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COLLABORATIVE LEARNING OF ROBOTICS WITH ELEMENTARY SCHOOL AND UNIVERSITY STUDENTS

Design of co-learning workshop and learning experiences

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ABSTRACT

Hilkka Lammi: Collaborative learning of robotics with elementary school and university students-Design of co-learning workshop and learning experiences
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In the future, the number of robots and their areas of application are expected to increase. Robotics literacy, knowledge and understanding of what robots are and what are their features, is a skill needed to form an appropriate relationship with the robots. Robot literacy is already taught to children in schools, but extra-curricular activities have been introduced in robotics education research as meaningful ways of learning different aspects of robots and robotics. The learners of robotics have benefited from co-learning experiences, where they collaborate with other groups of learners to solve problems and challenges together. Children collaborating in learning robotics with parents has proved to increase their knowledge, skills, and confidence regarding robots, and it has helped the parents to motivate their children to learn. The present research acknowledges the benefits of robotics co-learning for learners familiar with each other.

In this thesis, we designed and evaluated a co-learning robot workshop designed for the novel pairing of co-learners, 8^{th}-graders, and university students. The workshop consisted of three robot-related co-learning tasks, using robots Spot, QTrobot and Clicbot. The university students facilitated the workshop tasks. In the pre-study phase, we conducted a co-design week with one 15-year-old pupil participant, and we made an initial design for the workshop. Nine 8^{th}-graders and six university students participated in the workshop and the evaluation of it. The pupils' teacher participated in the pre-study and evaluation of the workshop. The workshop was held at Tampere University Hervanta campus in Robostudio, a multidisciplinary co-learning space with multiple robots.

The results of the co-learning robot workshop were positive, and the participants enjoyed the co-learning experience. The pupils learned about robots and programming, and the students learned about interacting with the pupils. Co-learning robot workshops are beneficial for the participants to learn about robots and about communicating with diverse people. However, there were some things to be improved in the workshop, such as communicating instructions or ice-breaking. We formed eight design implications from the gathered data for a more comfortable, safe, and fulfilling co-learning experience. The design implications include suggestions to put on effort into ice-breaking and visual instructions related to the tasks and safety. Additionally, to motivate the participants to learn, they should be given the freedom to make choices regarding their work.

Key words and terms: co-learning, robot literacy, human-centered design

CONTENTS

LIST OF ABBREVIATIONS

co-learning	collaborative learning
HCD	Human-Centered Design
HTI	Human-Technology Interaction
STEM	Science, Technology, Engineering, Mathematics

1 INTRODUCTION

This chapter gives the introduction to this thesis: what is the background and motivation for the topic, what are the research objectives and questions, and finally how this thesis is structured.

1.1 Background and Motivation

Robots are devices that perform complicated, often repetitive tasks automatically (Merriam-Webster, n.d.). Robots are becoming increasingly common in homes, workplaces, and other environments. There are practical home appliance robots, such as living assistance robots and nursing care robots (Purtill, 2019). There are food delivery robots (Aalto University, 2022) and robotic, self-driving cars (Yle News, 2022).

The number of robots is expected to increase in the future, which will alter our lives and ways of living. We must prepare for that by educating on robots and robotics. *Robotics literacy* is a skill that helps to form an appropriate relationship with robots. Robotics literacy includes knowledge of robots, the encouragement of curiosity related to robots and instruction of critical thinking and understanding intentions (Suto, 2013).

Robotics literacy and the broader subject of *informatics education* are still relatively new disciplines in European schools. The ways of teaching informatics education vary between countries based on the subject's name, the learning content, and the school subject the informatics education is included as a part of. The teachers are often left to fend for themselves. Informatics education or digital skills are essential for future generations for them to safely take an active part in a technology-driven and digital society (Eurydice, n.d.-b).

Robotics and programming go hand in hand in the technological education of children. Since 2016, programming has been included in the curriculum for pupils in Finnish elementary schools (Konttinen, 2016). Easily programmable, educational robots offer pupils great opportunities to learn about logical thinking and programming, as the robots' graphical, block-programming user interfaces are easy to understand. According to articles in Yle (abbr. for Yleisradio, Finnish national public broadcasting company), Finnish elementary schools use robots to practise programming and support learning other subjects (Vainio, 2016; Torikka, 2018).

