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PRIMARY SCHOOL PUPILS PROGRAMMING ROBOTIC APPLICATIONS
Learning Experience During a Long-Term Trial

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ABSTRACT

Chia-Hsin Wu: Primary School Pupils Programming Robotic Applications - Learning Experience During a Long-Term Trial
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Social Robots refer to either autonomous or semi-autonomous robots that interact and communicate with humans within an expected set of behavioral norms (Bartneck and Forlizzi, 2004). The humanoid appearance, speech recognition, and physical movement of robots are the key factors that achieve high acceptance in primary education (Woo et al., 2021). Moreover, the programmable attributes of educational robots allow them to be tailored for a wide range of academic goals and interaction preferences.

In light of the research presented by Ahtinen and Kaipainen (2020), the thesis is a continuation study to compare and reflect pupils’ robotic learning experiences. The goal of the thesis was to study the situation of integrating Nao social robots into the regular curriculum with a different approach, which is pupils acting as both the programmer and the tester of the robotic applications.

It is collaborative research with a Finnish primary school and the company Utelias Technologies Oy (eliasrobot.com), the research activities were conducted in a voluntary robotic course in primary school with 4th to 6th grade pupils. This thesis is exploratory research that utilizes the Human-Centered Design (International Organization for Standardization [ISO], 2019) and Research through Design (Zimmerman and Forlizzi, 2014) approaches. The study focuses on the user experience and process of Robot-Assisted Learning in an authentic environment and proposes design solutions to support Child-Robot Interaction. The design solutions are presented through a high-fidelity prototype, Nao Handbook, which allows users to validate the usage and functionalities of the final product.

The two approaches of implementing educational robots (Tanaka and Kimura, 2010; Asher, 1969), ethical concerns (Graaf, 2016; Ahmad et al., 2019; Zaga et al., 2015), and considerations of persuasive design (Bertel and Rasmussen, 2013; Jacobs, 2020) have inspired the research methods throughout the phases of pre-study to prototype evaluation. The research conducted field studies that include both qualitative and quantitative data collection methods. In the pre-study, the participants included two groups of pupils aged between 10 to 13 years old (n=25).

The research found out pupils had positive robotic learning experiences and the majority perceived Nao with a peer-like robotic character. They demonstrated significant interest in the embodiment of the Nao robot and improved their technology literacy along with robotic programming activities. To support long-term RAL activities, the research proposes an assistive website prototype, Nao Handbook. The design goals include introducing robotic physical attributes to facilitate connectedness between pupils and the Nao robot, guiding robotic programming activities in a
child-friendly approach, and lastly, complementing the usage of Elias Robot by presenting animation previews on robotic movement. In the prototype evaluation, the participants included two groups of 11 to 13 years old pupils with distinct learning backgrounds (n=28). The result has shown that the prototype implementation has perceived as a valuable tool in supporting the robotic learning of the first-time user. The Nao Handbook has good navigation and comprehensible content that fulfilled the suggested criteria of Design for Children (Ludi, 1996). Furthermore, the design of the main functionalities provides the cooperative company with a constructive software advancement proposal.

In conclusion, the growing attention of STEM (Science, Technology, Engineering, and Mathematics) education and the COVID-19 pandemic have accelerated the reliance on mixed learning methods. The thesis has discovered a potential RAL approach and proven that robotic learning activities can help to advance children’s technology literacy and computational concepts (Chen et al., 2020; Govind et al., 2020). To promote Robot-Assisted Learning, a specific guideline is required to facilitate long-term implementation. Thus, the thesis presents a set of design implications for developing educational robotic software for primary school children, which expect to support the development of educational technologies and contribute to the field of Human-Robot Interaction.


The originality of this thesis has been checked using the Turnitin Originality Check service.
PREFACE

In 2018, I participated in the exchange program at Tampere University and had my first contact with social robots. I was fascinated by the potential applications and improvements robotic technology can cause in our daily life. During the time, I had the opportunity to thoroughly explore my academic interest and decided to expand my knowledge in human-centered design.

I am grateful to be able to further study a master’s degree in human-technology interaction at Tampere University. I am especially appreciative of the direct guidance from my supervisor, Dr. Aino Ahtinen, who has provided me constructive feedback and shown great belief in me throughout my studies. I would like to thank Aparajita Chowdhury, a doctoral researcher who dedicated her summer to introducing me to the Nao robot and assisted me with the usage for the entire thesis duration. Additionally, I would like to mention the teacher, parents, and pupils of the primary school who participated in the thesis. Despite the difficult situation caused by the pandemic, they have contributed a considerable part to the research and have always been friendly and supportive to me along with the research activities.

From the time I started my exchange studies to the completion of my master’s thesis, I have improved both professionally and personally. I expect to keep up the positive attitude and contribute all the acquired knowledge in my future work. Last but not least, I would like to thank my family, who has always been encouraging me to pursue my dream and motivating me no matter where I am.

Chia-Hsin Wu
Tampere, 20.03.2022
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1. Introduction

This chapter introduces the thesis topic, including the research background and motivation. The content also covers the definition of key concepts in the field of Child-Robot Interaction and research questions. Lastly, the thesis structure section presents an overview of the focuses in each chapter.

1.1. Background and Motivation

Robotic technology has been widely integrated into educational activities. The humanoid appearance, speech recognition, and physical movement of robots are the key factors that achieve high acceptance in primary education (Woo et al., 2021). Moreover, the programmable attributes of educational robots allow them to be tailored for a wide range of academic goals and interaction preferences. Depending on the use case scenario, educational robots can adapt to several roles such as teacher assistants, learning companions, or even be the instructional material (Marino et al., 2019; Ahmed, 2012; Chang et al., 2010). However, these robotic roles all share common goals of engaging children in an active learning process and constructing hands-on experiences. The implementation of robotics has great benefits allowing children to develop academic and social skills from everyday learning (Anwar et al., 2019).

The previous research presented by Ahtinen and Kaipainen (2020) studied the situation of using a 60-centimeter-tall humanoid Nao robot and build-in lessons in its software, Elias Robot, for language learning purposes in the context of primary education. The robotic learning activities were guided by teachers in group settings. The study found that integrating robotic activities in an educational environment effectively maintains pupils’ interest and excitement even at the end of the 4-month research period. Furthermore, it was observed that deploying social robots in class can initiate positive competition and collaboration between pupils. Although frequent technical problems occurred, most pupils showed exceptional patience in attempting to talk to the robot repeatedly. On the other hand, teachers experienced stronger negative feelings such as frustration and decreased enthusiasm to use the robot in teaching. Due to the capability of adapting as an inspiring role model and creating spirited learning atmospheres, the researchers concluded that the educational robots have great potential to be combined into the school curriculum. Nevertheless, having close teacher-robot collaboration and guidelines about when and how to carry out robot-assisted learning is required for long-term implementation.

In light of the above-mentioned research, this thesis is a continuation study to compare and reflect pupils’ robotic learning experiences. Under the same research context, the
thesis is collaborative research with a local primary school in Tampere and Utelias Technologies Oy (eliasrobot.com). This Finnish company develops the software, Elias Robot, to be used with the Nao robot and other robotic platforms for educational purposes. However, instead of teaching children through the built-in robotic lessons, the thesis studies the situation of integrating the Nao robot into the regular curriculum with a different approach: pupils act as both the programmer and the tester of robotic applications.

This thesis is exploratory research that utilizes the Human-Centered Design approach. The study focuses on the user requirement of integrating educational robotics in an authentic environment (International Organization for Standardization [ISO], 2019). According to ISO 9241-11:2018, User Experience refers to “User’s perceptions and responses that result from the use and/or anticipated use of a system, product or service”. By understanding both the benefits and drawbacks of this particular method of robot-assisted learning, the thesis aims to support positive user experiences by enhancing the usability knowledge of the robotic software. This goal is related to the second approach used in the thesis, Research through Design (RtD), which applies the methods of design practice and the intention of generating new knowledge into scholarly research (Zimmerman and Forlizz, 2014). Zimmerman and Forlizz further mentioned that the RtD approach contributes to Human-Centered Interaction (HCI) by reflecting on the research objectives and investigating possible practices to improve the current situation. This approach breaks the technology restriction that allows target users to evaluate the design concept. Thus, after understanding user experience in robotic learning activities, the thesis presents a prototype supporting long-term robotic education.

1.2. Definition of Related Terms

The thesis focuses on exploring the connection between robotic technology and primary education. This section provides brief definitions of the key concepts used throughout the thesis. More detailed explanations and examples are presented in chapter 2, Literature Review.

Social Robot refers to either autonomous or semi-autonomous robots interacting and communicating with humans within an expected set of behavioral norms (Bartneck and Forlizz, 2004). Goodrich and Schultz (2007) further explained: “The types of robots/machines used in assistive applications vary widely in their physical appearance, and include wheelchairs, mobile robots with manipulators, animal-like robots, and humanoids” (p.214). Robots that deliver learning experiences through social interaction with learners are defined as Educational Robots (Belpaeme et al., 2018). Educational Robots are fre-
quently used as teaching tools to support learning by facilitating the development of computational thinking and problem-solving abilities (Datteri et al., 2013). Engaging educational robots in learning contexts has the benefit of providing personalized tutoring support and enhancing the technology literacy of students from the early phase of intellectual development (Chen et al., 2020; Govind et al., 2020).

Child-Robot Interaction (CRI) and Robot-Assisted Learning (RAL) are two terms related to educational robots. According to Shahid et al. (2014), “Child–Robot Interaction is currently emerging as a research area, and researchers are motivated by the possibilities of letting children interact and collaborate with a robot in a social and intuitive way” (p.86). In this thesis, RAL is categorized in the field of CRI. Augello et al. (2020) defined RAL as adapting robotic behavior with different roles (teaching platform, assistants, companions, co-learners) to meet educational requirements and assess learning outcomes. Shamsuddin et al. (2015) further supported the idea of RAL by highlighting that robotic intervention has proved to effectively increase engagement, level of attention, and spontaneous imitation during the learning process. Persuasive design is one of the most common approaches used in RAL. IJsselsteijn et al. (2006) defined persuasive design as “A class of technologies that are intentionally designed to change a person’s attitude or behavior” (p.1). However, the research stressed that persuasion should always be a voluntary change of behavior or attitude from the user. Persuasive design strengthens its advantages by including the use of multimedia, documented information, and providing the continuous yet credible experience of the interactive system (Lakovic, 2020).

In summary, the thesis focuses on the primary school pupils' programming experience of the software, Elias Robot, and testing the lessons they programmed on the educational social robot, Nao. As the development of the Elias Robot mainly focused on the audio interaction. The cooperated company, Utelias Technology Oy, specially enabled the internal feature of including the Nao animation codes onto the robotic applications in this thesis research. This arrangement supported pupils to append robotic physical movements along with the audio interaction. As a result, a printed list of Nao animation codes was distributed to pupils for manually completing the programming tasks throughout the pre-study sessions. All the terms, Robotic Applications, mentioned in this thesis refer to the lessons pupils have programmed in Elias Robot.

1.3. Objectives and Research Questions

Research has proven social robots can act as physical therapists that help children maintain motivation in repetitive rehabilitation exercises (Pulido et al., 2017), as well as practical tools to improve the attention skills of children with cognitive impairment (Ismail et
al., 2021). In the context of special education, the robot often has a predefined social character and is used to support the individual child at a time in the training session. Although current applications have shown great potential in utilizing robotics for child support, integrating this technology into general education is not yet a common approach (Ribeiro and Lopes, 2020). The thesis addresses this research gap by conducting a field study in a voluntary robotic course of a Finnish public elementary school, including 25 pupils in 4th to 6th grade, with the age of 10 to 13 years old.

There are five major phases in the thesis process, which comprise (1) Literature review, (2) Pre-study, (3) Implementation of the website prototype, (4) Evaluation of the website prototype, and (5) Design implications for educational software. This thesis aims to study pupils’ experience and interaction process in RAL, understand pupils’ perceptions of the social robot, and propose design solutions to assist CRI. Additionally, the research aims to benefit the cooperated company and educational institution by forming a set of design implications for educational robotic software development and reporting findings on children’s learning experiences. The research questions are formulated as follows:

**RQ1. What are the processes and learning experiences of primary school pupils programming and testing robotic applications?**

**RQ2. When pupils are programming and testing robotic applications, what are the (A) social characters pupils would assign to the robot, and (B) pupils’ perspectives towards the robot and its software?**

**RQ3. How can we support the robotic programming activity with an interactive assistive tool?**

Naturalistic studies refer to the method involving qualitative data to capture the emergent ways humans interact with technologies, e.g., robots (Deng et al., 2019). Deng et al. (2019) mentioned that the study should be conducted with minimal levels to nearly no experimental control over the situation to acquire a deeper understanding of authentic usage. However, it is not a conventional method in social robotics research due to the restricted and pre-defined setting in most study cases (Bertel, 2016). Bertel (2016) further explained the “long-term” aspect of the study often refers to “serial short-term interaction” in CRI research, and the robot is not considered as a part of natural teaching practice but the situation that is occasionally dependent on the presence of the researcher. This thesis shows the novelty of the topic by studying the robotic learning experience of target
users in authentic contexts. By carrying out a series of field studies and reporting findings supported by qualitative and quantitative research, the thesis has the strength to understand the actual scenario and contribute to the field of educational robotics.

1.4. Thesis Structure
A brief structure of the thesis is presented as follows. Chapter 2, Literature Review, focuses on the theory of educational social robots, principles of persuasive design, and software design for children. This section helps formulate research questions and provides suggestions for conducting the pre-study and designing an interactive prototype. Chapter 3, Research Approach and Methodology, presents the target user and study methods used in thesis research. Additionally, the section proposes the research phases, platforms, and approaches for ensuring research ethics. Chapter 4, Pre-Study, further explains the methods and procedure of the field study. This section presents findings from both classroom research and Elias robotic programs analysis. Chapter 5, Implementation of the Assistive Prototype, Nao Handbook, discusses the design concept and main functionalities. Furthermore, the content includes the used software and current implementation limitation in prototype development. Chapter 6, Evaluation of the Assistive Prototype, Nao Handbook, presents the second user study of the thesis. The section describes the methods, procedure, and conclusions derived from the evaluation. Chapter 7, Design implications for Robotic Software Development, establishes a set of robotic software design guidelines for children as target users. This section summarizes the insights gained from chapters 2 and 6 that expects to benefit the future RAL activities. Chapter 8, Discussion and Conclusion, concludes the thesis by answering the research questions with the key findings.
2. Literature Review

The literature review chapter discusses the theory and definition of social robots, examples of social robots for educational purposes, persuasive design principles, and finally, general guidelines of educational software design for children. This chapter presents related research and seeks knowledge for deducing users’ requirements and prototype design decisions.

2.1. Social Robots

This section introduces related terms and the adaptive roles of social robots. Additionally, the content includes approaches and ethical concerns of implementing robots in the educational environment. By providing an overview of the existing studies, the section aims to understand the theory and narrow the thesis’s focus.

2.1.1. Theory and Examples of Social Robots

With the development of information technology, the robot has evolved from a programmable device that performs repetitive assemblies to adopts various social roles for carrying out independent yet optimal work that can go beyond human limitations (Lin et al., 2012). Duffy et al. (1999) defined social robots as “A physical entity embodied in a complex, dynamic, and social environment sufficiently empowered to behave in a manner conducive to its own goals and those of its community” (p.4). In the field of artificial intelligence, embodiment refers to a robot’s bodily presence, which could be embedded with sensors and motors for physically interacting with the environment (Lee et al., 2006). The application of physical embodiment appends the humanoid features into robotics, meaning the machine is given the appearance or qualities of a human, which improves the experience of human-robot collaboration by carrying out multimodal communication. Miller and Feil-Seifer’s (2018) study pointed out:

*The field of embodiment addresses the need to understand how robots effectively interact with people and the environment in which they operate... insight into robot embodiment can help robot developers be aware of the role physical interaction plays in robot behavior and how perceptions of a robot can be affected by its physical instantiation. (p.2315)*

Thus, the physical embodiment is one of the significant factors to social robot development. Robots that can express emotion through physical movements fulfill the natural human behaviors, which consist of both verbal and non-verbal communication. Furthermore, the incorporation of human characteristics results in an efficient and intuitive human-robot collaboration.
Due to the rise in popularity of Human-Robot Interaction (HRI), social robots tend to be commercially available; accordingly, different dynamics of interactions have arisen (Jones, 2017). Jones (2017) explored the integration of a social robot in the healthcare environment. The research found out the adapted reliable and predictable characteristics of social robots are suitable for maintaining a calm atmosphere by sustaining patients' sense of security. Regarding the considerable burden of workload on health care workers, robots can be used to manage medical records and provide companion care services in hospitals. On the other hand, the study of Corrales-Paredes et al. (2021) has proven that HRI plays a crucial part in the signaling process as verbal communication exchanges more specific messages, such as the description of the current location and directional information. The research placed a robot in an indoor environment asking for directions from humans. As humans start to guide the robot using verbal description, the robot simultaneously updates, creates, and improves the navigation database. The research showed the robot has the algorithm to learn enriching environmental information through HRI, which would be helpful for advanced technology development. From conveying empathy in the healthcare environment to developing navigation data through HRI, these examples demonstrate robotics technology has expanded its application into a wide range of domains with extensive usage in our daily life. Instead of being an industrial tool that is considered the substitution of labor, robots are serving as trustworthy human assistants and companions in recent years.

