hand, on several occasions, the robot acted strange, was unable to respond to inquiries and often times abandoning the communication context. For our proposed design to work, supervision and controlled environment must be in place for both parties (children and the robot). A control authority is therefore crucial. Partially due to the immaturity of the technology operating the robot but also due to the infancy stage that the education system finds itself in when it comes to embracing robot technology for learning.

Chapter 6

Conclusion and Future Work

The aim of this study was to examine child-robot interaction when a humanoid robot is also included into the learning process. We conclude that the effort done during this research resulted in the effective development of a child-robot interface that engaged children aged 8 to 10 years old. The interaction consisted of two parts in which the children read a story to the robot: verbal and tablet-based. The first technique (verbal) involved reading a physical book and communicating with the robot through speech, while in the second method (tablet-based), interaction was accomplished entirely through the robot's tablet. We also believe that the two developed techniques fulfill our study objectives of evaluating the attitude, engagement, and effectiveness of utilizing a humanoid robot in the learning process. Since the robot lacks lower torso and considering the other technological constraints, all interactions consisted predominantly of speech, arm gestures and head motions.

We consider that our study provides a valuable, novel contribution to the field of Child-Robot Interaction. Furthermore, we believe that our research study can be used as a base for continuation of further exploration of child-robot engagement and further explore humanoid robots as learning companions.

Additionally, this study demonstrates that most kids aged 8 to 10 have no difficulty engaging with humanoid robots. This gives preliminary proof that humanoid robots may be integrated to learning activities seamlessly and efficiently. However, further research, both experimental and observational, is required in order to support the achieved results.

6.1 Future Work

There are several points that should be mentioned regarding future work. Although the accomplished results of this research study were satisfactory, there is still room for improvements.

Firstly, it would be interesting to test how language acquisition with Pepper robot would be in a different language. Considering that our experiment was conducted only in English, we do not have any evidence how Child-Robot Interaction with Pepper would be in other scenarios. Is Pepper capable of pronouncing words in languages other than English? Would the robot be able to understand children who speak Norwegian, for instance? This feature would give additional information on the CRI field of research.

Secondly, introducing a different robot to the participants (children) other than Pepper might result in different findings. Performing the exact same experiment with another type of humanoid robot would be an intriguing idea to examine.

Thirdly, the engagement sessions between child and robot examined in this study were rather brief and limited in duration. This implies that the interactions might have been influenced by a novelty effect, and their attitude might vary over time. In general, future long-term research with a strong emphasis on CRI is required.

Additionally, another factor to examine in the future is conducting the experiment in a real classroom setting instead of the (Virtual Reality) lab at NTNU. Despite our efforts to make this study as realistic as possible, it was not viable to involve children's actual teachers in the study due to the necessity for technical skills in managing the system. However, it is worth noting that traditional educators may guide children differently than the researchers did throughout the experiment. This has to be addressed in order to provide additional results on our findings. Teachers with no prior experience in robotics require professional training as well as time to analyze and plan learning activities that effectively utilize robots like Pepper in classrooms.

Lastly, considering that some of the participants had prior experience with humanoid robots and some had never interacted with any robot before, a comparative study between these two groups would be beneficial in shedding more light into the (Child-Robot Interaction) area. Future research could potentially do a comparative study of how children with no experience perceive the robot vs those with experience, and assess how/if their attitude changes after interacting with a humanoid robot.

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Appendix A

Consent Form

This appendix presents the consent form which the participants' parent/guardian had to sign before their child underwent the questionnaire and the experiment.

Consent Form

By signing below, you are consenting to take part in a research study 'Robot education programme 3 (ROPRO3).' Please read each part of this consent form carefully so that you understand what this project is about and how the data will be kept and processed.

The aims of the study is:

- Identify and understand Human-Robot Interaction behaviours.
- Explore children´s attitudes and engagement towards Pepper as a learning companion.

Voluntary: You may withdraw your consent to participate at any point. If you wish to stop, you may ask to leave the project at any point.

Confidentiality and Privacy: The whole process will be video recorded for analysis purpose. All data will remain confidential and anonymous. These results will only be used for the purpose of this research. The project will end on the 1st of June, 2022, and all raw data will be deleted at this point. Any personal information (name, gender and age) that may be collected, will be kept separate from the research data to ensure privacy and the same will be anonymized. Access to the collected data will only be given to researchers from the research group which consists of approximately three people. At the moment, this group consists of Dr Deepti Mishra, Dr Yavuz Inal, and Dafina Marku.