Outside school or otherwise traditional learning contexts, there have been successful studies of robotics workshops, where the pupils *collaboratively learn (co-learn)* about robots and other subjects using robots. The co-learners in these studies were children learning with their parents, grandparents, and other, possibly older children (Ahtinen et al., 2023a; Kandlhofer et al., 2014; Angel-Fernandez & Vincze, 2018). Co-learning has proved to be an excellent means to educate children on robotics and has several benefits. Co-learning combines the knowledge of diverse people and enables them to help the team according to their skills and knowledge. It brings the people closer together, and in a family context, it helps the parents to motivate children to learn, which is essential for their education.

The existing co-learning robot studies include mainly children and their parents as co-learners. This thesis studies a novel pairing of co-learners in a robotics workshop. The participants are 8th-grade pupils and university students studying Human-Technology Interaction (HTI). Teenagers, as participants in the co-learning robot workshops, are not as represented as younger children in the studies. The HTI students will be facilitating the workshop. Facilitating and collaborating with diverse people are essential skills for a person studying in the field.

The workshop is held in *Robostudio*, a multidisciplinary, co-learning space located in Tampere University Hervanta campus. Robostudio was opened in 2022 for educational and research purposes. There is a varied selection of robots, from educational robots designed for younger users to enterprise-level robots such as *Spot* or *Temi*.

The topic of this thesis is related to a larger robotics co-learning activity organised in Robostudio and the work done in this thesis can be utilized for a possible new course or additional learning experience for existing courses.

1.2 Research Objectives and Questions

The topic of robotics co-learning has been studied from the perspective of young children co-learning with their parents. It has proved beneficial for both their knowledge and confidence in technology. Does the situation change when the co-learners are not familiar nor the same age group?

This thesis aims to explore what are the learning experiences like for the learners and provide information on designing and evaluating robot co-learning workshops where the participants could feel accomplished and learn new things.

The research questions are the following:

1. **What are the co-learning experiences on the social robot activities for school pupils and University students when learning together?**
2. **What are the design implications for a co-learning robot workshop for school pupils and University students?**

1.3 Structure of the Thesis

The structure of the thesis is briefly described in this chapter.

Chapter 2, Related Work, defines the terms and context of the study. It defines robots, robotics literature and co-learning about robots, and reviews the prior research conducted on the topic of co-learning robotics.

Chapter 3, Methodology, describes the research approach and process of this thesis. It describes the phases of this research and research methods used in the different phases of the thesis. The research platforms, three different robots are presented. Lastly, the chapter reports about the research ethics of this study.

Chapter 4, Pre-study, describes the initial studies conducted with a participant from target group and a teacher for the target group. Both participants helped defining the goals of the co-learning robot workshop. The chapter presents the findings from the study.

Chapter 5, Design, describes the design process of the co-learning robot workshop.

Chapter 6, Evaluation, present the second study conducted with participants. The section describes the methods, procedures and conclusions done in the evaluation.

Chapter 7, Discussion and Conclusions, summarises and interprets the findings of this thesis research. The section proposes good practises for designing robotics co-learning workshops, discusses the limitations of this research, and answers the research questions.

2 RELATED WORK

This thesis study involves using robots in the education of both 8th-grade pupils and university students, who are learning the topic collaboratively. To understand the context of the co-learning robot workshop for the target groups, it is important to understand the related terms and concepts. These terms and concepts are presented in this chapter.

2.1 Robotics literacy

Robotics literacy is a key term for the context of this thesis. Before defining robotics literacy, we first define the basics of robots in the next chapter.

2.1.1 Defining robot, robotics, and robotics literacy

Robot

Robots are machines that operate automatically, and their purpose is to replace human effort. They can resemble and perform functions like humans (humanoids) or have other forms (Moravec, 2022). By standard ISO 8373:2021 Robotics — Vocabulary, the term robot is defined as a "*programmed actuated mechanism with a degree of autonomy to perform locomotion, manipulation, or positioning*" (International Organization for Standardization [ISO], 2021, p. 1).