Robots that have engagement behaviors, including the linguistic knowledge and ability to maintain social interaction, have added values in the field of research and education (Sidner et al., 2003). Integrating social robots in learning activities has explored a novel teaching method and created a proactive study environment. The following section will introduce the application and roles of social robots in educational contexts.

2.1.2. Social Robots in Educational Context

According to Anwar et al. (2019), robotics has become an effective tool for early education since the launch of the Logo programming language in 1967. After the cooperative development of Mindstorms robots with Lego Group and the Massachusetts Institute of Technology (MIT), the deployment of educational robotics expanded to support a variety of child activities, from day-to-day learning to academic contests. The trial findings support the hypothesis that robotics can adapt multidisciplinary educational approaches and assist children’s learning from the development of formal knowledge to personal strength, namely literacy and problem-solving skills. With the growing attention to STEM (Science, Technology, Engineering, and Mathematics) education, robotics offers the opportunity to engage educators and learners in process-oriented activities. Compared to the
traditional classroom setting where students act as the knowledge receiver, the process-oriented activity enhances classroom interaction for sustaining learning interest (Jung and Won, 2018).

Several types of robots have been utilized in educational settings. One example is the screen-free toy robots equipped with motorized wheels to be used with grid fabrics for the early-stage spatial orientation development. Shumway et al. (2021) examined kindergarten students’ mathematics engagement in solving tasks with robot toys. The research verified that programmable robot toys can involve mathematics in the curriculum through dynamic and interconnected approaches. Furthermore, it is possible to assist the preschool’s pupils’ development of spatial, measurement, and number knowledge. Another study discovered toy robots can serve as a companion for children with autism (Giannopulu et al., 2016). The study adopted a plant-shaped robot that expresses non-verbal emotions through nodding when accepting speech input. The slight variance behaviors convey the sense of relatedness for raising children’s willingness to communicate. It is due to the robot serving as a miniature of humans and expressing appropriately for children with autism. The study concluded the toy robot can support cognitive verbal and emotional information processing in autism training. These examples show the potential of basic robotics supporting children learning in both educational and psychological aspects. As the physical attributes of toy robots are designed accordingly to children’s preferences, the robotic features are highly acceptable in cooperation with study programs.

**Related studies: children program robotic application for educational purposes**

With the high usage flexibility, social robots can also function as interactive tools that assist children in developing computational concepts. The section presents three related studies to the thesis topic that assign children the task of programming robotic applications for educational purposes. The study of Gordon et al. (2015) designed a programming toolkit that enables preschool children to create their own rule for teaching the robot to interact. The study included a furry animal-like robot and a toolkit that consists of tangible materials such as stickers and books that introduce programming concepts to young learners. The CRI worked as the action-sequence rule designed by children can trigger the robot to conduct actions with a particular hand gesture. For instance, the robot will smile and greet when the user performs a thumbs-down gesture. The research concluded that intuitive interaction allows children to grasp the concepts of generating robotic rules and advance programming knowledge. The child-friendly social robot and its toolkit inspired a novel social scenario by presenting an engaging role-play learning experience to preschoolers.
Considering the in-demand skills of computer science, the study of Benotti et al. (2016) presented an educative software that allows pre-literate children to learn programming a robotic kit using the language of C++ and Python. The hardware is a 3-wheel programmable toy robot controlled by the educative software, UNC++Duino, an extended version of the software developed by Google, BlocklyDuino, that allows users to design the robotic movement by adding the instructional blocks. The educative software UNC++Duino was evaluated in the context of kindergarten and primary school children learning the fundamental programming structure and applying the knowledge to create a personalized robotic program. The study concluded that the intuitive robot programming platform and the simple “drag and drop” interaction method allow children to understand the concept of computer science in an engaging environment. Furthermore, the educative software can integrate the programming learning activities into the regular school curriculum from other disciplines such as astronomy and physics.

On the other hand, the research of Kanda et al. (2012) facilitated the learner-centered and collaborative learning approach with a novel teaching method. The study included a humanoid social robot as a teaching assistant to instruct 6th graders on basic knowledge of using the Lego Mindstorms and implementing the understanding to build a toy robot that can accomplish the mission by knocking down flags as obstacles. The humanoid robot was programmed to encourage children to stay up on their robotic learning tasks by praising the performance and suggesting positive competition between peers. The study found out that the limited capability of responding to questions from the robot can accelerate self-learning and problem-solving skills. Additionally, the robotic social behavior has associated itself with the role of a facilitator, which is highly acceptable in the educational contexts and beneficial to promote long-term CRI.

These studies demonstrate the various approaches and advantages of including robotic learning activities in general education. Compared to the teacher-centered method where the knowledge is instructed in a lecture-based teaching style, robotic education combines the learner-centered and collaborative learning concepts that enable children to develop a strong sense of self-motivation (Kanda et al., 2012). The examples mentioned above share the same concept of the thesis by leading children in robotic programming activities. However, the thesis focuses on the humanoid social robot that initiates other kinds of educational experiences, which is elaborated in the next section.

**Humanoid social robot for educational purposes**

The humanoid social robot is a more complex form of the educational robot, it endows with interactive abilities to perform advanced Human-robot communication. The human-
like appearance differentiates the robotic role from the conception of a toy to a companion. The study of Émond et al. (2020) compared children’s preference toward social robots with different appearances. The study involved two desktop-sized tele-operable robots, Jibo and Nao. Jibo has a 360-degree base, body, and head rotations as well as a touchscreen that is used as the main interface, whereas Nao is a humanoid robot that resembles human behaviors and supports co-speech gesture mimicry. The research ran workshops with pupils under age 13 and their parents to understand the first impression and general interests toward social robots. The research data presented that 58% of children and 65% of parents favored the humanoid type. Although there is no significant difference in preference data, the nonidentical robotic specialties led to distinct reasons. For instance, the web smart Jibo can initiate comparative open conversation while the humanoid Nao is advantageous in promoting engagement value. This study shows the reason behind the achievement of positive impressions humanoid robot retrieved and its potential for subject-specific learning purposes.

Pepper is another example of a humanoid robot. It is a life-size robot that communicates through the output of both audio and screen displays. Venture et al. (2017) analyzed intuitive CRI by giving children total freedom to interact with a dance guide robot in a free-time activity. The study observed that children had a mix of blushful and curious behaviors while spontaneously exploring the robot. This study strengthens the hypothesis that humanoid robots obtain positive impressions among children and novelty effects that encourage long-term CRI. Besides its appealing appearance, another study presenting humanoid robots is feasible to be used in combination with educational methodologies. The research of Castellano et al. (2021) programmed the Pepper robot to be a serious game interface for building up children’s awareness about waste recycling. The implementation of interactive games on robotics results in natural turn-taking between peers. Not to mention the robotic program includes waste material-related images that allow children to easily acquire new knowledge and perceive efficacy in the concept of sustainability. The research drew promising possibilities in promoting necessary skills to children with the help of social robots. It is due to the perception of trustworthiness robots have gained facilitates high-level concentration from children during learning activities.

These examples show the capability of humanoid social robots in educational contexts and the attribute that differentiates them from other robot types. From taking the role of entertainer during free-time activities to combining serious game approaches for teaching the concept of waste recycling, humanoid robots are prevalent tools that can effectively raise learning motivation and start building computational thinking from early education.
With the growing popularity of social robots, some approaches have been utilized to support robotic implementation in the learning environment.

**Approaches for utilizing educational social robots: Care-Receiving Robot and Total-Physical Response**

Two approaches stand out in robotics education to maximize the outcome of integrating social robots into the school curriculum. The first approach was presented by Tanaka and Kimura (2010) for an ethically safer and broader social acceptance of robotic usage in childhood education. This approach is called Care-Receiving Robot (CRR), meaning the children are responsible for instructing a specific skill to the robot, which is programmed to show gradual improvement along the way. Compared to the Childcare-robot approach, where the robot has the role of a caregiver to children. CRR aims to enhance the chance of indirect practice and accelerate natural learning motivation by endowing children the role of a caretaker (Figure 1). Gargot et al. (2021) deployed CRR in the severe dysgraphia treatment for children by asking them to conduct a writing demonstration. The co-writer setup includes a computer tablet and software to automatically extract children’s handwriting and generate a worse one for the robot. Meanwhile, the researchers programmed the robot to pretend to write on the tablet by moving its arms. The CRR provides the child with a learning partner for improving concentration and re-examining his handwriting. After 20 continuous weeks of therapy sessions, the research found out the child’s learning motivation has restored, avoidance behaviors disappeared in all kinds of activities, and most importantly, the handwriting quality and posture have dramatically improved. The research proved the “Learning by Teaching” method is ideal due to its contribution to the reinforcement of children’s self-esteem and enhancement of spontaneous learning.

![Diagram of Childcare-robot and Care-receiving robot approaches](image-url)

**Figure 1.** The comparison of (a) Childcare-robot and (b) Care-receiving robot approaches (Tanaka and Kimura, 2010).

The second approach was proposed by Asher (1969) for Robot-Assisted Language Learning (RALL). The Total Physical Response (TPR) approach improves linguistic recogni-
tion and promotes stress-free learning by associating vocabularies with coordinated physical movements (Figure 2). TPR expects to increase children’s information retention and intention of participation by engaging them in amusing learning scenarios that execute physical activity along with the command of foreign utterances. Nguyen et al. (2020) compared children’s learning progress of studying with two different approaches, TPR and GTM (Grammar-Translation Method), which focuses on memorizing grammatic rules and the translated meaning between foreign and native languages. The quantitative pre-test/post-test measurement has proven TPR is much sufficient in improving vocabulary retention. It further aroused more active attitudes and recognition of the used method from the participant. Additionally, the research discovered TPR could achieve better RALL results with two other teaching methods, group implementation and full curriculum integration. In this instance, the application of TPR is advantageous for advancing both academic (reading, listening, speaking, and writing) and cognitive (concentration and memory) skills.

![Figure 2](image)

**Figure 2.** The scenario of the Total Physical Response approach (Asher, 1969).

These two approaches provide a concrete idea of integrating educational social robots through practical implementations. Giving the instructor role to children and including interactive physical activities during the learning process can result in greater accomplishment and enhance academic performance. These approaches also inspired the method of conducting this thesis research. The first CRR approach is associated with the children’s role as a programmer and a tester of the Nao robotic program. While carrying out the programming tasks, children are responsible for “teaching” the robot to instruct a certain knowledge. It aims to build up their motivation and explore a different type of CRI. The second TPR approach relates to the children’s task of including animation codes in the robotic applications to initiate gesture-speech integration from the Nao robot. It is to elevate children’s interest in the social robot by creating appealing learning experiences. As children are the primary users in the robotic interaction, having interactive methods for engaging children in the coursework is relatively important.

**Ethical concerns of educational social robot**

Although applying robotics into the primary education curriculum does seem like a beneficial practice, several ethical issues need to be considered. According to Tolksdorf et
al. (2020), children are one of the vulnerable user groups that tend to follow robots’ suggestions strictly. Therefore, reinforcement about the research limitations and guidelines are required. As stated by de Graaf (2016), “The interactions between humans and computer technologies are increasingly complex and humanlike, increasing the importance of the role psychological aspects of our relationships with those technologies take on” (p.590). By sharing the same physical environment and having advanced social interactions with the robot, it is possible to impact the children’s cognitive attributes, emotional attachment, and perception about social roles.

Ahmad et al. (2019) investigated whether the emotion adaptive robot can influence children’s social engagement and language learning. The research presented an “emotion and memory” model that enabled the robot to recognize and adapt to the child’s developed emotion in vocabulary learning sessions—the robot proceeded by giving positive feedback when the child answered correctly and vice versa. The research revealed a higher duration of eye contact, and active verbal responses were obtained from children when the robot responded optimistically. It concluded that the robot’s supportive behaviors greatly impact children’s performance and confidence. The result brought to light the importance of selecting justifiable emotions for educational robots and the negative effect it might cause. Zaga et al. (2015) carried out another research to determine the impact different robotic social characteristics may cause on children’s task engagement. The research designed two kinds of social robot characters, peer-like and tutor-like, to act as a companion of children for completing puzzle tasks. The peer-like robot has a high-pitched voice, emphatic speech style, and stays in a seated position. Whereas the tutor-like robot has a low-pitched voice, interrogative speech style and remains in a standing position. The study assigned 5 pairs of children in each condition and found out the peer-like robot groups were able to complete tasks faster and result in less error. Moreover, researchers observed the peer-like character triggered children's optimal focus of attention and a higher frequency of physical contact with the robot. The study addressed the importance of introducing an appropriate robotic social role in CRI. Depending on different user groups, having suitable robotic settings will significantly affect children’s cognitive engagement, attention level, and the tendency to be involved in long-term interaction.

These ethical aspects about including social robots in early childhood learning form general guidance for conducting user study and prototype design of the thesis. As stated in the previous sections, there are several scenarios where children would envision a robot as a supportive companion due to its advanced social features. In this situation, children tend to demonstrate a higher level of confidence and empathy while encountering prob-
lems during robot interaction. To maintain positive robotic learning experiences, providing immediate assistance and guidance upon request would be ideal to avoid unnecessary interruption. It is because children should be the target user, and authentic behaviors should be observed for analysis. Education involving persuasive attempts is a common approach to create engaging contexts and raise learning motivations. The next section will introduce persuasive design and its application in the robotic learning environment.

2.2. Persuasive Design
Fogg (2003) defined “Persuasive technology is interactive computing systems that designed to change people’s attitudes and behaviors” (p.1). Early implementations of persuasive design focused on promoting the concept of a healthy lifestyle to adults. Considering from another perspective, the concept of promoting behavior change is constantly used in or viewed as teaching activities. With the growing role of the internet, persuasive design reaches its best performance in the digital form and thus widely spreads its application from the field of commerce to formal education. The reasons why digital presentation stands out from traditional media and human persuaders are its interactivity, persistency, and the broad-scale of data processing (Fogg, 2003).

However, Jacobs (2020) raised attention to the ethical concerns about the use of persuasive design. The research mentioned a rational persuasive design should exclude any possible scenario of coercion and manipulation. In the behavior change process, coercion refers to the deprivation of choice caused by irresistible force or treats, while manipulation indicates the hidden influence on a person’s decision-making. Considering the importance of maintaining a person’s autonomy, the research of Jacobs (2020) concluded three criteria of persuasive technology: (1) A persuasive technology may never block or burden users’ options (2) A persuasive technology must make its users aware of the persuasion tools by notifying the fact of being intentionally persuaded, and (3) A persuasive technology must persuade users in alignment with their personal goals. For instance, a persuasive mobile application to encourage a healthy lifestyle should share a common intention with its users. During the usage, users are obligated to be informed about options other than the suggested one and able to stop the service anytime without consequences. Most importantly, users are expected to have a constant awareness of all the given notifications and awards are related to the application of persuasion.

Regarding the abovementioned criteria of implementing a rational persuasive design, Schutz (1981) mentioned the persuasive computer program indeed causes a fundamental effect in children’s education. For instance, in the situation where children learn through interacting with social robots, the learning activity becomes active, self-directed, and most importantly, contains recognizable personal purposes. By contrast, motivation and
improvement are limited when children are provided with traditional in-class teaching or even popular educational television programs. It is because children stay in the role of information receivers instead of spontaneous learners. Motivation contributes a crucial part to the field of education. The strategies persuasive design uses in setting bright learning intentions include rewarding, self-monitoring, personalization, social facilitation, trustworthiness, etc. (Murillo-Muñoz et al., 2021). The persuasive design opens the opportunity for users to establish a personal goal and thrive through the learning process with the assistance of social robotics. Social robots are social actors designed to conduct persuasive interventions in educational contexts (Bertel and Rasmussen, 2013). Bertel and Rasmussen (2013) narrowed down the persuasive potential of social robots in five principles:

**Attractiveness:** Visual attractive technologies tend to be more persuasive.

**Similarity:** Technologies embedded with similar attributes to humans are more persuaded.

**Praise:** Technologies expressing positive feedback through words, images, symbols, or sounds during interaction would increase persuasiveness.

**Reciprocity:** Applying the idea of reciprocity in technologies can trigger human feelings of obligation in returning the favor.