Your Rights: Consent forms will be kept separate from the research data. You have the right to request access to, deletion, correction and limitation of your personal data, as well as the right to data portability (copy of the data) and the right to send a complaint to the Data Protection Officer for the data controller or The Norwegian Data Protection Authority.

What Gives us the Right to Process Personal Information About You: We process research data based on your consent by signing below. On behalf of NTNU, the NSD - Norwegian Research Data Center AS has assessed that the processing of personal data in this project is in accordance with the privacy policy.

How to find out more: If you have any questions, concerns, or would like to find out more, please contact Deepti Mishra at deepti.mishra@ntnu.no, Yavuz Inal at yavuz.inal@ntnu.no, or Dafina Marku at dafinam@stud.ntnu.no. You may also contact NSD – Norsk senter for forskningsdata AS, by email at personvernombudet@nsd.no or by phone at +47 55 58 21 17.

By signing below, you are stating that you have read the information above and that you consent to take part in this research.

____ ______________

Signature Date

Appendix B

Pre-test Questionnaire

This appendix presents the pre-test questionnaire used for collecting participants' data during the experiment.

Pre-test questionnaire

ID: ______________________

Answer the following questions in short sentences. There is no wrong or right answer.

What do you think a robot is?	Answer:
Have you seen a robot before? If yes: - When? - Where? - How many times?	Yes/No
Have you played with a robot before? If yes: - When? - Where? - How many times? - What did you play?	Yes/No
What do you think about reading a book with a robot?	Answer:

What do you think about using a robot for learning English words?	Answer:
Can you be friends with a robot? - If yes, why? - If no, why?	Answer:

Appendix C

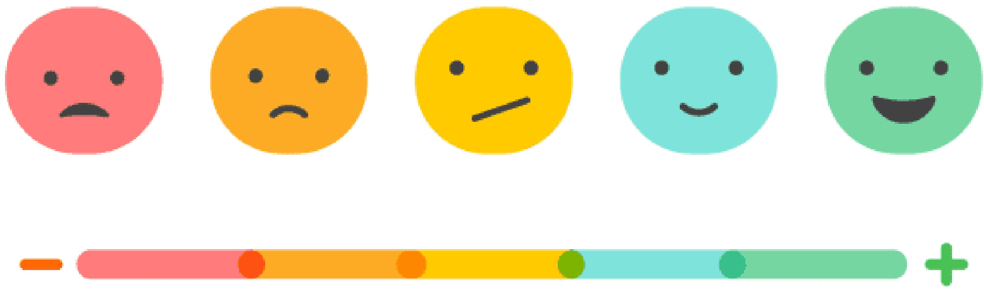
Mid-test Questionnaire 1 & 2

In this appendix you can find two mid-questionnaires used for analyzing the two different methods of child-robot interactions in our experiment.