Robots have versatile uses, which they are designed for. We are describing the next two types: educational robot and social robot, because the terms are further used. These terms are not exclusive, and a robot can be included in many categories.

Educational Robot

Educational robots are a teaching resource that can be used both in and out of the school context. They can be used to enhance learners' interest, engagement, and academic achievement in various fields of STEM education but also outside STEM fields (Anwar et al., 2019). STEM is an acronym for subjects of study: Science, Technology, Engineering, and Mathematics (Cambridge Dictionary, 2023a). The use of educational robots aims to aid the learners to accumulate the knowledge by active construction, handling, and control of robotic environments, but also collaboration (De Cristóforis et al., 2013). According to Miller et al. (2008) the concept of educational robot includes both the hardware (preassembled or as kits or components) and the software (programming environments and code). Examples of educational robot are Clicbot, Alpha Mini, Kibo, and Lego Mindstorms.

Social Robot

According to Duffy, B. (2003, p. 177-178) a s*ocial robot* is:

> "*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*".

Social robots are autonomous or semi-autonomous, and they follow the behavioural patterns expected from them by the targeted users interacting and communicating with them (Bartneck & Forlizzi, 2004).

Examples of social robot are Alpha Mini, QTrobot, Nano, and Pepper.

Robotics

Robotics means "*the engineering discipline dealing with the design, construction, and operation of robots*" (Moravec, 2022, para. 1). Similarly, ISO standard 8373 defines robotics as the science and practice of designing, manufacturing, and applying robots.

In education, robotics is utilised for learners in all levels of education. In addition to STEM topics, such as programming, math, and problem-solving, robotics can even be utilised in teaching music and art (Miller & Nourbakhsh, 2016).

Robotics literacy

Educating on robotics is called robotics literacy. It refers to understanding what a robot is, how it looks like, how it works and how and where it can operate (robotic application areas). Robotics literacy is a form of technical literacy (Jäggle et al., 2019).

Additionally, robotics literacy is a form of *media literacy* and is the means of forming an appropriate relationship with intelligent robots (Suto, 2013).

According to IGI Global Dictionary, the term robotics literacy is not yet thoroughly defined, but has the following meaning:

> *"What is Robotics Literacy*
>
> *Encompasses the knowledge, skills, and attitudes specific to robotics a person is expected to demonstrate. The content of robotics literacy shares common grounds with STEM fields and needs to be further elaborated."* (IGI Global, n.d.a)

2.1.2 Importance of robotics literacy

Teaching robotics is beneficial for improving students' personal characteristics, skills, and abilities, such as creativity, collaboration, team-working, self-direction, communication skills, social and cross-cultural skills, and social responsibilities. These skills are essential in the future digitalised world (Khanlari, 2013).

Robotics and robotics literacy in early age may encourage women and minorities to pursue education and careers in technology fields, where said groups have been underrepresented (Cannon et al., 2007).

Different generations (born before or after the “home robot age”, “digital natives”) have different values and viewpoints towards robots, which can cause cross-generational problems. Robotics literacy may help to solve these problems. Using robots in improper ways can cause issues that robotics literacy could prevent. Robot literacy requests to think about (home) robots critically (Suto, 2013).

All in all, robotics literacy is beneficial both for individuals and societies. Individuals who are educated in robotics, have better tools to interact with robots, and they understand their functions. When more people are familiar with robots, it helps to design for a better *human-robot interaction* experience for a bigger robot user audience, which can benefit whole society.

2.1.3 Robotics literacy in schools

In a report *Informatics education at school in Europe* (Eurydice, 2022), education on robotics is included in areas called informatics education or digital literacy, and the terms and curriculums related to teaching robotics vary between European countries. Information education also includes subjects, such as programming, design and development, and safety and security.

Some elementary schools in European countries offer optional robotics studies, and some European countries “*mention robotics as an important area of informatics education, while other countries address robotics in relation to programming”* (Eurydice, 2022).

Robotic literacy is taught to school pupils of all ages around the world, and there are a lot of resources to teach robotics. The field is still relatively young, and the educators teaching the subject are “left to fend for themselves” (Fanny et al., 2020).

Schools often include teaching robotics in STEM subjects. The reason for utilising robotics in STEM subjects is that the robots provide concrete, authentic, accessible, and motivating experiences for children (Yuen et al., 2014).