**Authority:** Technologies with authorized social roles are assumed to be more persuasive.

The humanoid robot used in this thesis research, Nao, fulfilled the principles of serving as a persuasive social robot. The amiable appearance has proven to achieve the image of reliability among children and parents. The human-like physical movement and touch sensors further encourage natural physical interaction from children. Besides the physical characteristics, the use of the Nao robot works in combination with its software, Elias Robot, which stores several language learning courses. During the robotic learning process, Nao usually serves as an instructor or learning companion by directing the progress. The software will then praise the user’s performance by rating pronunciation accuracy and rewarding the learning persistency with amusing movements. The persuasive design has had promising results in education, the next section will introduce the essential factors, specific requirements, and expectations to consider when designing educational software for children.
2.3. Design for Children
The previous sections have covered the topic regarding educational social robots and persuasive design approaches. However, approaches to design vary by the behavior segmentation and cognitive processes of target audiences. For instance, the same user interface may appear intuitive and visually appealing for adults but have a high tendency to confuse children. Likewise, in the context where the learning platform switches from textbook to software, the design theories of outlining the learning contents move along. To answer RQ3 by finding the method to support robotic programming activity with an interactive assistive tool, this section focuses on the requirement and suggestions for designing educational applications for primary school pupils. From the learner-centered design perspective, highly interactive technology-based learning allows children to involve in a wide range of roles, i.e., users, testers, informants, and design partners (Goolnik et al., 2006). Hence, instead of merely relying on observation results to understand the shortcomings of the current system, it is beneficial to include children as design partners to gain genuine insights.

Ludi’s (1996) study focuses on gathering children’s comments to design educational software. He further summarized three major considerations: (1) The difference between challenge and difficulty, (2) The balance between game and exercises/instruction, and (3) Use of multimedia elements. The first consideration suggests the educational program should be challenging enough to absorb new knowledge yet not too difficult to maintain users’ confidence and learning desire. The second consideration focuses on developing an educational program with a proper degree of gamification elements to create a favorable user experience while acquiring new knowledge. Lastly, the third consideration stresses the importance of including multimedia elements (graphics, audios, animation, texts) into the educational program to enhance the attractiveness and interaction possibilities. However, appending a reasonable number of attached files is crucial for avoiding slow loading to delay the user flow. The study carried out by Stålberg et al. (2016) invited children as co-designers to develop an interactive application that facilitates participation in healthcare situations. The study involved children throughout the research to create preferred graphic and animations designs for the application. Additionally, the prototype was iterated evaluated by children for adjusting the difficulty of given tasks and improving the overall usability. During the cooperation process, children regarded it as a positive experience to work along with the design project as their opinions were highly valued. The evaluation result found that the given tasks in the interactive application can be easier understood by children when the interface adopts familiar graphics. Moreover, it is essential to include
an ordinary size ratio to identify the scene without hesitation. For instance, having a different size for the adult and child character and distinctive elements for the clinic and waiting room design.

This section summarized fundamental principles and a related research example of designing for children as the target audience. Additionally, it provided inspiration and guidelines on the design implementation, which is an assistive website prototype named Nao Handbook, serving as an instructional tool for robotic learning. Regarding all the considerations mentioned above, the thesis involved children in the prototype implementation process for presenting preferable and practical design solutions.

2.4. Summary

All the related research presented in this chapter has drawn an understanding of humanoid social robots and provided suggestions for conducting user research and prototype design. In reference to the existing validated theories and design principles, the thesis presents research findings and viable solutions to support long-term CRI.

The first section, Social Robots, started with the background introduction includes the definition explanation and the functionality of the robotic physical embodiment. Having a thorough knowledge about what makes a robot social has created a solid foundation for the thesis research. The section further narrowed down into the field of educational social robots by presenting the trial launch of robotics in the educational context and finally leading to the domain of humanoid social robots. To comprehend related approaches of integrating social robots into the authentic learning environment, the content introduces two approaches of Care-Receiving Robot and Total-Physical Response. These two approaches support the user research process and study result of this thesis work. Finally, the section concluded with ethical concerns about the use of social robots, which include introducing the robot with a friendly image, i.e., peer-like social character, providing positive feedback, and sufficient assistance. These findings contribute to the research activities, including conducting pre-study and designing an interactive prototype for keeping up children’s confidence along the process of robot interaction.

The second section, Persuasive Design, presented the development process of persuasive technology and its connection with teaching activities. Additionally, the section highlighted the ethical use of persuasive design. The Nao robot fulfills three criteria of persuasive design by presenting a wide range of interactive and programming options on its user interface that allows users to create lessons in alignment with their personal learning goals. As the target users of the Nao robot are schoolchildren in this thesis, the Elias Robot software can be improved by communicating the fact of being persuaded in a more
intelligible matter to avoid confusion. The section summarized the characteristic of the Nao robot by matching up its features with the presented persuasive robot principles. Moreover, it outlined the capability of the Nao robot and the reason of selection for the thesis work.

The third section, Design for Children, emphasized the considerations in designing for different focus groups. It inspired retrieving suggestions from children to ideate the prototype design. Based on the analyzed user study result, the thesis proposes a website prototype that serves as an assistive tool for pupils’ robotic learning. The main functions of the prototype include the introduction of the robot’s physical attributes, guidance on programming the robotic software, and finally, the preview of the robot’s animated movement. The detailed information regarding prototype design and limitations is further elaborated in chapter 5, Implementation of the Assistive Prototype, Nao Handbook.

In summary, all the acquired insights from the related literature have contributed to the research methodology (Table 1). For instance, considering ethical aspects and the use of persuasive technology throughout the phase of pre-study and involving children in the procedure of prototype design. The next chapter presents the user study approaches and major research phases of the thesis. Additionally, it covers the strategy of following research ethics and protecting data security.

Table 1. Implications for further research phases.

<table>
<thead>
<tr>
<th>Research Implications from Literature Review</th>
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<tr>
<td><strong>Pre-study</strong></td>
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<td>• <strong>Care-Receiving Robot</strong></td>
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<td>Pupils’ role as the programmer and the tester of robotic applications (Tanaka and Kimura, 2010).</td>
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<tr>
<td>• <strong>Total-Physical Response</strong></td>
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<td>Pupils’ given task of appending Nao animation code onto the robotic applications (Aster, 1969).</td>
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<tr>
<td>• <strong>Ethical Concerns</strong></td>
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<tr>
<td>Investigate which robotic social role pupils would assign to the Nao robot in the natural CRI (Zaga et al., 2015).</td>
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<tr>
<td>Provide assistance upon request during CRI to maintain pupils’ autonomy and positive RAL experiences.</td>
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<tr>
<td>• <strong>Persuasive Design</strong></td>
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<tr>
<td>Examine whether the software, Elias Robot fulfill the criteria of persuasive design (Jacobs, 2020) and the Nao robot comply with the principles of serving as a persuasive social robots (Bertel and Rasmussen, 2013)</td>
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<tr>
<td><strong>Prototype Implementation</strong></td>
</tr>
<tr>
<td>• <strong>Persuasive Design</strong></td>
</tr>
<tr>
<td>Implement prototype design following the three criteria of persuasive design (Jacobs, 2020)</td>
</tr>
<tr>
<td>• <strong>Design for Children</strong></td>
</tr>
<tr>
<td>In reference to the considerations of educational software design (Ludi, 1998) and involve pupils’ in the ideation process of prototype implementation (Stålberg et al., 2016)</td>
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3. Research Approach and Methodology

This chapter discusses the research approaches and data collection methods used in the thesis. The content also involves major phases and the relevant objectives throughout the research process. And lastly, the chapter introduces the research platforms, target users, and strategies to ensure research ethics.

3.1. Research Process and Phases

There are five major phases in the thesis process. Figure 3 displays the phases of the thesis and corresponding outcomes; further descriptions of the tasks are presented below:

![Figure 3. Research phases of the thesis.](image)

**Phase 1: Literature review**

The first phase of the literature review studied all the scientific research related to the thesis topic. The content includes the theory and examples of educational social robots, the persuasive design used in the children-robot interaction, and consideration of software design for children. This phase presented the thesis framework and formulated the research questions. Most importantly, a set of research implications was acquired and contributed to the methodology used in phases 2 and 3, namely Pre-study and Implementation of the assistive prototype.

**Phase 2: Pre-study**

The second phase of the pre-study conducted user research in the field study. The pre-study gathered data from both qualitative and quantitative approaches following the guideline of research ethics. The phrase aimed to understand the authentic use scenario of the educational robot and its software for conceiving practical design solutions.

**Phase 3: Implementation of the assistive prototype**
The third phase of prototype implementation presented an assistive website, Nao Handbook, that contains an introduction of the Nao robot, the preview of the robot’s animated movement, and step-by-step guides on programming the software, Elias Robot. All the design solutions included in the prototype are based on the analyzed results from the pre-study. The interactive technique includes haptic input, visual and audio output. The website prototype was designed by using Adobe XD and Illustrator.

**Phase 4: Evaluation of the assistive prototype**

The fourth phase conducted prototype evaluation with pupils in a Finnish primary school. The goal of the evaluation section is to validate the usability of the prototype and obtain feedback for assessing users’ acceptance. Additionally, the prototype evaluation focused on pupils’ learning experience with the assistance of the website prototype. The collected result helped to examine whether the design solutions can support robotic learning activities.

**Phase 5: Design implications for educational robotic software**

The last phase proposed a set of design implications for educational software. After reflecting on findings gathered throughout phases 1 to 4, the thesis generated some recommended guidelines to consider while designing educational robotic software for primary school children. It expects to benefit the cooperated company by reporting findings in a constructive matter as a software advancement proposal.

### 3.2. Research Approaches and Data Collection Methods

The thesis contains two research approaches. The first one is Human-Centered Design. According to ISO 9241-210:2019, Human-Centered Design is an approach of system design and development that improves usability by focusing on the users, requirements, and expectations. To improve the robotic learning experience and propose a feasible RAL approach for primary education, the thesis obtained a thorough understanding of elementary school pupils' experience of programming and testing robotic applications. The focus of the research includes pupils’ learning process, user experience, pupils’ perception toward the social robot. The Human-Centered Design approach was carried out as a field study across the phases of the pre-study to the evaluation of the assistive prototype. The second approach is Research through Design (RtD). Zimmerman and Forlizzi (2014) explained RtD as an approach that carries out the scientific study with the employment of methods, practices, and processes of design practice. However, compared to design practice, the RtD approach has systematic ways of interpreting and reinterpreting the understanding of the world and requires detailed documentation of the rationale for actions taken during the design process (Zimmerman and Forlizzi, 2014). Utilizing the RtD approach in HCI allows researchers to actively reflect on research goals during the design
process for constructing viable methods for the current situation. Additionally, the RtD approach is an effective tool to communicate the design concept with target users and receive realistic feedback for improvement. After analyzing the result obtained from the pre-study, the thesis utilized the RtD approach in the phase of the assistive prototype implementation. The thesis presents a website prototype, Nao Handbook, to provide a complete guide supporting primary school pupils programming the robotic applications. The Nao Handbook was evaluated by two groups of primary school pupils, one group with experience interacting with the Nao robot and conducting programming tasks on the Elias Robot while the other group without, to compare and validate the usability of the prototype. The detailed description of data collection methods used in pre-study and interactive prototype evaluation are listed and explained below:

1. **Observations of pupil’s robotic activities**

   There were two observation phases conducted along with the classroom activities in this research. The first phase included 6 observation sessions for 1.5 hours from September to October 2021. The observations were carried out with an observation form (Appendix D), which focused on pupils’ learning process of robot-assisted learning. It aimed to acknowledge the advantages and disadvantages of CRI for finding design solutions to support pupils’ robotic activities. The second phase was carried out 2 sessions of 45 minutes prototype evaluation in December 2021. The observation findings were noted down in a blank sheet. The main goal was to examine the usability and ensure the user interface design meets all the considerations mentioned in section 2.3, Design for Children.

2. **Semi-structured group interviews with pupils**

   Carrying out along with the observation method in the phrases of pre-study and prototype evaluation. The research conducted semi-structured group interviews (Appendix E) with pupils with the assistance of the responsible teacher. In the pre-study, the group interviews aimed to understand pupils’ learning experience and perception of the robot. In prototype evaluation, the group interviews (Appendix H) expected to gain insights from pupils about the usability and improvement areas of the prototype. This type of research tends to be exploratory, meaning the interviews mainly include open-ended questions to encourage insightful comments from pupils and validate the usability of the prototype.

3. **Paper questionnaire for pupils**

   In the last section of pre-study and prototype evaluation, the research activities ended by inviting pupils to fill out a short paper questionnaire. Two different versions of the anonymous questionnaire were implemented in each phrase. For the pre-study, the questionnaire (Appendix F) consists of a revised 5-point Likert scale, Self-Assessment Manikin
(SAM) (Bradley and Lang, 1994), 1 multiple choice question to know the perceived robotic role, and 3 open-ended questions to note down the encountered problem and course arrangement suggestions. However, the incomplete responses showed the SAM scale and open-ended questions are too complicated for pupils. Therefore, the analyzed result only included the completed questionnaire responses, and the questionnaire for prototype evaluation (Appendix I) has changed to two questions asking the usability of the prototype and overall learning experience with a 3-point Likert scale.

4. Reflective expert talks with the teacher
The expert interview is a qualitative method to better understand a specific field by investigating implicit dimensions of knowledge from the experienced interviewees (Doeringer., 2021). The reflective expert talks method adapted the concept of the expert interview by discussing with the responsible teacher about the classroom research findings at the end of every pre-study session. The main difference to the expert interview is that the reflective expert talks did not include a set of pre-defined interview questions but focused on exploring current challenges in RAL and the possible design solutions. It is considered a brainstorming process that inspired the design of the interactive prototype.

5. Robotic programs analysis
After each pre-study session, the robotic programs, i.e., robotic applications and the Elias Robot software, were analysed by the researcher to comprehend pupils’ learning progress. It aimed to focus on the learnability aspect of the Elias Robot. The analysis examined the content of robotic applications created by pupils as well as presented the usability of the Elias Robot. It is to understand the reason of problems that occurred during CRI, including the pupils’ programming mistakes and the intended usage of the Elias Robot.

3.3. Data Analysis Methods
As presented above, both qualitative and quantitative data were collected in the thesis research. However, the qualitative data was comparatively more dominant among the research process. In the pre-study, the qualitative data obtained from observations, group interviews, open-ended questions in the paper questionnaire, and reflective expert talks were noted and analyzed by affinity diagram technique. The affinity diagram technique is used to externalize and organize a large amount of raw data from field studies (Lucero, 2015). The thesis arranges the notes of affinity diagram into 7 sections that record teacher’s tasks, student’s tasks, observation notes, situation, student’s and teacher’s point of view, conclusion, and lastly, prototype design direction. The method of organizing notes helped to assort and compare findings obtained from each pre-study session and further ideate the feasible design solution to conduct prototype design. In the prototype evaluation, the qualitative data obtained from observations and group interviews were
directly organized and rephrased in a written report to communicate research progress to
the thesis supervisor. The written report helped to assort the collected data and assist the
researcher in presenting research findings in this thesis.

Lastly, in both pre-study and prototype evaluation, the quantitative data collected by Lik-
ert scales in the paper questionnaire were analyzed using the software of Microsoft Excel.
The collected data were calculated and presented by the mean and standard deviation
values. Although naturalistic studies tend to rely on the qualitative data collection method,
the quantitative data retrieved in the thesis supports the qualitative research findings and
further examines pupils’ affective experiences through statistical analysis.

3.4. Research Platform
The research platforms of this thesis include the Nao robot and its programmable lan-
guage learning software, Elias Robot (Figure 4). The Nao robot is an intelligent humanoid
robot with customizable functions developed by Aldebaran robotics. It is equipped with
25 motors and 14 touch sensors to deliver physical interaction. To carry out audio inter-
action, the 4 microphones, 2 loudspeakers, and 2 video cameras embedded in the robot
can be used for sound locating, facial and speech recognition (Haggerty and Thapa, 2014).
The 60-centimeter-tall Nao robot has an aesthetically pleasing human-like appearance
and appropriate size to attract children’s attention and intention of interaction.

Figure 4. The language learning robot, Nao (Source: softbankrobot-
ics.com/emea/en/nao), and its programmable software, Elias Robot (Source:
Utélia Technologies, eliasrobot.com).