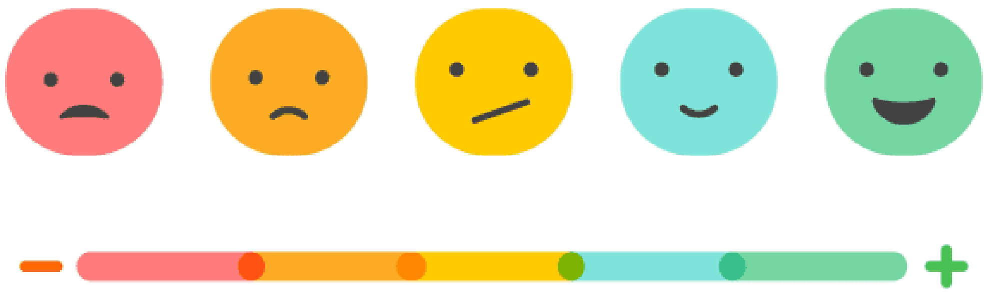
Mid-test questionnaire 1

ID: ____________________

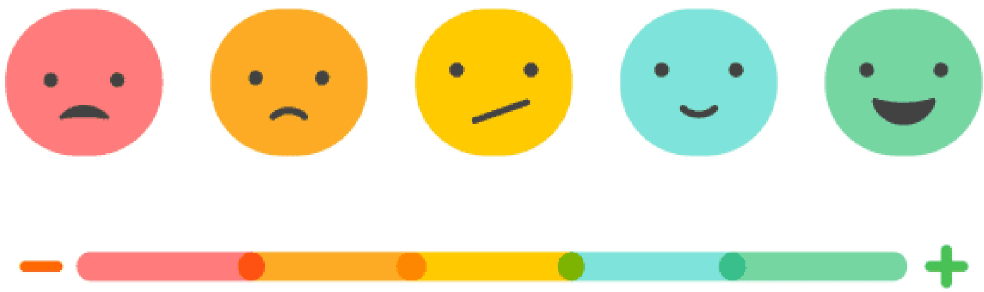
How was reading the book to Pepper?



How was interacting with Pepper through speaking?



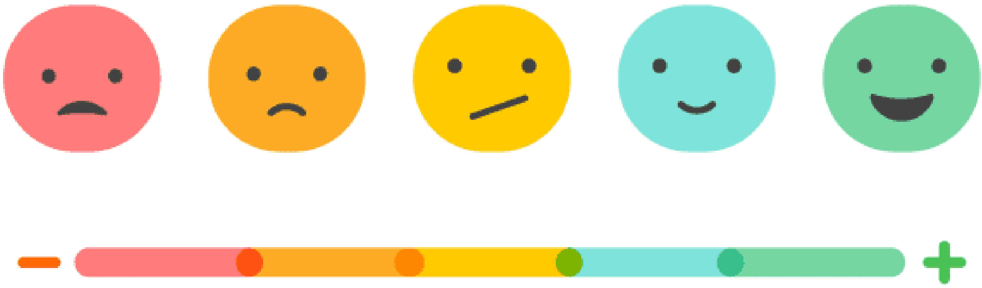
How was answering the questions through speaking to Pepper?



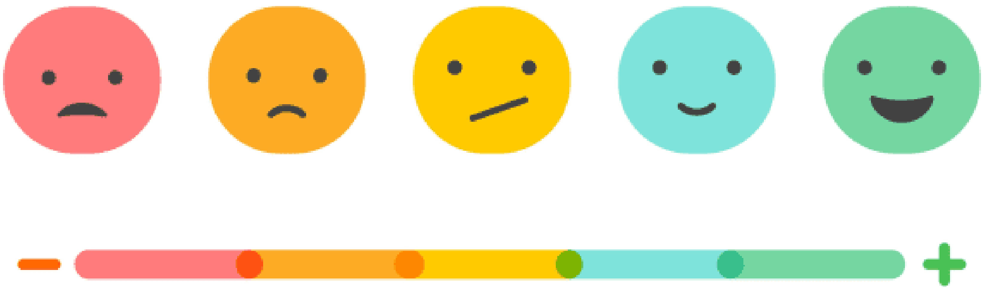
Mid-test questionnaire 2

ID: ______________________

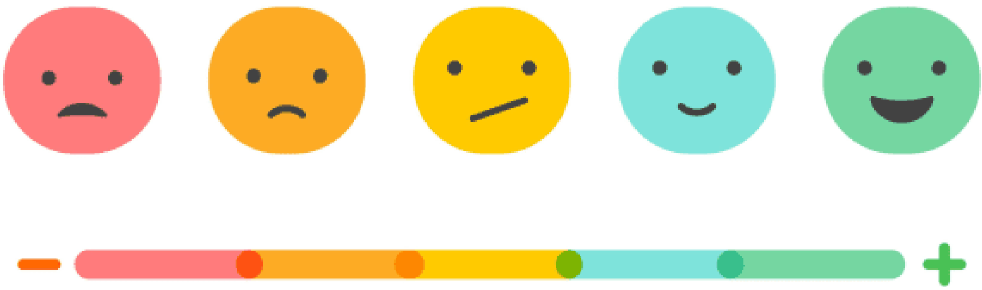
How was reading the book from Pepper’s tablet?



How was interacting with Pepper through the tablet?



How was answering the questions through Pepper’s tablet?



Appendix D

Post-test Questionnaire

This appendix contains the post-questionnaire used for data collection after the experiment.

Post-test questionnaire

ID: ______________________

Measuring learning outcome:

Answer the following questions in short sentences. There is no wrong or right answer.