On the other hand, out-of-school activities and context in robot workshops may motivate the learners and help them focus on increasing their knowledge of robotics (robotics literacy) (Jäggle et al., 2019).

2.1.4 Robotics workshops in Robostudio

The first iteration of co-learning robot workshops in Robostudio was conducted in the spring of 2022, and we participated as a facilitator. The co-learning model for these workshops is called *Robotour* (Ahtinen et al., 2023b). The Robotours were organised for pupils aged 10-14, and university students facilitated the groups.

The theme for the co-learning, in addition to robots, of those workshops was data privacy. The participating pupils learned about the robots which can transfer data through the cloud. There were a few different robot stations which had pre-programmed robot demos. Due to the uncertainty of some of the robot's data-transferring location and use, some social robots' usage was limited. The cameras had to be covered, and the robots had to be placed behind glass to limit picture and sound recording. Pictures or voices of people are considered private information.

Most pupils thought the workshop was a pleasant and positive experience, and they learned new things about the robots and their features. The pupils' feedback suggested that the workshop could have been longer, have more activities and they were interested in programming and building robots. They also wished to have an opportunity to ask more questions about robots (Ahtinen et al., 2023b).

From this feedback, we got the idea to include programming in the workshop, as the pupils could gain hands-on knowledge on how a robot is programmed to use its features.

2.2 Co-learning in robotics education

2.2.1 Definition of co-learning

Before exploring the benefits of co-learning in learning about robots, it is fundamental to understand what collaboration and co-learning mean.

According to Cambridge Dictionary (2023b), collaboration is a situation in which "*two or more people work together to create or achieve the same thing*".

Across academic fields, the term co-learning (short for collaborative learning) has different definitions, and it is challenging to provide a single comprehensive definition for it (Dillenbourg, 1999, pp. 1-2). The broad definition, according to Dillenbourg, is: "*a situation in which two or more people learn or attempt to learn something together*".

IGI Global Dictionary gives the following definition:

> *"Co-learning aims at the collaborative construction of knowledge, in which co-learners are able to expand their social networks, integrate open learning with collective research and co-author collaborative productions."* (IGI Global, n.d.b)

The people who participate in co-learning can be called co-learners. The co-learners have different reasons to work together: to solve a problem, complete a task, or create a product (Laal & Ghodsi, 2012).

The definition of co-learning is similar to the definition of collaboration, but with the difference of the goal to learn something in the process.

2.2.2 Benefits of co-learning

According to Laal & Ghodsi (2012), compared to individualistic or competitive working or learning, the learners benefit more from co-learning socially and psychologically, as co-learning results in "*more caring, supportive, and committed relationships; and greater psychological health, social competence, and self esteem*" (Laal & Ghodsi, 2012, p. 487). The co-learners achieve higher results and are more productive.

As informatics education and robotics literacy are essential skills of the future and working on solving real, complex engineering problems, collaboration in diverse teams is fundamental (Yuen et al., 2014). Working on IT or IT-related projects is often multidisciplinary and requires the ability to work with diverse groups of people. Co-learning experiences train the person to participate in the diverse collaboration.

2.2.3 Co-learning about robots

In this chapter we are exploring studies made on robotics co-learning. There are a few studies that focus on parents or grandparents supporting and collaborating with young children learning about robots. One study involves young children co-learning with teenagers.

Relkin et al. studied the effect of parents' support on children's informal learning experience with robots. The experience included co-learning about coding with a KIBO robot, which is a screenless robot which can be programmed with tangible wooden blocks. Parents engaged as coaches, who asked questions, offered suggestions, and verbally acknowledged the children's actions. The children's role in the workshop was described as playmates or planners. In a co-learning situation, the informal environment, instead of a classroom, and the support from family members resulted in children/families being more interested in coding and being more engaged (Relkin et al., 2020).

In the study by Chung & Santos (2018), children participated a Robofest Carnival, where they solved STEM challenges with the guidance of their parents. The parents were trained for the task beforehand, as they were not confident about their knowledge of STEM subjects. The Robofest Carnival program increased the students' knowledge of some STEM subjects. The program empowered the parents to inspire and motivate the children to learn STEM subjects, which has a significant role in the children's education. (Chung & Santos, 2018).