The artificial intelligence-based language learning software, Elias Robot, is developed by
the cooperative company of this thesis, Utélia technologies (eliasrobot.com). The Elias
Robot has a voice-based user interface to be used with the Nao robot. The content of the
software includes numerous ready-made language courses designed by experienced teachers for different skill levels. It supports the learning of more than 20 languages and provides instant positive feedback by points and robotic movements to enhance engagement during the process. On top of the build-in courses, the Elias Robot allows users to create customized learning materials that increase the flexibility to introduce robotic technology into daily learning (Figure 5). The personalized feature of the lesson enables the user to include a video link, practice phrases with repeat and remember exercises, and create a dialogue to chat with the robot. The intuitive interface of the Elias Robot and the aesthetically pleasing appearance of Nao has an excellent advantage for children’s entertainment and education, which are also the reason for research platform selection for the thesis. Additionally, the Elias Robot enables users to append physical robotic movements in their robotic applications by manually typing the Nao animation codes (Figure 6). Currently, more than 500 animation codes are arranged in a list that introduces the usage and different categories of the movement. The printed list of Nao animation codes is distributed to pupils to be used in the programming task on Elias Robot.

Figure 5. The Lesson Editor in the Elias Robot (Source: Utelias Technologies, eliasrobot.com).

<table>
<thead>
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<th>Animation</th>
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<th>Tags</th>
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<td>animations/Stand/BodyTalk/BodyTalk_10</td>
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Figure 6. The list of Nao animation codes (http://doc.aldebaran.com/2-1/naoqi/audio/animatedspeech_advanced.html).
3.5. Target Users and Research Ethics

For the pre-study, the thesis was conducted in total 6 sessions of 1.5 hours weekly user study for 3-month, starting from September to November 2021 at a Finnish primary school. Two groups of pupils participated, including 4\textsuperscript{th} graders and 5\textsuperscript{th} to 6\textsuperscript{th} graders, the number of students in each group was 4 and 21, with the age of 10 to 13 years old. For the interactive prototype evaluation, the thesis carried out 2 sessions of 45 mins evaluation with the target users. The participants include the same group of 5 to 6\textsuperscript{th} graders who participated in the pre-study and a new group of 6\textsuperscript{th} graders, the numbers of students in each group were both 14, with the age of 11 to 13 years old. During the course, the whole class was divided into small groups of 2 to 5 pupils. All the research activities involved primary school pupils were proceeded in the classroom under the supervision of the responsible teacher.

Research permission from the city of Tampere was obtained before the start of the study. To ensure research ethics, one online information sheet (Appendix A) and one informed consent form (Appendix B) were provided to and filled by the parents before starting the research. A shorter version of the information sheet was also provided to pupils (Appendix C). Parents were required to communicate with pupils about the research contents and discuss their willingness to participate. Only the pupils who agreed to participate and provided the signed informed consent form are included in the study. All the information sheets and consent forms of this study were written by the researcher in English and translated by the thesis supervisor before sending them out to parents. During the research process, all the participants have the right to withdraw from the study and ask to exclude collected study results without providing any reason. Withdrawing from the study will not cause any consequences. The consent form used to collect pupils’ names only served for recording the willingness to participate. This identification information was not connected to any recorded data in the classroom research sessions. The result did not publish details of any single pupil but presented the findings obtained from the whole group. All the research activities involving primary school pupils were neither video nor audio recorded. The collected data from this thesis research were stored in the servers of Tampere University. All the data will be deleted once the research is published. Lastly, all the pictures included in this thesis do not include pupils’ faces or any identifiable information.
4. Pre-Study

The pre-study chapter describes the data collection methods and participants, the overall research procedure, and major findings. The pre-study contributes to acknowledging the current situation and challenges of integrating robotic applications into primary education, which helps to generate ideas for creating an interactive prototype to assist learning.

4.1. Methodology

The pre-study was conducted as a field study. It followed the Human-centred approach to gather both qualitative and quantitative data from observations, semi-structured group interviews, questionnaires, and reflective expert talks with the responsible teacher. In the section of observations and group interviews, handwritten notes were collected. No audio or video was recorded for data gathering to maintain a stressless learning environment for pupils.

The observations were conducted with an observation form (Appendix D) along with the classroom activities. The observed data consists of pupils’ interaction process with the robot, emotional reaction robot evokes in pupils, unexpected issues that occurred during the CRI, and finally, the possible improvement methods for the situation. The semi-structured group interviews (Appendix E) focused on pupils’ learning experience of each pre-study session, the questions include: What do you think about the robot? What robotic feature do you prefer? What kind of task do you perform for the robotic interaction? A paper questionnaire (Appendix F) was used to obtain more detailed insights from pupils. The questionnaire adopted the Self Assessment Manikin (SAM) scale (Bradley and Lang, 1994) and modified the graphical character with the image of the Nao robot (Figure 7). It aimed to present an attractive emotional assessment scale to children that show distinct differences in each option. The questionnaire also contains one multiple-choice question asking the social role pupil perceived from the robot. Additionally, three open-ended questions were included inquiring about the preference to learn with the robot, challenges encountered during the classroom activity, and possible suggestions to improve the robot and its software. Finally, the reflective expert talks with the teacher were carried out at the end of the class to wrap up the research activity and discuss the arrangement for the next pre-study session.
4.2. Procedure

The thesis was carried out in total 6 pre-study sessions at a Finnish primary school. The two-group participants included 4 pupils from 4th grade and 21 pupils from 5th to 6th grade, with the age of 10 to 13 years old. Each group of participants had one pre-study session every two weeks, and the distribution consisted of 2 sessions with 4th graders and 4 sessions with 5th to 6th graders. Each session took place in a voluntary robotic course for 1.5 hours from September to October 2021.

In the first 10 minutes of every class, the responsible teacher gave a short introduction about the use of the Elias Robot and announced the task to pupils. After the introduction, the pupils were asked to set up the Nao robot and laptops for the programming task, which took about 5 minutes. The class continued with the 60 minutes free CRI section. For the 5th to 6th graders who had earlier robotic learning experiences, the class proceeded with
the free group formation among pupils to program robotic applications on the Elias Robot software and tested them on the Nao robot. The 4th graders who did not have robotic learning experiences were encouraged to try out incorporated functions on the Nao robot in the first class and instructed to create some basic programs following the examples provided from 5th to 6th graders in the second class. During the CRI, pupils had sufficient time to explore the Nao robot and its software without restraint. The responsible teacher was in class to provide support upon request to minimize interruption of pupils’ learning process and observe the authentic behaviors. The last 15 minutes were reserved for the rounded-off section in class. It started by asking pupils to shut down the laptops and Nao robot and return to class for the semi-structured group interviews. The group interviews were held with the help of the teacher in translating questions from researchers and answers from pupils in between Finnish and English. At the last pre-study session in both classes of 4th and 5th to 6th graders, the paper questionnaire was distributed. The reflective expert talks with the teacher were carried out for 10 minutes every time after the whole teaching section. Lastly, each pre-study session ended with the researcher checking through the robotic applications created by pupils on the Elias Robot and organizing all the received data into an affinity diagram (Appendix G) and excel document. All the methods of analyzing collected research data have been described in the third section of chapter 3, Data Analysis Methods.

4.3. Findings

This section summarizes the findings retrieved from both classroom research and robotic program analysis. The methods used in classroom research include observations, group interviews with pupils, questionnaires, and reflective expert talks with the teacher. To seek inspiration for designing the interactive prototype, the researcher of the thesis further analysed robotic programs to understand pupils’ learning progress and usability of Elias Robot.

4.3.1. Findings from Classroom Research

This section summarizes the classroom research findings into three parts: the pupils’ interests and perspectives towards the Nao robot and its software, pupils’ interaction, and perceived characters of the Nao robot.

**Interests and perspectives towards the Nao robot and its software**

Most pupils showed great interest and positive feelings towards the Nao robot. The voluntary robotic course where this thesis research was carried out has the goal of exploring pupils’ interests and trying different learning methods. Therefore, the in-class atmosphere was relatively relaxed and enthusiastic. Pupils indicated the main reason for participating in this course is to have complete freedom interact with the robot and complete their own
robotic program. Starting from the second pre-study session with 5th to 6th graders, the printed version of the Nao animation codes was distributed to pupils for appending robotic movements in the robotic program. The observations found that pupils showed greater concentration on the programming tasks after distributing the list of Nao animation codes. Additionally, they were attracted by the robotic animated movements and thus were encouraged to include animation codes for distinct interaction. As physical interaction was introduced, the level of optimism in learning increased among pupils.

At the end of the course, 21 pupils reaffirmed their high intention to learn with robots in the paper questionnaire. The result from the 5-point SAM scale shows pupils’ affective experiences for three emotion elements of valence, arousal, and dominance. The mean value and standard deviation value of the SAM emotion elements are displayed in Table 2 and Figure 8. The valence emotion element (-2 = unhappy, 0 = neutral, 2 = happy) was reported positively (M = 1.19, SD = 0.74). It supports the observed situation that pupils had pleasant learning experiences throughout the process. The arousal emotion element (-2 = calm, 0 = neutral, 2 = excited) was rated mediocre (M = 0.09, SD = 1.09). It shows that pupils had mostly regular and occasionally a small degree of excitement during CRI. The last dominance emotion element (-2 = controlled, 0 = neutral, 2 = in control) indicates pupils had minor control over the robotic interaction (M = 0.76, SD = 0.83). For the open questions, the answers include, “I like to study with the robot because it’s different”, “I like it. It’s fun. Although it doesn’t understand everything from me at first”, and “I like it because the program can be coded”. The questionnaire responses show having assistance in maintaining an exciting learning atmosphere and providing instructions in programming robotic applications would be beneficial in solving the current problems of CRI and support pupils’ interest in programming.

Table 2. The mean value and standard deviation value of the SAM scale.

<table>
<thead>
<tr>
<th>SAM Emotion Elements</th>
<th>Mean</th>
<th>Std.Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valence Unhappy(-2) / Happy(2)</td>
<td>1.19</td>
<td>0.74</td>
</tr>
<tr>
<td>Arousal Calm(-2) / Excited(2)</td>
<td>0.09</td>
<td>1.09</td>
</tr>
<tr>
<td>Dominance Controlled(-2) / In Control(2)</td>
<td>0.76</td>
<td>0.83</td>
</tr>
</tbody>
</table>
In addition to the SAM scale, the paper questionnaire includes three open-ended questions asking the challenges pupils had encountered, suggestions for improvement, and advice for a different course arrangement to interact with the Nao robot and its software. For the first question concerning challenges pupils had during the robotic activities, pupils addressed the technical problem (speech recognition and connection issues) of the Nao robot and the difficulties in programming the robotic application on Elias Robot. The responses include, “I don’t really understand the system, my program did not work”, “Using the lesson editor is challenging because it is not very clear”, and “It is difficult to find the right photo and animations. Sometimes there are bugs, and the robot does not listen to me”. For the second question asking suggested improvement methods for the Nao robot and Elias Robot, most pupils agreed to simplify the usage of the Elias Robot by including more detailed usage instructions and the design of the graphical user interface. The responses include, “Having an easier list for the animations” and “The Elias Robot could include instruction and more pictures”. One pupil mentioned the disadvantage of the Nao robot by suggesting, “The robot can get better at listening to the speech”. Although the Elias Robot has room for improvement on its usability, one pupil mentioned the learnability by commenting, “I eventually learned how to edit”. Finally, for the last question seeking advice on the arrangement of the robotic class, pupils highlighted the possibility of integrating the robot into language learning. The responses include, “We could use it in English class” and “It could be fun to use the robot for practicing new language”. Besides the usage for academic learning, other comments such as, “I wish to bring my own robot to class” and “I just want to use the Nao robot more” indicated pupils have positive perspectives towards the robot and expect more robotic interaction in class.
However, the number of responses from the questionnaire was limited. It implies that the SAM scale and open-ended questions may be too difficult for pupils to answer through written texts. There were 21 completed responses of the SAM scale out of 24 participants, and more than half of responses from open-ended questions were returned as, “I don’t know” or “I have no suggestion now, but Elias can be improved”. The situation raised the importance of altering the data collection according to the target users’ ability to obtain insightful feedback and target users’ requirements and expectations.

Interaction with the Nao robot
Although technical problems such as the connection issue and the poor speech recognition frequently occurred during CRI, pupils demonstrated considerable patience in conducting repeated attempts or awaiting assistance from the teacher. The general interaction with the robot was proactive with the procedure of pupils mainly focusing on programming their robotic programs and testing a small part of the program on Nao occasionally to reassure the functionality. According to the testing results, pupils thus continued their programming tasks by creating new elements or revising errors. It was observed that pupils were attracted by the embodiment of Nao. The fact that pupils responded positively to the robotic movement had created an encouraging and entertaining learning atmosphere. The robotic behaviors such as appealing appearance and rewarding movements formed a straightforward and natural interaction. For instance, pupils attempted to have eye contact with the robot expecting to catch its attention and improve speech recognition. Furthermore, frequent physical contact such as handshakes and imitation of robotic movement also transpired during CRI.

Characters of the Nao robot
The collected data from the multiple-choice question of the paper questionnaire shows the majority perceived the robot as their classmate (14 participants), which can be considered a learning companion as pupils mentioned the robot is suitable for language courses. Pupils had pleasant experiences with the state-of-the-art robotic teaching arrangement and described the robot as “a friend” and “a nice guy”. Few pupils indicated that the robot acted as their teacher or teacher assistant (7 participants). However, the robotic social character as a teacher was recognized mainly by younger pupils from the 4th grade who did not perform that many programming activities. In addition to the data from the questionnaire, the observations found out that the novel way of interacting with Nao has associated the robot with the image as a technical tool, which is not related to any humanoid social character. It is due to the pupils focusing on programming the robotic application instead of learning from the robot itself. The perception of the robot as a tool was discovered by both the responsible teacher and the researcher. For instance,
pupils have shown great confidence and concentration in programming robotic applications and interacted with the physical Nao robot mainly for the purposes of testing the programmed functions. In other words, instead of following the well-known pattern of CRI where pupils focus on interacting with or learning from social robots. The fact that children consider the robot as a technical tool is a positive sign. It implies that the technology literacy of primary school pupils has significantly advanced within a short time, in which they are able to develop a novel relationship with the robot. The improvement allows them to carry out robotic learning tasks with distinct perspectives and interaction methods.

In conclusion, the characters of the social robot discovered in the pre-study can be arranged into two categories. The first category includes the humanoid character of a classmate and a teacher, while the second category represents the non-humanoid character of a technical tool. The result discovered the various interactions pupils have had during CRI.

4.3.2. Findings from Robotic Programs Analysis

This section presents the pre-study findings from two perspectives, including the content analysis of robotic applications created by pupils and the usability evaluation of the Elias Robot. The summarized results aim to cover all the concerning aspects discovered from the authentic usage of target users. Additionally, these findings have contributed to the development of design solutions for improving the robotic learning experience.

Analysis of the content of robotic applications

While programming in the Elias Robot, pupils were asked to create a course that acted as a folder to comprise several personalized lessons. The teacher has instructed pupils to add the title “TUNI” with the number of their grade level in front of the course name they defined, for instance, “TUNI4_coursename”, which allows the researcher easily to distinguish between several robotic applications during analysis. The robotic applications refer to the lessons pupils programmed in their created course. The content of robotic applications pupils created mainly consists of their previous knowledge across the field of language and history. The complete lesson program includes a template that consists of learning sections: “Introduction”, “Watch”, “Quiz”, “Repeat”, “Remember”, and “Chat”. The robotic applications show that most of the pupils were able to program quiz questions, accepted answers, and the robot’s feedback for creating a complete lesson. Related pictures and video links were also appended in the lesson to increase general attractiveness (Figure 9). Furthermore, pupils demonstrated the knowledge of deleting, duplicating, and relocating learning sections in their preferred arrangement.
Figure 9. The example of robotic application programmed by pupils in the pre-study (Source: Utelias Technologies, eliasrobot.com).

Although the function of creating lessons is quite complete, the function of appending Nao animation codes has not been developed in the current Elias Robot. In other words, pupils can only view the associated movement while testing robotic applications on the physical Nao robot. However, a printed list of Nao animation codes was distributed to manually type into the robotic application to enhance physical interaction. The example of a complete code to initiate robotic movement looks as “^run(animations/Stand/Emotions/Positive/Happy_1)”. The code starts with a circumflex mark and “run” as the command of the movement. The main control keys for calling the movement are separated by forward slash marks and placed in a bracket with a specific order. Except for the word
“animations” in the control keys, others should begin with a capital letter. The analysis of robotic applications shows the Nao animation codes may be too complicated for pupils to type as numerous typographical errors and incomplete codes were discovered. Moreover, the robotic movements are split into two categories of standing and sitting. To activate the standing type of animation, the robot should remain standing before being switched on and vice versa. The function of automatically switching between the standing and sitting robotic movements has not been established. Nevertheless, this programming rule was not clearly explained in the list of Nao animation codes. For instance, the instruction about the right section to place the codes in the robotic applications. Hence, pupils were confused that the robot did not respond accordingly when all the codes were appropriately appended. Furthermore, as pupils had no idea how the physical robot will react to the animation codes, some subtle animated movements were accidentally ignored and were considered as programming errors in robotic applications.