What was the book about?	Answer:
What did you learn today?	Answer:
What characters do you remember from the book?	Answer:

Which words do you remember from the quiz?	Answer:
Did you enjoy learning with the robot? - If yes, why? - If no, why?	Answer:
What was the most enjoyable part of learning with the robot?	Answer:
Which part did you enjoy more, reading from the book or from the tablet? - Why?	Answer:

Circle the correct spelling of the following words:

Cloudds	**Clouds**
Comb	**Commb**
Hills	**Hils**
Journey	**Jornay**
Kyte	**Kite**
Owl	**Owel**
Sneze	**Sneeze**
Tre	**Tree**
Whisper	**Wisper**

Did you know any of these words before? Yes/No

If yes, mark the words which you didn't know before.

Measuring child – robot interaction:

In each question, circle the number that you feel describes your opinion best.

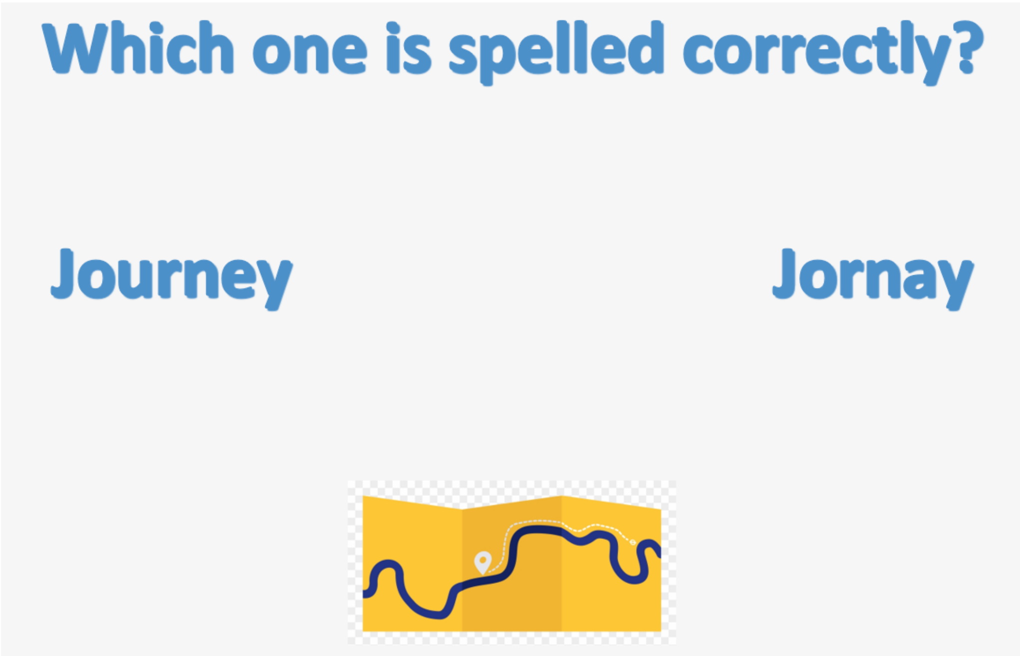
Did you enjoy reading the physical book to the robot? - If yes, why? - If no, why?	Answer:
Did you enjoy reading the book from the robot's tablet? - If yes, why? - If no, why?	Answer:
Was it easy to understand the robot when it was giving instructions through speaking? - If yes, why? - If no, why?	Answer:
Was it easy to understand the robot when it was giving instructions through the tablet? - If yes, why? - If no, why?	Answer:
Was it easy to interact with the robot through speaking? - If yes, why? - If no, why?	Answer:

Was it easy to interact with the robot through the tablet? - If yes, why? - If no, why?	Answer:
Was the robot nice while speaking? - If yes, why? - If no, why?	Answer:
Was the robot nice while being silent? - If yes, why? - If no, why?	Answer:
Could the robot understand you easily? - If yes, why? - If no, why?	Answer:
Was the robot boring while speaking? - If yes, why? - If no, why?	Answer:
Was the robot boring while being silent? - If yes, why? - If no, why?	Answer:
Did you enjoy the whole experience? - If yes, why? - If no, why?	Answer:

Appendix E

Quiz Questions

The images shown below are presented as an example of the questions included in the quiz during the experiment.


Which one is spelled correctly?
Journey
Jornay