Bers (2007) presents *Projects InterActions*, a series of multigenerational constructionist workshops where the participants (parents and children 4-7 years old) were encouraged to learn by doing. They created their own robots, using Lego Mindstorms robotics kits and the Robolab drag-and-drop programming language, and learned about programming and building. Both parents and children gained confidence and competence regarding technology in general. Parents learned "*how to model learning by asking questions, managing frustration, and not giving up when things do not work as expected*" (Bers, 2007, p. 550). The new, technologically rich learning environment seemed to motivate non-traditional parent learners to join. Still, parents and children learn differently and have different experiences and exposure to IT.

Moreover, the workshop's parent participants, who were technically more skilled, benefited most from the workshop, as they already knew the basics. The article proposes that technologically-literate parents provide assistance to teachers using technology in the classroom and in need of extra hands. The parents participating in such workshops can "*begin to reflect about their own learning experiences and might become strong advocates for the power of learning with technology in early childhood*" (Bers, 2007, p. 550-551) and be allies for the teachers in the challenge of teaching technological literacy.

Also, Kandlhofer et al. (2014) conducted a cross-generational robotics project study. The learners were pre-school children, pupils, and pre-school children's grandparents. The term "co-learning" is not mentioned in the article. However, the idea is there: the participants were collaboratively solving different hands-on experiments, offering their help, and learning to use educational robots. The cross-generational concept was successful, and the pupils enjoyed the experience.

In 2018 Angel-Fernandez and Vincze published an article about an educational robot workshop, where they introduced a storytelling element. The storytelling robot workshop was expected to foster creativity. The participants (children aged 6-18) first learned about programming a robot, and the second session focused on storytelling. For the storytelling part, the participants were grouped according to their roles: designers of the story, technicians to create it and directors to coordinate the other groups' work. The stories would have to relate to the previously acquired knowledge in the workshop.

The participants liked learning in a group and felt it benefited their learning. They learned about robots and technology but did not acknowledge *creativity* or knowledge of art in design and implementation phases. Using creativity may have been unconscious to the participants, as it was possible to observe their engagement in the activities and possible improvement in creativity. The most difficult task in the workshops was for the the older participants to collaborate with the young children (Angel-Fernandez & Vincze, 2018).

Ahtinen et al. (2023a) conducted a co-learning social robot study, a Robocamp, where the participants were families, and the co-learning took place in the families' homes. For one month, the families were given weekly social robot challenges, which they did with an Alpha Mini robot. Alpha Mini is an educational and social robot that can be programmed with block-programming (Génération Robots, n.d.). Home as a location for co-learning created a safe and comfortable learning space. It allowed the learners to adopt their personal perspective for learning and find a suitable role in the experience according to their skills, age, willingness, and time resources. In general, the authors recommend including the freedom to conduct the co-learning tasks according to participants' preferences, for example, by giving open-ended and structured tasks.

Familiar context has its benefits, but the home context brings data privacy and safety challenges in addition to children being a vulnerable user group. A home is a private place, and the robots there should not cause insecurity. The freedom given for the task can also be challenging for children if the time used with the robot is unhealthy extensive or if the usage of the robot needs to be supervised. The learner must be allowed to quit the activity at any point (Ahtinen et al., 2023a).

2.3 Summary

Robotics literacy and technical literacy are the skills of the future and children need to be educated in it. Robotics are a versatile tool to teach and learn different subjects, robot or non-robot related, as they provide concrete hands-on experiments.

Parents have an important role in children's education by motivating and inspiring children, and co-learning has proved to be an efficient way to share knowledge and bring generations together in a positive way. Ideally co-learning allows the learners to find their suitable role and tasks according to their skillset and knowledge, so that the whole team of co-learners can achieve their mutual goal or solve a mutual challenge.

As presented, there are a few examples of children co-learning with parents and grandparents about robots, but not robot co-learning studies with students and teenagers. By students we mean university students, who are adults unfamiliar with the teenagers. In the context of this research, the co-learners in the situation are 8th-grade pupils (teenagers, 13-14 years old) and university students. We are aiming to find out, it these novel co-learner groups have similar positive experiences.