Even though the situation was slightly hectic while programming the robotic applications, pupils received full support from the teacher throughout their learning process. Several sessions of whole-class activity were carried out to test the robotic application created by different groups of pupils. Pupils were fascinated by the content created by their classmates and the various types of robotic movements. The increase of motivation and confidence in programming from pupils were observed.

**Analysis of the usability of the software, Elias Robot**

Elias Robot is a language learning application for different voice-enabled devices, e.g., smartphones, tablets, and laptops. It enables users to learn through the platform with or without the physical robot. The editing function of the software is intended for teachers as the target users and can be used on different robotic platforms. This section presents an overview of the usability of the software Elias Robot. Firstly, the Elias Robot will guide the user to connect with the physical robot after logging in. As stated, as the software can be used in combination with different robots, users will be prompted to select the robot type on the connection page (Figure 10).
Secondly, the Lesson Editor will appear after users successfully connect with the physical robot (Figure 11). However, if the users only intend to use the software for creating the lesson, the “Create” button can directly lead the users to the Lesson Editor by skipping the connection steps (Figure 12).

Thirdly, users can either continue to edit the lesson they created earlier or create a new lesson once accessing the Lesson Editor. Figure 13 presents the template of the lesson for editing by teachers.
In summary, the Elias Robot is a learning application that can be used either separately or in combination with the physical robot. The lesson editor function of the robot was developed for the use of teachers in personalizing the course content. The students were expected to use the software by anonymous login with a specific classroom code provided by their teacher. In other words, the arrangement of this research has assigned the student the tasks as a teacher in programming the robotic applications. Additionally, since the development of the Elias Robot focuses on speech interaction, including a function to append the Nao animation code on the robotic applications is not the main focus. However, the company, Utelias Technology Oy, has considered expanding this function in their future work. Most importantly, this section reports the version of the Elias Robot used at the time of the thesis research. The Utelias Technology Oy has continued working on creating functionalities and the advancement of the Elias Robot software.

4.4. Summary

In summary, pupils had positive experiences throughout the process of programming robotic applications and interacting with the Nao robot. Even though some obstacles appeared during the CRI, pupils’ interest and patience towards the robotic activities remained high. The result was supported by both the qualitative data (observations, group interviews, open-ended questionnaires’ questions) and quantitative data (SAM scale). The perceived robotic characters from pupils included a classmate, a teacher, and a technical tool. It implies that pupils felt close with the robot, found the robot applicable in tutoring, and most importantly, their technology literacy has considerably enhanced to
naturally establish a new approach of robot interaction. The new approach of robot interaction refers to pupils concentrating on their given programming task and interacting with the physical Nao robot for the purpose of testing the programmed functions. The discovery is a novel type of CRI, in which pupils actively contribute their knowledge in robot interaction instead of learning directly from the robot.

From the robotic programs analysis, the remarkable programming progress from pupils has been acknowledged as well as the usability problems of the current Elias Robot. According to the concluded findings, the thesis presents an assistive website prototype, Nao Handbook, to support pupils’ interest in programming. The main functions include introducing the physical attributes of the Nao robot, providing guidance on using the Elias Robot, and previewing animated robotic movements. The next chapter explains the design concept and functionalities of the prototype.
5. Implementation of the Assistive Prototype, Nao Handbook

This chapter introduces the design goals of the assistive website prototype and design decision in relation to the ethical concerns and approaches of utilizing educational social robots mentioned in chapter 2, Literature Review, and the classroom study result from chapter 4, Pre-Study. This chapter further provides a thorough overview of the functionality of the prototype and the current limitation of implementation.

5.1. Prototype Design and Description

The results obtained from the pre-study provided inspiration and ideation for designing a website prototype to assist robotic learning activities. It was observed that pupils delivered impressive programming progress during their self-exploration of the Nao robot and the Elias Robot. Considering the development of the Elias Robot was intended for the use of education professionals and several questions pupils have had related to the programming tasks, the thesis proposes an assistive website prototype that benefits robotic education by addressing the frequent problems that occur during CRI. The design rationale of the website prototype is to encourage the long-term utilization of educational social robots by introducing thorough robotic interaction guidance in a child-friendly approach. The method of designing instructional material for RAL has been implemented in related research. For example, the research of Hong et al. (2016) proposed a Robot-Assisted Language Learning framework (RALL) including multimedia resources that allows the teacher to program the language course based on the content of authorized textbooks. However, since the platform of programming lessons for robotic learning has been created, the researcher of the thesis designs an external assistive tool that provides a comprehensive guide to promote the learner-centered approach in CRI.

High-fidelity prototypes have an authentic look to the final product due to its detailed attributes; they are intended to test the information design, visual design, and interaction design with end-users for receiving direct feedback (Arnowitz et al., 2007). Following the recommendation of involving children in the design process from section 2.3, Design for Children, a high-fidelity prototype allows pupils to experience how the final product will operate and inform recommendations about the improvement (Rudd et al., 1996). The thesis presents a high-fidelity assistive website prototype, Nao Handbook, introducing the physical attributes of the Nao robot, providing step-by-step guides on programming the Elias Robot, and previewing robotic movements with associated animation codes. To avoid copyright issues, all the images’ materials were created by the researcher using the software of Adobe Illustrator and exported for the development of the website prototype in the software of Adobe XD. The design goals of the implementation of the website prototype are presented below,
1. Facilitate connectedness between pupils and the Nao robot by introducing robotic physical attributes.

2. Create smooth robotic learning experiences by guiding programming steps on the Elias Robot.

3. Support the creation of robotic movements on the Elias Robot by presenting animation previews with the associated codes.

The ethical concerns and two approaches to utilizing educational social robots, Care-Receiving Robot (CRR) (Tanaka and Kimura, 2010) and Total-Physical Response (TPR) (Asher, 1969), presented in section 2.1.2, Social Robots in Educational Context, have impacted the design decision. In reference to the ethical concerns of integrating social robots in educational contexts, the website prototype introduces the background of the Nao robot in an encouraging and positive manner. The Nao Handbook acts as an assistive tool that presents the robot with a friendly image and instructs pupils along with their programming activities. It is to maintain pupils’ self-confidence and long-term learning motivation.

The CRR approach (Tanaka and Kimura, 2010), which gives children the role of a caregiver matches the studied situation where pupils act as both the programmer and tester of the Nao robotic program. While pupils were conducting their programming tasks, the similarity here is pointed out as pupils attempting to “teach” the robot a certain knowledge. Therefore, the Nao Handbook supports the CRR approach by presenting guidelines and procedures for programming robotic applications. Finally, the TPR approach (Asher, 1969), which enhances children’s engagement by including physical interaction in the robotic learning activities conforms with the pupils’ task of appending animation codes in the program. Hence, the Nao Handbook strengthens the TPR approach and supplements the current Elias Robot by showing the video previews of robotic movement with its animation code. The next chapter will introduce the functionalities of the Nao Handbook in support of related figures.

5.2. Functionalities

There are three main functions in the assistive website prototype, Nao Handbook, including “Meet Nao”, “Tutorial”, and “Animation”. All the functions are connected to the main home page, which allows users to navigate around the content. The Nao Handbook aims to attract pupils’ visual attention by choosing the cool color scheme (green, blue, purple) that relates to the thesis topic about computer sciences. The main page contains playful yet not overcomplicated images that present the robotic programming activities (Figure
14). It also includes a short description of the objective of the prototype and the name of the cooperated institutions on the left side. Every clickable button provides the hotspots hints by changing the color when placing the cursor to optimize the website navigation. Additionally, all the web pages have an “NAO” button on the upper right corner that acts as a shortcut to the main page (Figure 15). The rest of the section is divided into three parts for a detailed introduction to the main functions.

**Figure 14.** The main page of the website prototype, Nao Handbook.

**Figure 15.** The “NAO” shortcut button to the main page (the Meet Nao function).

**Function 1: Meet Nao**
To facilitate connectedness between pupils and robots, the first function of “Meet Nao” presents the basic information of the robot (Figure 16). The information includes height, weight, gender, family, and area of expertise. Furthermore, there are embedded audio files on every webpage for carrying out self-introduction and showcasing the sound effects of power switches with the authentic voice of Nao. It is to present the robot with a peer-like image that has been widely perceived and preferred by pupils.
Figure 16. The first function of the prototype, Meet Nao.

The function has three subsections that further present the robotic physical attributes in the area of head, body, and limb (Figure 17). Each webpage contains basic transition animation when users navigate between each subsection. It is to create a high engagement value of pupils and foster curiosity about Nao while freely exploring the content. Every subsection is presented in a dictionary format that includes the title, a list of equipped hardware, and audio and written descriptions about the corresponding functionalities. The subsections aim to lay the foundation of robotic interaction by providing a basic user guide for physical HRI in an organized manner. For instance, the description of functionality in the Head subsection includes “My eyes and ears are equipped with LEDs, they will shine colors when listening to you”, and the description in the Body subsection contains “By long pressing the power button, you can wake me up or send me to sleep”.

Figure 17. The three subsections in the Meet Nao function, (a) Head, (b) Body, and (c) Limb.

**Function 2: Tutorial**

Considering the errors pupils have made while programming robotic applications on the Elias Robot, the second function of “Tutorial” provides thorough instruction for supporting pupils' programming tasks (Figure 18). The function describes the programming steps in sequence with three subsections, including “Login and Connection”, “Create Lessons”, and “Program Lessons”. Each subsection consists of 5 to 11 steps demonstrating the procedure of performing programming tasks on the Elias Robot with related screenshots and written explanations. The purpose of including both pictorial and written instructions is
to minimize the uncertainty of the learning content by developing comprehensive examples. For example, the written and pictorial instructions (the robot’s image and screenshot of Elias Robot) complement each other by forming complete guidance in acquiring the IP address from the physical robot in the subsection of “Login and Connection” (Figure 19).

Figure 18. The second function of the prototype, Tutorial.

Figure 19. A thorough guide from both written and pictorial instructions.

The webpage has a clear interface by marking the tutorial steps in numbers and including indicators that allow pupils forward to the next steps or subsection at their own pace (Figure 20). Taking the programming problems pupils encountered in pre-study into account, the tutorial function focuses on explaining the method of connecting with the physical robot, the tips of programming robotic applications, and most importantly, the correct place to type the Nao animation codes. The tutorial function expects to serve as a Nao programming manual that demonstrates the programming tasks in an understandable way. Moreover, the function arranges the programming procedure in an organized manner that aims to provide an example for educators in planning the teaching demonstration and assist pupils in their regular programming practices.
**Function 3: Animation**

The third function of “Animation” presents the preview of Nao animated movement with the corresponding codes (Figure 21). The function includes a simple instruction on using the list of the Nao animation codes and the effect of the keyword used to launch animations in a pop-up window (Figure 22). For instance, the “^start” keyword will initiate robotic movement simultaneously with the audio response from the robot. The function aims to compensate for the lack of animation preview function and guidance on the usage of animation codes in the current Elias Robot.
The function divided the animation into two subsections of “Sit” and “Stand” according to the robotic position. Each subsection consists of movements from 8 categories: “Waiting”, “Reaction”, “Gesture”, “BodyTalk_Speaking”, “BodyTalk_Thinking”, “Emotion_Positive”, “Emotion_Neutral”, and “BodyTalk_Listening/Emotion_Negative” (Figure 23). Among all the common categories, the last group of codes is the particular case where they substitute each other by only the robotic sitting position has the code in “BodyTalk_Listening” but not “Emotion_Negative” and vice versa. After clicking on the button displaying a related picture and the name of its category, the short video of the robotic animation and the corresponding code is represented in a pop-up window. Users can view another animation video or go back to the category selection page through the navigation bar on the pop-up browser (Figure 24). Each video lasts around 3 to 5 seconds and will be played in a loop if users remain on the same page. The videos were edited to remove the background noise and change the brightness and contrast adjustment for presenting the most authentic audio effect and favourable visual presentation.
5.3. Implementation Limitations

Some restrictions occurred during the process of the prototype implementation. In the phase of prototype ideation, another direction came along as designing a pop-up avatar instructing the usage of the Elias Robot and developing an additional feature of previewing robotic animations and append the codes on the current software (Figure 25). The main concept is to present the user guide directly on the same interface that has achieved the sense of familiarity from users. However, implementing this design direction requires development cooperation from the company, Utelias Technologies Oy. It would require a longer time to agree on the software design and development. Additionally, since the Elias Robot can be used on other robotic platforms, building function merely around the Nao robot is not considered as an ideal solution. Therefore, considering the limited time for prototype design and evaluation, the thesis thus focuses on designing an external website prototype alone by the researcher.

Figure 25. The design direction of creating a pop-up avatar and the function of appending animation codes on the Elias Robot.

Although the assistive website prototype, Nao Handbook, can present more information than the abovementioned method of implementing pop-up avatar, it also has encountered challenges and limitations during its usage. Firstly, it requires the solitary user to constantly switch between two browsers (Elias Robot and Nao Handbook) during their programming tasks for following the instructions. Therefore, having the group work by opening Elias Robot on one laptop and Nao Handbook on the other would be a better use case scenario. In this learning setup, pupils would have full access to the content of both web pages and improve their collaboration and problem-solving skills by working in teams. Secondly, due to the limitation about the size of attached files on the software, Adobe XD, the website prototype cannot append a video with a length of above 5 seconds. Consequently, the number of the enclosed files was limited, and subtle animations were mainly created by the transition effect between different web pages. The situation restrained the delivery of various interactive features on the prototype. Thirdly, the fact that the Nao animation list has more than 500 robotic movements causes the difficulty of recording and presenting all the animation videos. Hence, the prototype only presents one
animation from each category of two robotic positions, which is in total 16 videos of robotic movement. The situation allows the prototype to provide a brief overview of the Nao animation and its usage but not a completed categorized database to support long-term robotic programming activities. Lastly, the Adobe XD software restricted users to copy the text in the design from a shared prototype link. The situation makes it impossible for pupils to duplicate the animation codes onto their robotic applications but remains in the method of manually typing. However, the condition can be improved by distributing the link to the online version of the Nao animation list while carrying out programming tasks in class.

5.4. Summary

In conclusion, this chapter introduces the implementation of the assistive website prototype, Nao Handbook. The content addresses the design rationale related to the ethical concerns and approaches of integrating educational social robots in the school curriculum introduced in chapter 2, Literature Review. For instance, the Meet Nao function supports the mentioned ethical concerns by introducing the Nao robot with the preferred peer-like social character, while the Tutorial and Animation functions support the CRR and TPR approaches with comprehensible instruction. The chapter further presents the major functions of the Nao Handbook in detail with the support of the corresponding screenshot and listed design goals. Furthermore, the content consists of a discussion about the current limitation in prototype implementation, including the reasoning on the selection of final design direction and corresponding solutions. The next chapter will continue with the evaluation of the assistive website prototype, Nao Handbook, with target users in the same research environment as the pre-study.

Prototype link: https://xd.adobe.com/view/c26608e6-2e71-4530-ad61-bf0874a35cd5-9735/?fullscreen&hints=off

This chapter introduces the participants and research procedure of evaluating the assistive website prototype, Nao Handbook. The content discusses the rationale behind the adjustment of the data collection method compared to the pre-study. The main goal of the prototype evaluation is to validate the functionalities and assess whether the design meets the requirements and expectations of target users.

6.1. Methodology

Following the RtD approach (Zimmerman and Forlizzi, 2014), the thesis conducted the assistive website prototype evaluation with pupils from the same primary school where the pre-study was organized. In reference to the user study methods used in the pre-study, the prototype evaluation includes both qualitative and quantitative data from observations, semi-structured group interviews, and questionnaires. Likewise, the data was collected by hand-writing notes to maintain a natural environment for pupils.

The observations were conducted along with the evaluation and noted down by the researcher on a blank sheet at the end of the session. The observed data includes the pupil’s interaction process and the overall usability of the prototype. The semi-structured group interviews (Appendix H) aimed to understand the user experience and support the findings from observations. The interview questions include: Does the prototype have an understandable tutorial about programming robotic applications in the Elias Robot? Does the prototype have a clear user interface for you to navigate around? Does the prototype have an attractive graphic design? The incomplete questionnaire responses from the pre-study indicated the open-ended questions might be too difficult for pupils to answer. The evaluation adopted a new questionnaire containing two questions with a 3-point Likert scale asking the prototype's usability and pupils’ learning experience (Appendix I). The participants include the same group of 5th to 6th graders who participated in the pre-study and the other group of 6th graders where only 1 pupil had robotic learning experiences. The purpose of having two groups of pupils with different backgrounds is to assess whether the prototype design is widely accepted by the target users and validate all the functionalities can be easily comprehended by the first-time user. In other words, the prototype expects to serve as an intuitive assistive tool that supports the path of robotic programming and interaction without any prerequisite from users. All the methodologies implemented in the prototype evaluation were conducted to answer RQ3. The next section will present the procedure of the prototype evaluation.

6.2. Procedure

The thesis was conducted two evaluation sessions with pupils of 5th to 6th grade voluntary robotic course and 6th grade French language course. The number of pupils in each class
was 14, with the age of 11 to 13 years old. The length of each prototype evaluation was 45 minutes and was arranged in December 2021.

In the first 5 minutes of the evaluation session, pupils were asked to set up the laptop for the prototype evaluation. The researcher was continued by briefly introducing the purposes of the prototype and three main functions with the usage demonstration. For the French language class, which was the first time meeting the researcher, a short self-introduction was given. The responsible teacher further assigned the tasks and instructed pupils to access both the websites of Elias Robot and Nao Handbook to conduct the evaluation. The entire introductory and tasks assignment process took about 10 minutes. The evaluation session proceeded with 20 minutes of pupils conducting prototype evaluation either in pairs or individually. Since the taught subject is different in each class, their tasks for prototype evaluation differ. The group of 5th to 6th grade pupils in the voluntary robotic course was assigned with prototype testing for reporting the usability and user interface design. In contrast, the group of 6th grade pupils in the French language course was given the task of creating French lessons about Christmas on the Elias Robot by following the Tutorial function on the prototype. Although the time was too short for 6th grade French class pupils to test the programmed robotic applications on Nao, the robot was placed as a companion and demonstration in front of the class. The learning activities had the same condition as the pre-study in which pupils had complete freedom to conduct their own tasks while the researcher and the teacher were standing by for immediate assistance. The last 10 minutes were scheduled for the semi-structured interviews and questionnaire. The interviews were mainly carried out in English with the occasional help of translation from the responsible teacher. The evaluation session ended by distributing the anonymous questionnaire to pupils. Finally, the researcher noted down the findings from observations and interviews right after collecting all the returned questionnaires. All the methods of analyzing collected research data have been reported in the third section of chapter 3, Data Analysis Methods.

6.3. Findings
As mentioned earlier, the two groups of pupils who participated in the prototype evaluation were not assigned the same task. Therefore, this section reports the observations and interviews findings separately in chronological order. Nevertheless, the questionnaire results from the two groups are presented altogether at the end of the section to statistically compare and reflect the user experience and perception of the prototype usability.

Prototype evaluation with 5th to 6th grade pupils in the voluntary robotic course: usability testing and user interface evaluation
Observations found out among the three functions, i.e., Meet Nao, Tutorial, and Animation, in the website prototype, the Animation function is the most popular among pupils. They enjoyed browsing different robotic movements and mentioned that the attached animation codes are helpful for programming robotic applications. Some pupils even played with the robotic sound of the animation video by constantly increasing and decreasing the volume. Although the teacher showed concern about the brightness of the video may be too dark, pupils did not feel the same way. However, one pupil mentioned: “Elias’s sound is a bit scary”. Accordingly, half of the class agreed to add cheerful background music to balance out. Another pupil mentioned that the usage instruction of the Nao animation codes in the Animation function is indeed helpful.

For the Tutorial function, pupils were able to navigate their way around different tutorial sections (Login and Connection, Create Lesson, Program Lesson), meaning all the buttons are clear and can redirect users to their intended webpage. One pupil said: “The Tutorial is good, and the instruction is not too long or worded for the first learner”. The Meet Nao function was comparatively less attractive, as pupils showed little interest in listening to the attached audio files. One pupil encountered a problem while assessing the Limb introduction page due to an internet problem, reducing the file size could be a possible solution and maintain a smooth user flow. In summary, even though this class had long-term robotic programming experience, the interest in the Nao robot remains high. During the evaluation process, observations found out pupils were attracted to small details such as a small video screenshot picture in the tutorial section and animated buttons (Figure 26). One pupil mentioned: “The graphics and colours are attractive and playful”.

Figure 26. Attractive details in the Nao Handbook, i.e., animated buttons.

**Prototype evaluation with 6th grade pupils in the French language course: Tutorial function and assistive usage evaluation**
Some pupils worked in pairs by opening the webpages of Elias Robot and Nao Handbook on separate laptops to follow the step-by-step guide in the Tutorial function in proceeding with the programming task. Others who tend to work individually by opening the webpages of Elias Robot and Nao Handbook on the same laptop encountered a chaotic situation while programming due to the constant switches between two browsers. The section reports the findings and possible improvement methods in accordance with the procedure of pupils following the step-by-step guide on the Nao Handbook to conduct programming tasks on the Elias Robot. Therefore, the content addresses the arisen issues on both sites simultaneously.

Most pupils had problems finding the “Elias for Nao” button to access the Elias Robot on the Utelias Technologies website and the “Create” button to program the lesson in the Elias Robot after login (Figure 27). On the website prototype, some pupils tried to click the buttons on the demonstration screenshots in the Tutorial function and were stuck in the section of physical robot connection since it was not required to do so. These issues may be solved by applying specific instructional texts to the website prototype, Nao Handbook. Apart from the unfamiliarity to the usage at the beginning, pupils were able to find the corresponding tutorial section to their task, which supported the previously observed situation that the website prototype has good navigation.

![Image of Elias Robot website](ELIAS.png)

Figure 27. The “Elias for Nao” and “Create” buttons to access the Lesson Editor (Source: Utelias Technologies, eliasrobot.com).

Although pupils had some difficulties getting familiar with the Elias Robot and website prototype, they demonstrated high task persistence and understood the problem after receiving assistance from the teacher or the researcher. They were excited about the amusing pictures in the built-in library of the Elias Robot (Figure 28). This reaction of attraction to small details is the same as robotic class pupils towards the graphic in the website prototype. Most of the pupils included simple vocabulary lessons and video in the robotic
program (Figure 29), this progress is impressive considering only a short time was given. The evaluation concluded that the Tutorial function is helpful in instructing robotic programming tasks for novice users. At the end of the session, more than half of the class showed interest in learning French with the Nao robot but indicated the robot cannot replace their teacher. Pupils found the robot cute and tried to catch its attention by waving to it. In summary, the website prototype could be improved by including more instruction to avoid confusion during usage. For instance, some pupils tried to log in to the Elias Robot using the username and password of their own school account instead of the account information given by the teacher.

Figure 28. Amusing images in the built-in library of the Elias Robot (Source: Utelias Technologies, eliasrobot.com).
Figure 29. Examples of robotic applications programmed by the French language course pupils as first-time users (Source: Utelias Technologies, eliasrobot.com).

**Questionnaire results from pupils in the voluntary robotic and French language courses**

There were two 3-point Likert scale questions in the paper questionnaire (Figure 30). The first question was “Is the website easy to use?”, followed by the second question of “How was your overall learning experience?”. The responses were calculated as -1=poor, 0=average, and 1=good. The mean and standard deviation values are presented in Table 3 and Figure 31. For the 5th to 6th grade voluntary robotic course, the return responses of the first question indicated all the pupils agreed the Nao Handbook is easy to use (M = 1, SD = 0). Except one pupil answered “average” in the second question, others had excellent learning experiences (M = 0.92, SD = 0.26). On the other hand, the 6th grade French language course pupils responded the Nao Handbook has decent usability as 3 out of 14 pupils answered “average”, and no “poor” response was collected (M = 0.78, SD = 0.42). For the second question of understanding pupils’ learning experience, the collected and analysed data is identical to the robotic class which has one answer as “average” and 13 answers as “good” (M = 0.92, SD = 0.26). The result demonstrates the pupils require subtle assistance on the usage of the Nao Handbook on their first trial. However, the straightforward content allows them to understand the usage within a short time. Furthermore, the interactive features and visually rich graphics on the Nao Handbook effectively create an engaging yet enjoyable learning experience.

![Nao Handbook Prototype Evaluation Form](image)

Figure 30. Nao Handbook, prototype evaluation 3-point Likert scale questionnaire.

<table>
<thead>
<tr>
<th>Question</th>
<th>0</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the website easy to use?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How was your overall learning experience?</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3. The mean value and standard deviation value of the 3-point Likert scale.
### Figure 31. The result of the 3-point Likert scale.

<table>
<thead>
<tr>
<th>3-point Likert Scale Questions</th>
<th>Mean</th>
<th>Std.Dev</th>
<th>Mean</th>
<th>Std.Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Q1: Is the website easy to use?</strong></td>
<td>1</td>
<td>0</td>
<td>0.78</td>
<td>0.42</td>
</tr>
<tr>
<td><strong>Q2: How was your overall learning experience?</strong></td>
<td>0.92</td>
<td>0.26</td>
<td>0.92</td>
<td>0.26</td>
</tr>
</tbody>
</table>

#### 6.4. Summary

The chapter introduced the used methodology and procedure of evaluating the assistive website prototype, Nao Handbook. The content covers the participants and their particular tasks for assessing prototype usability. The findings reported the qualitative data (observations and group interviews) of two study groups separately but compared and reflected the qualitative data (questionnaire) at the end of the section. Both data collection methods supported each other and verified that the prototype has decent usability, practical functionalities, and attractive user interfaces to assist pupils’ robotic learning. However, real-time support from education professionals and detailed instructional texts are required to facilitate better usage and avoid confusion.

To sum up, the Nao Handbook enriches pupils’ robotic learning by presenting a purposeful design that focuses on users’ requirements. It allows the first-time learners to create and program robotic applications and have a basic knowledge about the Nao robot over a short time. Concluding the findings from the literature review, pre-study, and prototype evaluation, the next chapter presents a set of design implications for designing educational robotic software for primary school children.
7. Design Implications for Robotic Software Development

The thesis summarizes a set of five design implications as guidelines of robotic software development for primary school pupils as target users. The list expects to provide constructive considerations for the design and development of the educational robotic software, which refers to the software to be used in combination with the social robot. The presented design implications were inspired by the research findings retrieved throughout the phases of the literature review to prototype evaluation. The purposes of presenting the list include encouraging the relative studies in the field of CRI and improving the design implementation of educational robotic software.

1. Introduce the Basics of Social Robotics

Having a fundamental understanding of the used material and method is favorable for the learning outcome. As the complicated hardware and software functionalities of educational robots may discourage spontaneous interaction from young learners, presenting a brief introduction about robotics on the interactive software is essential. The content can include but is not limited to robotic physical attributes, interactive techniques, application area, etc. Considering the ability of the target users, the basics of robotics should be elaborated in entertaining and intelligible manners. It is to attract maximum attention from children and deliver a realistic expectation about the robotic functions. Additionally, acknowledging the strengths and limitations of the social robot can avoid negative experiences caused by over-anticipation. The term over-anticipation refers to the unrealistic perception towards robotic attributes pupils may have, including the communicative approaches, sensory perception, usage limitation, etc.

2. From Companion to Technical Tool

One of the significant findings from this thesis research indicated that pupils enhanced technology literacy resulted in a novel approach of robot interaction. That is to say, as pupils have developed further knowledge in programming the robotic applications, they tend to concentrate on the programming task and interact with the physical robot mainly for the purpose of testing the functions they created. Compared to the common RAL in which pupils directly learn from the robot, the task-oriented behaviors have shown that pupils actively contributed their prior knowledge into the process of robot interaction and utilized the social robot and its software as a technical tool.

Regarding the ethical consideration in which the humanlike CRI has proven to influence cognitive development (Graaf, 2016), and children are considered as vulnerable users to be influenced by robot’s persuasive behaviors (Tolksdorf et al., 2020), it is advisable to introduce the robotics with the purposes of serving as a technical tool. Having the changes
in perception towards the used technology is aim to (1) Remind users of the objectives of implementing educational robots, (2) Have awareness about the appropriate extent of bonding with educational robots, and (3) Raise attention to the influence of persuasive design while interacting with educational robots.

3. **Provide Usage Instruction for the Built-in Functions**
   It is recommendable to instruct the usage on the built-in functions of educational robotic software. The instruction would allow users to understand the basics of the major functionalities and proceed with the recommended procedure. For the classroom contexts, the usage instruction can assist educational professionals in providing individual instructions to the students. On the other hand, the usage instruction can also act as a tutoring tool in the home learning environment. For instance, including a series of comprehensive usage instructions would equip the software with the strength to engage users in an interactive environment and proceed with self-paced learning. To conclude, the usage instruction is considered as a supportive feature that enables users to carry out independent work and receive immediate assistance in their regular use. Additionally, it has the potential to serve as an example for education professionals to prepare teaching demonstrations and propose a novel learning arrangement.

4. **Support Alternative Methods of Input**
   Most software developers focus on creating appealing content through the incorporation of various output modalities. However, designing software that can adapt other alternative input methods is equally important. The thesis found out that the lack of a secondary input method to communicate responses has disrupted RAL and decreased the possibility of expanding the utilization of robotic technology to other educational contexts. For example, the current Elias Robot software can only receive users' responses through audio input during the lesson. However, speech recognition can be easily influenced by several factors, including background noise, internet connection, the physical distance between users and the robot, etc. Under these circumstances, users have no choice but to skip to the next question after several false attempts. In this situation, the haptic input could be a practical secondary input method. It allows users to continue their interaction with the robot by selecting or typing the response when the default audio input method does not function. In conclusion, having an additional input method allows users to interact with the technology flexibly and prevent frequent technical issues from interrupting the learning progress.

5. **Maintain Consistency in User Interface Design**
Delivering a consistent user interface design can improve the intuitiveness and usability of the developed software. It would enable users to get better familiarized with the system and concentrate on their tasks. For instance, the Elias Robot software achieves high consistency in user interface design by including hotspot hints on every clickable button and creating an identical website layout for desktop and mobile devices. On the other hand, the assistive website prototype presented in the thesis, Nao Handbook, failed to include incomprehensive hotspot hints and therefore misled users on clicking the pictorial instruction instead of the effective buttons. The example addresses the importance of adapting consistent design components to enhance users’ confidence with accessible navigation.
8. Discussion and Conclusion

This chapter summarizes the key findings by answering the research questions, reflecting the research results in light of related studies, and discussing the research limitations. The content aims to elaborate on the novelty of the thesis and present suggestions and possibilities for future research.

8.1. Summary of Findings

The thesis conducted 6 pre-study sessions with 25 pupils and 2 prototype evaluation sessions with 28 pupils in the context of a voluntary robotic course of a Finnish public primary school. The research methods included observations, group interviews with pupils, questionnaires, reflective expert talks with the teacher, and robotic programs analysis. The objective of the pre-study was to assess pupils’ experience of robot-assisted learning. The learning tasks included programming robotic applications on the Elias Robot and testing the programmed robotic applications with the physical Nao robot. After gaining an understanding of the users’ requirements and current issues in RAL, the researcher of the thesis designed an assistive website prototype for supporting further robotic learning activities and carried out the evaluation to validate the usability. The findings retrieved from the pre-study are aimed to respond research question 1 and research question 2. The findings obtained from assistive website prototype implementation and evaluation are expected to answer research question 3.

The first research question of the thesis was: **What are the learning processes and experiences of primary school pupils programming and testing robotic applications?**

In the current research case, the process of RAL activities proceeded in pre-study included the phases of (1) Having a 10-minute introduction and task announcement given by the responsible teacher, (2) Continuing with the 65-minute free CRI section, and (3) Wrapping up the session with group interviews and questionnaire distribution. The free CRI section included pupils setting up the Nao robot and laptops, conducting programming tasks on the Elias Robot, and testing the programmed robotic applications on the Nao robot. The entire CRI section was carried out as a self-learning process to maintain children's autonomy with support from the teacher upon request. Pupils spontaneously implemented their subject-specific knowledge of language and history into robotic applications. Furthermore, they learned how to program robotic applications and execute effective robot interaction from experiences. For instance, separating accepted answers by a comma while programming and talking to the Nao robot from a certain height can improve speech recognition. According to the interviews and questionnaire results, pupils had positive learning experiences throughout the course. They concluded the learning experiences with the statements “I like to study with the robot because it's fun and different, although it doesn't understand me at first” and “I like it because the program can be
Even though several technical problems, e.g., connection and speech recognition issues of the Nao robot, randomly appeared during the CRI, pupils demonstrated exceptional patience in repeating attempts and seeking assistance. It was observed that pupils showed greater concentration on the programming tasks after being given the task of including the Nao animation codes in robotic applications from the second pre-study session. During the robot interaction, they were attracted by the physical embodiment and demonstrated great motivation to extend the content of their robotic applications to foster CRI. Additionally, pupils initiated natural communication involving physical interactions, i.e., eye contact, patting, handshake, and touching, with the robot further supported the observed amusing and enjoyable learning experiences.