3 METHODOLOGY

3.1 Research approach and process

The research phases of this thesis are based on Human-Centred Design (HCD) process. In ISO 9241-210 standard Human-Centred Design is defined as an "*approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge and techniques*" (International Organization for Standardization, 2019). In this thesis, instead of interactive systems or a product, the approach is applied in the design of a co-learning robot workshop event.

The activities of the HCD (Figure 1.) development process are understanding and specifying the context of use, specifying the requirements of the users, prototyping, and evaluating the prototype. The purpose of the evaluation is to find out if the requirements are met. One of the principles of HCD is that the design process is iterative, which means the activities are repeated when necessary. The other principles are:

a. base the design upon understanding the context of use (user, task, environment)
b. throughout the design process, involve users in the design activities
c. user-centred evaluation drives and refines the design
d. take into consideration the whole user experience in the design process
e. include multidisciplinary skills and perspectives in the design team (ISO, 2019).

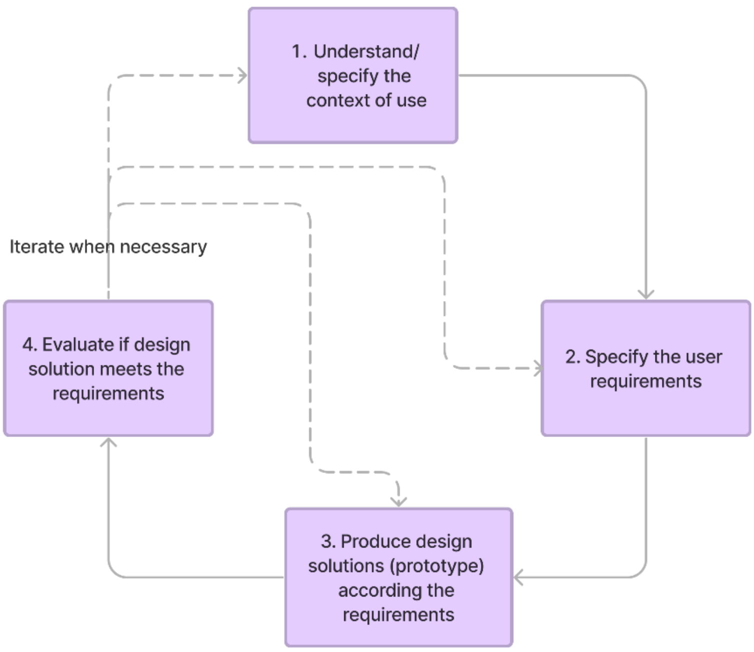

Figure 1. HCD approach design activities according to ISO (2019).

3.2 Research methods

Data gathering

The data gathering methods we utilised in this thesis include mainly qualitative data gathering methods, but the evaluation phase includes one questionnaire, which involves gathering quantitative data through a questionnaire.

Qualitative data helps to understand the experiences, meanings, and perspectives from the participant's point of view (Hammarberg et al., 2016). Qualitative data gathering is essential for gaining the knowledge of the participants experiences from the workshop.

We gathered the qualitative data through semi-structured interviews, observation, a questionnaire, and an essay writing assignment. We conducted all the semi-structured interviews during the pre-study and evaluation phases. One of the interviews was a group interview. The observation method we used during this thesis was free-form, and it contained observing the participants' verbal and non-verbal expressions, such as comments, behaviour, and expressions of feelings.

The quantitative data gathered in the questionnaire in workshop evaluation has questions for rating the experiences from 1 to 5 (1= disagree and 5=agree).

Data Analysis

As stated in the Data Gathering section, qualitative data is more dominant in this thesis. Data analysis methods are first described for qualitative data.

We utilised the thematic analysis method to analyse all three transcriptions of the semi-structured interviews. Thematic analysis is a qualitative method that involves identifying, analysing, and interpreting patterns of meaning (themes) within the data (Clarke & Braun, 2017). The advantages of thematic analysis include the suitability for diverse sample sizes and data collection methods.