The second research question of the thesis was: **When pupils are programming and testing robotic applications, what are the (A) social characters pupils would assign to the robot, and (B) pupils’ perspectives towards the robot and its software?** For question 2A, the collected questionnaire responses indicated that the majority considered the Nao robot as a “classmate” (14 participants). Pupils described the robot as a friend or a nice learning companion. Besides the perceived peer-like character, most pupils from the 4th grade and a few pupils from the 5th and 6th grade suggested the Nao robot had the character of a “teacher or teacher assistant” (7 participants). The result is due to some pupils did not perform that many programming tasks but interacted with the built-in functions or robotic applications programmed by their peers. In addition to the humanoid social characters, both the responsible teacher and the researcher observed that the novel learning approach of assigning pupils the task to program robotic applications has associated the robot with another character as a “technical tool”. It is due to pupils concentrating on the programming task and interacting with the physical Nao robot mainly for testing the function they programmed. Compared to the common RAL in which pupils learn from the robot, the thesis discovered a novel CRI where pupils actively contribute their knowledge and initiate spontaneous learning in robot interaction. The discovery is a positive sign indicating that the pupils’ technology literacy has drastically increased, allowing them to develop a brand-new relationship with the robot. In conclusion, the perceived social character of the robot can be presented by two categories, namely the humanoid character of a classmate and a teacher and the non-humanoid character of a technical tool. The result showed the various approaches of robot interaction and perceptions pupils have had.

For question 2B, pupils had intense curiosity towards the robot due to the novelty effect. They indicated that the main reason for participating in the course is to freely interact with the robot and learn how to create robotic applications. Pupils suggested the Nao
robot is beneficial to be used for language learning purposes. As for the pupils’ perspective toward the Elias Robot, pupils indicated that the undeveloped function to support the input of the Nao animation codes and lack of usage instruction had disadvantaged the overall user flow. Some responses from the questionnaire regarding this issue include “The Elias Robot and the list of Nao animated codes should be easier to use” and “The Elias Robot could include instruction and more pictures, e.g., graphical user interface”. However, one pupil confirmed the learnability of the Elias Robot by stating, “I eventually learn how to program”. Meanwhile, some pupils raised the suggestion of improving the course arrangement by integrating the use of the robot into the language class. The responses include, “It could be fun to use the robot for practicing new language”. Besides the potential robotic usage in academic learning, pupils highlighted the intention of engaging in long-term CRI by stating, “I wish to bring my own robot to class” and “I just want to use the Nao robot more”. In summary, although the robot has achieved great popularity among pupils, pupils particularly mentioned that the robot cannot be the replacement of their teacher. The situation implied that introducing the robot as a learning companion or an instructional tool could be the preferred application method in primary education. Additionally, it is crucial to have teacher-robot collaboration to execute RAL and assist with unexpected technical problems.

The third research question of the thesis was: **How can we support the robotic programming activity with an interactive assistive tool?** The thesis presents an assistive website prototype, Nao Handbook, including the three functions of “Meet Nao”, “Tutorial”, and “Animation”. The design implemented abundant graphical elements and multimodal interaction (visual output, audio output, and haptic input) to attract pupils’ attention and learning motivation. The Nao Handbook aims to support the usage of the Elias Robot and promote robotic learning activities in a child-friendly approach. The relative methods include introducing the robotic attributes to form a holistic perspective about the used technology, providing the step-by-step tutorial to support pupils’ programming tasks, and presenting the usage and previews of robotic animated movements to foster physical interactions in CRI. The results of prototype evaluation showed that the Nao Handbook is indeed a helpful tool in guiding first-time users on how to program robotic applications in the Elias Robot. To support further research in the field of CRI and promote robotic learning activities, the thesis summarized a set of design implications of developing educational robotic software for primary school children (Table 4). The list aims to report the thesis findings in an organized and understandable manner. Additionally, it expects to provide constructive considerations for the design and development of the educational robotic software, which is to be used in combination with the social robot.
Table 4. Design implications for robotic software development.

<table>
<thead>
<tr>
<th>Design implications</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Introduce the Basics of Social Robotics</td>
<td>Presenting a brief introduction allows users to understand the functionalities and limitation of the used technology, which can avoid negative learning experiences caused by over-anticipation.</td>
</tr>
<tr>
<td>2. From Companion to Technical Tool</td>
<td>There are three reasons of introducing the robotics as a technical tool: (1) Remind users of the objectives of implementing educational robots, (2) Have awareness about the appropriate extent of bonding with educational robots, (3) Raise attention to the influence of persuasive design in educational robots.</td>
</tr>
<tr>
<td>3. Provide Usage Instruction for the Built-in Functions</td>
<td>Usage instruction enable users to conduct independent work and receive immediate assistance. It can also serves as an example for education professionals to and propose a novel learning arrangement and prepare teaching demonstration.</td>
</tr>
<tr>
<td>4. Support Alternative Methods of Input</td>
<td>Having an alternative methods of input allows users to interact in a more flexible approach and prevent technical issues to interrupt the learning progress. It further has the potential of expanding the usage to various educational contexts.</td>
</tr>
<tr>
<td>5. Maintain Consistency in User Interface Design</td>
<td>A consistent user interface design can improve the intuitiveness and usability of the software. The accessible navigation enables users to get familiarize with the system and concentrate on their tasks.</td>
</tr>
</tbody>
</table>

8.2. Discussion about the Thesis’ Contribution

This section presents the main contribution and the novelty of the thesis. Following the research procedure, this section separately discusses the findings in four subsections, namely naturalistic field studies about human-robot interaction, innovative robotic learning approach, the reflection of the research findings, and lastly, the design of the assistive website prototype, Nao Handbook.

Naturalistic field studies about human-robot interaction

Naturalistic studies that have minimal levels of experimental control and rely on qualitative data to understand the approach of humans interacting with robots is not yet a common method in social robotics research (Deng et al., 2019; Bertel, 2016). The thesis demonstrates the novelty of the topic by conducting long-term naturalistic studies of primary school pupils’ experiences of robotic learning in an authentic environment. Compared to the conventional RAL, where the social robot instructs a certain knowledge to children (Castellano et al., 2021), the thesis focuses on an innovative learning approach, which is children programming robotic applications for educational purposes. According to related studies, assigning children the role of the programmer is beneficial in facilitating the learner-centered and collaborative learning approach (Kanda et al., 2012). Furthermore, it has the potential to integrate programming learning into the regular curriculum that responds to the growing in-demand information technology skills (Benotti et al., 2016). However, prior research has focused on the pupils’ programming tasks of toy robots (Gordon et al., 2015; Benotti et al., 2016; Kanda et al., 2012). Therefore, the thesis aims to address the research gap by studying the situation of primary school pupils programming and testing the robotic application of the humanoid social robot, Nao. As the
social robots have incorporated humanoid features, e.g., physical embodiment and human characteristics, that enable multimodal communication, the thesis expects to raise contribution by investigating a novel method of RAL in primary education contexts.

**The innovative robotic learning approach**

To maximize the learning outcome of RAL, the thesis implemented the concept of the two approaches, Care-Receiving Robot (CRR) (Tanaka and Kimura, 2010) and Total-Physical Response (TPR) (Asher, 1969), into the research methodology of the pre-study. The CRR approach relates to the pupils’ role as the programmer and the tester of the robotic applications. By creating an environment where pupils instruct the robot to behave in a certain way, the research aims to explore the learning experience and possibility of CRI. On the other hand, the TPR approach inspired the assigned tasks to pupils of appending the Nao animation codes in the robotic applications for creating robotic movements along with the audio interaction. The reason for assigning the task is to elevate pupils’ interest in robotic activities and support multimodal interactions along the learning process. These approaches were successfully utilized and shown impact in the thesis research. For instance, with the implementation of the CRR approach, pupils demonstrated active attitudes in learning how to program the robotic applications and further combined their subject-specific knowledge, i.e., language and history, into the programming content. Moreover, by carrying out the TPR approach, pupils showed great interest in the robot interaction and further concentrated on the programming task during the learning activities. The two approaches have helped to support the “learning from teaching” activities and initiated spontaneous learning behaviors and intrinsic motivation from pupils.

**Reflection of the research findings**

As the thesis is a continuation study of the research presented by Ahtinen and Kaipainen (2020), some identical findings were discovered. Firstly, the result from the pre-study suggested that pupils had positive robotic learning experiences, and the majority perceived the Nao robot with the character of a classmate. The finding is similar to the previous discovery in which the robot was recognized as an encourager and a learning companion. However, the research further observed that pupils who have had RAL experience developed a different perspective, in which they regarded the robot as a technical tool. For instance, as pupils have gained knowledge in programming robotic applications, they concentrate on the programming tasks and interact with the Nao robot for the purpose of testing the content they programmed. This discovery has demonstrated spontaneous learning behavior from pupils. The situation is a new finding that did not appear in previous studies, in which pupils tend to perceive knowledge from the robot interaction. The
thesis has discovered a potential RAL approach and agreed with related studies that integrating robotics activities into the curriculum can foster the development of children’s technology literacy and computational concepts (Chen et al., 2020; Govind et al., 2020). Secondly, robotic integration can initiate positive collaboration between pupils and create an encouraging learning atmosphere in class. The findings also match the previous discovery where pupils showed empathy and demonstrated spontaneous turn-taking between peers during the robot interaction. Lastly, pupils showed high interest and motivation to interact with the robot throughout the long-term interaction, i.e., from the phases of pre-study to prototype evaluation. It is identical to the previous discovery, in which pupils responded positively to the amusing robotic behaviors and attempted to initiate physical interaction. The findings imply that pupils demonstrated a strong bond with the social robot due to the implementation of persuasive design. It strengthens the importance of applying ethical considerations to the use of the educational social robot as children are vulnerable users who tend to strictly follow and are easily influenced by robots’ suggestions (Tolksdorf et al., 2020).

The design of the assistive website prototype, Nao Handbook

The assistive website prototype, Nao Handbook, introduces the capability of the Nao robot and provides usage guidance of the robotic software, Elias Robot. The Nao Handbook addresses the ethical aspects by presenting the Nao robot with a friendly and preferred image, i.e., a peer-like character, and providing sufficient assistance that allows pupils to conduct self-paced learning in the programming activities. The design goal is to build a thorough understanding of the used technology to avoid over-anticipating thoughts pupils may have. The over-anticipating thoughts refer to the unrealistic robotic attributes pupils may assume, including the communicative approaches, sensory perception, usage limitation, etc. The Nao Handbook followed the summarized criteria of persuasive design (Jacobs, 2020) by designing functions in alignment with pupils’ goals of robotic programming. Moreover, it included the considerations of designing for children (Ludi, 1996) by creating multimedia elements and inviting pupils to participate in the phase of design ideation and prototype evaluation. In response to the suggestion from the research of Ahtinen and Kaipainen (2020) that scenarios and guidelines about the RAL are required for further implementation, the tutorial function in the Nao Handbook serves as a demonstration to assist education professionals with the teaching preparation. Finally, the set of design implications is a summary that presents the thesis findings throughout the phases of the pre-study to prototype implementation and reflects all the considerations related to educational robotic software mentioned in chapter 2, Literature Review.
8.3. Research Limitations

Some challenges limited the research activities throughout the process of the thesis study. This section summarizes the three major limitations and detailed explanations below.

1. Technical limitations

The Nao robot and the Elias Robot have some technical limitations that interfered with the usage and research activities in the pre-study. For the Nao robot, the most frequent problems are the internet connection and speech recognition. The recurring situation imposed significant challenges in creating a smooth learning experience for pupils. Furthermore, the teacher and the researcher were required to occasionally focus on solving the technical issues instead of assisting or observing pupils in programming activities. The inconvenience caused some waste of time and even disrupted the robotic activities. For instance, once the Nao robot was overheated and therefore couldn’t function in class due to the accidental placement on an EVA form mat. The Elias Robot consists of two interfaces for different target user groups. The Lesson Editor was developed intended for education professionals to create interactive lessons. In contrast, the Elias Robot application was designed for 7 to 12 years old children to practice spoken language. The thesis research assigned the teacher’s role of conducting programming tasks to primary school pupils. As a result, the malfunctioning robotic applications and numerous programming errors can cause a decrease in users’ confidence during the learning process.

2. Prototype implementation

In the process of prototype ideation, another design direction was presented as creating a pop-up avatar to instruct the programming tasks and developing an animation preview function on the current Elias Robot. A further agreement on the design and development of the approach is required to discuss with the cooperated company, Utelias Technologies Oy. However, the time for prototype implementation was limited due to the teaching schedule of the voluntary robotic course. As a result, the researcher of the thesis thus created an external assistive website prototype, Nao Handbook, that aims to address all the users’ requirements mentioned in the pre-study. Nevertheless, the Nao Handbook was created with the software Adobe XD, which has a strict limitation on the size of the attached file. Additionally, the list of Nao animation codes consists of more than 500 animated movements. These situations constrained the variety of the content and narrowed the purpose of the Nao Handbook to serve as suggestions for designing advanced built-in functions in the Elias Robot and a brief overview of the animated movements of the Nao robot.

3. Prototype evaluation
The prototype evaluation has had the same restriction as the prototype implementation, which was having limited time for conducting research. Therefore, it resulted in three shortages along the evaluation process. The first shortage was the lack of iterative design. Even though some usability problems were found in the prototype evaluation, the researcher did not have the room to schedule re-design and the second evaluation. The second shortage was the lack of thorough assessment of the Nao Handbook function. The statement refers to the French course pupils who were asked to follow the Tutorial function for creating language lessons on Elias Robot. It restricted the researcher to observe first-time users' learning experience and reaction towards the other two functions. The third shortage was the exclusion of testing robotic applications on the Nao robot. The situation again describes the condition of prototype evaluation with the French course pupils. Compared to the pre-study (65 minutes), the insufficient time of CRI in prototype evaluation (45 minutes) left no room for pupils to test the program and interact with the Nao robot. The situation had confined first-time users to have a comprehensive robotic learning experience. Furthermore, as children are the target group that requires additional consent from their parents due to the research ethic, the participant recruitment was comparatively challenging.

8.4. Conclusion

The thesis adopts the Human-Centered Design (International Organization for Standardization [ISO], 2019) and Research through Design (Zimmerman and Forlizzi, 2014) approaches to conduct long-term naturalistic studies for understanding CRI in an educational context. The research observed that the primary school pupils had positive robotic learning experiences and were further motivated to continue engaging in the RAL activities after the long-term study.

The pre-study found out that pupils created a strong bond and followed the suggestion of the social robot reaffirmed with the theory that CRI affects children’s cognitive attributes (Graaf, 2016; Ahmad et al., 2019; Zaga et al., 2015). As the section of ethical concerns presented in chapter 2, Literature Review, it is important for future research to study the preferred and ethically safe methods of integrating the social robot into daily learning. Additionally, a more extended period of research that focuses on the persuasiveness of the social robot is encouraged. Since the thesis was conducted as a continuation study of Ahtinen and Kaipainen (2020), both identical and novel discoveries were reported. In addition to the situation of CRI, the thesis broadened the scale of the research and further focused on the users’ requirements for long-term robotic learning.

The prototype implementation presented an assistive website prototype, Nao Handbook, to promote primary school pupils’ RAL learning activities. The design consists of the
suggested features, including the graphical user interface, programming guidance, and robotic animation support. The design goal is to provide an effective tool that introduces pupils to the environment of RAL. The prototype evaluation had validated the Nao Handbook has the strength that allows the first-time user to comprehend the usage of the Nao robot and the Elias Robot in a short time. Moreover, the content of the prototype can serve as a design suggestion for the cooperated company to develop new functions, as well as an example or learning material that assists the educational professional in conducting teaching practices.

Lastly, the thesis created a set of five design implications for educational robotic software development. The list is expected to report the research findings in an organized and understandable manner. Furthermore, the content includes the considerations retrieved from literature review and research activities, namely from the phases of the pre-study to prototype evaluation. The design implications aim to encourage future studies in the field of CRI and provide guidelines in supporting and improving the implementation of educational robotic software.
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Shamsuddin, Yussof, H., Hanapiah, F. A., Mohamed, S., Jamil, N. F. F., &


Appendices

Appendix A.1_ Information Sheet of Pre-Study for Parents, English Version

User Study Information Sheet: Primary school pupils programming robotic applications for their peers – Learning experiences during a long-term trial

N.B. The document will be translated into Finnish and distribute to parents in a digital format. The parents will be required to give their consent by clicking a box, and typing their name and their child’s first name

Purpose of the research

Welcome! Your child has been invited to participate in a user study for a master’s thesis research carry out by Chia-Hsin Wu, a student at Tampere University, study program of Human-Technology Interaction. The purpose of this user study is to focus on the learning experience of primary school children 1) programming robotic applications for peer’s learning, and 2) interacting with robotic applications programmed by peers. The information learned in this user study will be used for scientific research purposes leading to the master’s thesis. The findings may also be published in scientific articles and social media publications. All research and publishing activities will follow the strict policy of science, including research ethics, data security, and the full anonymity of the participants in the analysis and publication phase.