For analysing the essay answers, we utilised an affinity diagramming technique. Affinity diagramming (or affinity mapping, the KJ method) is a technique commonly used in HCI research that can be used for organising qualitative data that is unstructured, far-ranging, and dissimilar in content (Lucero, 2015). We compiled the affinity diagram in an online software called Mural[1], which enables online sticky notes.

We analysed the small sample of quantitative data from the pupils' workshop evaluation questionnaire by calculating the averages for the ratings using Microsoft Excel software.

[1] *https://mural.co/*

The quantitative values can be utilised to support the results of the qualitative findings of the evaluation phase of the research.

3.3 Research phases

In this thesis research process, there are five phases, which are presented in Figure 2.

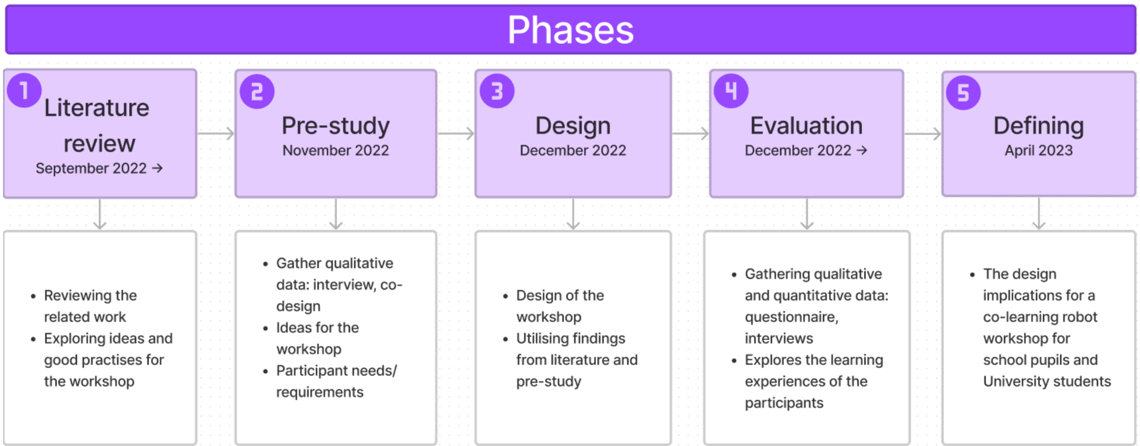

Figure 2. The research phases of the thesis.

Phase 1. Literature review

The first phase of the study was the literature review, which aims to define the framework and context of the study. The related work includes description of robots, educational and social robots. and robotics literacy. The content provides a review of robotics literacy and existing studies of co-learning robot workshops and discusses the benefits of co-learning in robotics context.

Phase 2. Pre-study

The second phase was the pre-study, which was conducted from the pupils' and a teachers' point of view. We had participants from both perspectives: a pupil and a teacher provided their insights about the workshop. Qualitative data was gathered from both the participants, and the goal of the pre-study phase was to understand the participants' needs and expectations in relation to the workshop.

Phase 3. Design of co-learning robot workshop

The third phase was the design phase, where the workshop contents and details were designed and planned. We utilised the information collected in the literature and pre-study phases. The facilitator participants were also included in this phase, and they had possibilities to make alteration to the workshop content.

Phase 4. Evaluation of co-learning robot workshop

The fourth phase of the thesis research was the evaluation phase, in which we conducted and evaluated the co-learning robot workshop. Both the 8^{th}-graders and university students took part in the workshop and the evaluation of it. Students took part in a group interview and pupils filled in a questionnaire and wrote essays. We analysed the material.

Phase 5. Defining design implications of co-learning robot workshop

The fifth and last phase of the research is utilising the findings from the evaluation and defining design implications of co-learning robotics workshop.

3.4 Research platform

During the whole process of this thesis research, we used all nine robots of the Robostudio collection. The robots are listed in Appendix A. They were all tested briefly in the pre-study phase.

From these robots, we consider only three of them as the research platforms of this thesis, as they were chosen and used in the design and evaluation phases as well. These robots are shown in Figure 3. and described in the text below.