Procedure

The research includes a 3-month user study for 1.5 hours every week starting from September to November 2021. The research takes place in [anonymized] school under the supervision of teacher [anonymized], and the thesis supervisor Aino Ahtinen (Tampere University). The visiting hours of the researcher to [anonymized] school will be from 12:15 to 13:45. The target group in this study includes pupils of 4th grade and 5-6th grade. During the class, the teacher will divide the whole class into small groups that consist of around 5 to 7 pupils and assigned tasks to either using Elias editor to program robotic applications for peer’s learning or interacting with robotic applications programmed by peers.

The data collection methods include observations and semi-structured group-interviews. There are two phases in this research. The first research phase will take place from September to October using an observation method that focuses on pupils’ learning process and experience while interacting with the robots. We will also explore what kind of social character the pupils will define for the robot. At the end of the class, the study will be followed by a semi-structured group interview with pupils. This is aimed to acknowledge benefits and problems that occur during Child-Robot Interaction for finding design solutions to support pupils’ robotic activities.

In the second research phase, starting from the beginning to the end of November, the research will carry out a design evaluation with pupils. The evaluation process includes prototype introduction, observation of the usage, and group interview. The main goal is to examine the usability with target users for potential improvement.

All the research activities involve with primary school pupils will proceed in the classroom under the supervision and assistance of the responsible teacher. The type of research tends
to be exploratory, meaning that the interview will mostly include open-ended questions to obtain insightful opinions from pupils. In another word, there will be no right or wrong answers to the interview questions.

The language of group interviews with pupils will be decided according to pupils’ preference and carry out with the assistance of the responsible teacher. All the activities conducted during the course of research will strictly follow the latest coronavirus regulations. If the situation got worsens and couldn’t allow to carry out in-class research activities, an alternative plan such as arranging an in-class camera for video call will be agreed upon together with the responsible teacher for continuing the study. In this situation, a separate notice and informed consent will send to parents and pupils communicating about the changes.

Before starting the research, this information sheet/consent form and an attached privacy notice will be provided to and signed by the parents. A shorter version of the information sheet will be provided to pupils. Parents are kindly asked to communicate with pupils about the research goal and discuss the willingness to participate. Only the pupils who are agreed to participate and provided the signed informed consent form will be included in the study. During the research process, all the participants have the right to withdraw from the study and/or obtain their personal information without providing any reason, withdrawing from the study will not result in any consequences. However, the information that has been collected before the withdrawal participation will continue to be used for research purposes.

All the qualitative data received from the observation and interview section will be collected by hand-writing notes. There will not be any collection of identification information about primary school pupils. The result will not publish any details of any single pupil but presenting the findings obtained from the whole group. All the activities involve with primary school pupils will not be either video or audio recorded at this point. If further research activities require to include video or audio recording, additional permission will be asked from both parents and pupils. Lastly, all the pictures that will be published in this research will not include pupils’ faces or any identifiable information.

Confidentiality

Named researchers, Chia-Hsin Wu and Aino Ahtinen from Tampere University, will manage and analyze the study data. As stated above, your responses will remain confidential, and no identifiable information will be included in any transcripts or reports. The research data will be stored on a secure drive of Tampere University, and it will be stored for five years. These consent forms that include the names of the parents and children are not connected to the collected research data. After five years all data will be deleted.

Benefits and risks

The benefits of the research include that all the participating pupils are able to program or interact with social robots for language learning purposes for an entire semester. As well as the participating teacher will have the chance to integrate social robots into educational activities in a novel approach. All the research and in-class activities will be conducted under the supervision of the responsible teacher to ensure the pupils’ safety and comfort.

Tietosuojailmoitus/Research Privacy Notice

You can find the Tietosuojailmoitus/Research Privacy Notice through the following link:
https://tuni-my.sharepoint.com/:b:/g/personal/chia-hsin_wu_tuni_fi/EeLMkIT4bhVLrtlf-tartIYBw_I1xgIpuuZAUY4g6Ec8g?e=hREiGy

**Contact**

For any questions or concerns regarding this study, please do not hesitate to contact:

Chia-Hsin Wu, student of Human-Technology Interaction, chia-hsin.wu@tuni.fi

Aino Ahtinen, University lecturer, aino.ahtinen@tuni.fi
Tiedote tutkittaville: Alakoululaisten robottiohjelmoiminti ja ohjelmien käyttö - Pituustekeiset oppimiskokemukset (Primary school pupils programming robotic applications for their peers – Learning experiences during a long-term trial)

Tutkimuksen tarkoitus


Kaikki tutkimukseen liittyvät aktiiviteitit tapahtuvat kurssin aikana luokkahuosessa opettajan lännessä ollessa sekä avustusella. Tutkimus on luonteeltaan kartoitavaa tutkimusta, jossa oikeita eikä vääriä vastauksia ei ole, joten arvostamme ihan kaikenlaisia oppilaiden vastauksia esimerkiksi ryhmäkeskusteluissa. Ryhmäkeskusteluissa käytämme joustavasti suomea tai englantia sen perusteella, mikä tuntuu parhaalta oppilaiden näkökulmasta. Kurssin opettaja auttaa mahdollisessa kielen kääntämisessä.


**Tietoturva**


**Hyödyt ja riskit**

Kurssille osallistuvat oppilaat pääsevät oppimaan uusia asioita robottien ohjelmoinnista sekä vuorovaikutuksesta robottien kanssa. Kurssin opetuksellinen sisältö annetaan opettajan toimesta, ja sen lisäksi lopputyöntekijä tulee esitteleämään suunnitelmaan apustyökaluja oppimiseen. Tutkimuksessa noudatetaan tiukasti tieteellisen tutkimuksen kriteereitä, joten osallistuminen on turvallista. Lopputyöntekijän osallistuminen vuorovaikutusaktiviteetein ei aiheuta epämukavuutta, sillä se tapahtuu aina opettajan lainsäädöllössä.

**Tietosuojailmoitus**

Tutkimuksen Tietosuojailmoitus on nähtävissä seuraavan linkin takaa:

https://tuni-my.sharepoint.com/:b/g/personal/chia-hsin_wu_tuni_fi/EeLMklT4bhVLrtlfartLNYbw_1xglpuuZAUy4g6Ecp8g?e=hREfGy

**Yhteydenotot**

Tutkimukseen liittyvissä kysymyksissä voi ottaa yhteyttä opettaja [anonymisoitua] tai tutkimuksen suorittajiin:

Chia-Hsin Wu, Ihmisen ja teknologian vuorovaikutuksen opiskelija, Tampereen yliopisto, chia-hsin.wu@tuni.fi

Aino Ahtinen, Yliopistonlehtori, Tampereen yliopisto, aino.ahtinen@tuni.fi
Appendix B.1_ Informed Consent form of Pre-Study for Parents, English Version

Robot Programming and Use of Programs for Elementary School Students - Long-Term Learning Experiences

If your child agrees to participate in the study and as a guardian gives him or her permission to participate, please complete the consent form below by September 2, 2021. Participation is completely voluntary, and you can cancel the study later by notifying teacher [anonymized] or the researchers.

☐ I have read more about the study and discussed participation with my child. My child wants to participate in the study, and I give my consent for my child to participate

Name of guardian _____________
Child's first name _____________
Date _____________

Appendix B.2_ Informed Consent form of Pre-Study for Parents, Finnish Version

Alakouluisten robottiohjelmointi ja ohjelmien käyttö - Pitkäkestoiset oppimiskokemukset


☐ Olen lukenut tutkimuksen lisätiedot ja keskustellut lapseni kanssa osallistumisesta. Lapseni haluaa osallistua tutkimukseen ja annan suostumukseni lapseni osallistumiselle

Huoltajan nimi _____________
Lapsen etunimi _____________
Päiväys _____________
Appendix C.1_ Information Sheet of Pre-Study for Pupils, English Version

User Study Information Sheet: Primary school pupils programming robotic applications for their peers – Learning experiences during a long-term trial

Welcome! You have been invited to participate in a user study for a master’s study carried out by Chia-Hsin Wu, a student at Tampere University. The purpose of this user study is to focus on your learning experience of 1) programming robotic applications for peer’s learning, or 2) interacting with robotic applications programmed by peers. This is scientific research, meaning that we can publish some articles about the findings. However, your name or any identifiable information cannot be recognized from any of the publications, which makes participation in the study safe.

It is a 3-month user study that takes place every week from 12:15 to 13:45, in the class of the teacher [anonymized]. The class will take place from September to November 2021. During the class, the teacher will divide you into groups with other 5 to 7 pupils and assign tasks to interact with robotic applications. The study would need your assistance in testing a design program that hopes to support your in-class robotic activities. The study includes observation and group interviews for understanding your learning experience with robots. There will be no right or wrong answers to the interview questions, we would like to know your true opinion about the robotic learning activities.

You have complete freedom to decide whether you would like to participate in the study, and it is you also have the right to stop at any time by informing your parents or teacher. But all the data that has been collected will continue to be used for study purposes.

I sincerely hope that you will have a great time learning with the Nao robot!

Best regards,
Chia-Hsin Wu, the researcher of the study

Appendix C.2_ Information Sheet of Pre-Study for Pupils, Finnish Version

Tietoa tutkimuksesta: Alakoululaisten robottohjelmointi ja ohjelmien käyttö - Pitkäkestoiset oppimiskokemukset


Sinulla on vapaus valita, haluatko osallistua tutkimukseen vai et. Kerrotaan päätöksesi huoltajalleesi, niin hän välittää tiedon siitä meille. Voit myös myöhemmin ilmoittaa joko huoltajalleesi tai opettajalleesi, jos et haluakaan osallistua tutkimukseen.

Toivon, että sinulla tulee olemaan mukavaa robottien kanssa 😊

Ystävällisin terveisin,
opiskelija Chia-Hsin Wu

### Appendix D_ Observation Form of Pre-Study

<table>
<thead>
<tr>
<th>Date and interaction time:</th>
<th>Pupils’ task group:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Robot’s social character defined by pupils in this task group:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Teacher’s role and teaching method in this task group:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Learning goal, tasks and evaluation:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How do pupils react to the behavior of robot? Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>How do pupils managed to interact with the robot? (Interaction process)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What emotional reaction does the robot evoke in pupils? Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What went well?</th>
<th>Are there any unexpected issues? What could be improved?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Possible improvement methods:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>
Appendix E_ Interview Questions of Pre-Study

1. What do you think about the robot?
2. Do you prefer to learn with robot? Why?
3. Do you have any challenges in the use of the robot? What kind?
4. Do you like the appearance and gesture of the robot? Why?
5. What do you like about the robot? (Gesture, voice, features, application)
6. What social role do you feel the robot has? (Teacher, peer, student, assistant)
   How do you feel about it?
7. How do you interact with/program the robot? (What kind of task did you perform)
8. Do you have any suggestion for improving the robot?
Appendix F.1_ Questionnaire of Pre-Study, English Version

User Experience Survey
The purpose of this survey is to understand your learning experience today in the robotic programming class.

- Please select the picture which represent your emotion today while using the editor and/or interacting with the robot.

[Images of robots in different emotional states labeled Unhappy, Calm, Controlled, Happy, and Excited with numbers 1 to 5]

- Do you think robot is your

☐ Teacher  ☐ Classmate  ☐ Student  ☐ Other

- Do you like to learn with robot? Why or why not?

[Blank space for response]

- Can you describe what kind of challenge did you have while using the editor or interacting with the robot?

[Blank space for response]

- Do you have any suggestion for improving the robot or the editor?

[Blank space for response]

- Do you have other idea about the use of the robot and/or the class arrangement?

[Blank space for response]
Appendix F.2_ Questionnaire of Pre-Study, Finnish Version

Käyttökokemustutkimus
Tutkimuksen tarkoituksena on ymmärtää oppimiskokemuksia valinnaisainekurssilla. Valitse kuva, joka kuvastaa tunteitasi, joita sinulla on kun käytät roboettia ja editor-ohjelmaa.

Unhappy 1 2 3 4 5 Happy

Calm 1 2 3 4 5 Excited

Controlled 1 2 3 4 5 In controlled

- Onko robotti mielestäsi sinun...

☐ Opettajasi   ☐ Luokkakaveri   ☐ Oppilas   Joku muu ______________________

- Tykkäätkö opiskella robotin kanssa? Miksi tai miksi et?


- Mitä haasteita sinulla on ollut käyttäessäsi editor-ohjelmaa tai kun olet käyttänyt roboettia


- Miten parantaisit roboettia tai editor-ohjelmaa?


- Onko sinulla ideoita robotin käytöstä tunneilla?


Appendix G: Affinity Diagram of Pre-study's Qualitative Result

<table>
<thead>
<tr>
<th>Date/ student group</th>
<th>Task/Teacher</th>
<th>Observation notes</th>
<th>Situation</th>
<th>Pupils’ and teacher’s point of view / observed reaction</th>
<th>Conclusion</th>
<th>Design direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/3, 5&amp;6th graders: N=14</td>
<td>Introduced the usage of Elias Robot</td>
<td>Most pupils had robotics learning experience as they were quite handy with it. They even applied knowledge from language, mathematics, and history while programming.</td>
<td>I was able to observe two groups out of three due to the situation of submitted consent. Pupils were automatically divided themselves into groups.</td>
<td>Student POV: Pupils said they selected this class because it sounds new and fun, after first time trying, they like this class more than others due to the complete freedom of interacting with the robot.</td>
<td>The interview will start from the second visit. The teacher online questionnaire and interview will be changed to “report form” meaning discussing the in-class testing methods and design direction.</td>
<td>Instructional video about the use of Nao and Elias Robot.</td>
</tr>
<tr>
<td>9/17, 5&amp;6th graders: N=21</td>
<td>Demonstrated on the usage of animation code in the Elias Robot</td>
<td>Some pupils were more focused on the task than the first time of free exploration on Nao and Elias Robot.</td>
<td>Pupils were a bit frustrated when the animation didn’t work in the “chat” section. Regularly pupils check the printed list and manually type the animation list when timing and time-consuming.</td>
<td>Some robotic applications pupils created were very good, e.g., recognizing fruit. It can be good to let 4th graders test the program next week.</td>
<td>An add-on function for Elias Robot which can be beneficial to guide pupils adding the animation code while programming.</td>
<td></td>
</tr>
<tr>
<td>10/1, 5&amp;6th graders: N=21</td>
<td>Showed some example robotic applications created by 5&amp;6th graders and assigned the tasks of the day</td>
<td>Some 4th graders expected the interaction with robot and get amazed by the movement. Others focused on the programming task and didn’t think about the interaction.</td>
<td>Pupils got quite happy with the animation list. They tried to plan to robot while having you contact for increasing voice recognition. It would be good to let 4th grader group test robotic applications from peers.</td>
<td>A webpage that consists of both instructional video about the use of Nao and the Elias Robot, and provide a preview of the animation list (gt)</td>
<td>A pop-up videoItalian instructing the usage of the current Elias Robot software and an add-on function about the usage and provision of animation code.</td>
<td></td>
</tr>
<tr>
<td>10/8, 4th graders: N=4</td>
<td>Showed some example robotic applications created by their peers</td>
<td>The group of 3 girls was more focused that others, but they lost interest eventually due to the technical problem. The SAM questionnaire was distributed at the end of the class.</td>
<td>Pupils were attached to the direct interaction of the robot, e.g., moved Nao and the reaction from touching their hands on Nao’s feet. They worked on the lesson Editor due to the enormous technical problem of the robot.</td>
<td>Pupils got bored and distracted. The Elias Robot and the Nao’s hardware need to be improved and meet the real situation in the classroom (i.e., no access to power). Consider the robotic application using the interactive website design.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10/15, 5&amp;6th graders: N=18</td>
<td>The teacher tested the robotic application “TUNI FOOD” with the whole class</td>
<td>Dialogue didn’t work as always. Teacher puffed pupils were scared by Nao’s witch laugh while the programmer pupils found it funny.</td>
<td>Pupils were clam and knew what to do right after being separated in groups. Teacher was especially amazed by the history program created by one pupil.</td>
<td>Elias Robot and animation list should be easier to use. Robot better help to maintain order in class (e.g., having silent music) and move along with embedded video link.</td>
<td>Considering how can I solve most of the current problem with the interactive website design.</td>
<td></td>
</tr>
</tbody>
</table>
Appendix H_ Interview Questions of Prototype Evaluation

1. Does the prototype have an understandable tutorial about programming robotic applications in Elias Robot?
2. Does the prototype have a clear user interface for you to navigate around?
3. Does the prototype have an attractive graphic design and color selection?
4. Do you prefer to use this prototype while learning with robot? Why?
5. Do you have any challenges in the use of the prototype? What kind?
6. What function do you like the most? (Meet Nao, Tutorial, Animation)
7. Do you have any suggestion for improving the prototype?
Appendix I_ The 3-point Likert Scale Questionnaire of Prototype Evaluation

**Nao Handbook_ Prototype Evaluation Form**

- Is the website easy to use?

![Likert Scale](image)

- How was your overall learning experience?

![Likert Scale](image)