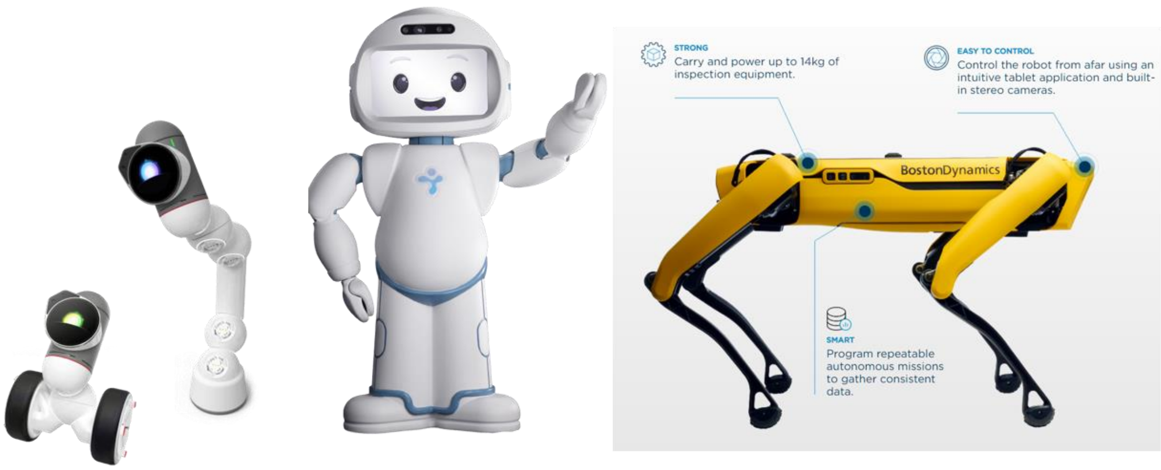

Figure 3. Two different built Clicbots (Source: *https://keyirobot.com/pages/products-page*), QTrobot waving (Source: *https://luxai.com/product/qtrobot-research-platform/*) and Spot (Source: *https://www.bostondynamics.com/products/spot*)

The chosen robots represent all quite different group of robots as they were designed for different use cases, and they have different features. In this research, they are all considered educational robots, because they are used for teaching.

Clicbot [2] is an educational robot, which is modular, which means it is possible to upgrade it with modules. The Clicbot robot is built and customized with particles, like a brain, joints, wheels, suction cups, and sensors. There are different-sized kits where the building particles vary.

With a Clicbot application, the robot can be programmed with block programming to make movements, sounds, and sense surroundings. The application also includes programming tutorials and a community for the users to share Clicbot projects. (KEYi Tech, n.d.). In Robostudio, there are a few different Clicbot kits.

QTrobot[3] is a humanoid social robot produced by LuxAI S.A. It is designed to be used principally in the education of autistic and other special needs children, as the robot has many pre-programmed facial expressions and hand gestures. QTrobot has different recognition or tracking features that can recognize users' emotions, poses, faces, speech and images. It can be programmed to say sentences with a text-to-speech feature in more than 30 languages. (LuxAI S.A., 2023).

QTrobot can be programmed with block programming in LuxAI's online Visual Studio or text-based programming languages Python, C++, or JavaScript. The robot comes with two tablets: Educator and Learner. The educator tablet runs the QTrobot programs and the educator can operate the programs with it, and the learner tablet is used for answering the educator's programmed questions (QTrobot Documentation, n.d.). Robostudio has one QTrobot.

Spot[4] (named *Tassu Spot Robonen* in Tampere University) is a four-legged mobile robot. Spot is an industrial robot, and it is designed to automate routine inspection tasks in versatile terrain. Spot comes with a tablet, which is used to control the robot and it is possible to upgrade it with "extras" such as arm, thermal camera, or radios (Boston Dynamics, n.d.). Using the tablet there are controls for moving forward/backwards, tilting the robot, climbing stairs, adjusting the height, and pre-programmed dance motions. Robostudio has one Spot robot.

3.5 Participants and research ethics

In this thesis study, we designed a co-learning robot workshop. The workshop was aimed at 8th-graders and university students, which were our target groups. 8th graders in Finnish elementary schools are typically 13-14 years old teenagers. 8th-graders were chosen

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[2] *https://keyirobot.com/en-eu/pages/products-page*

[3] *https://luxai.com/product/qtrobot-research-platform/*

[4] *https://www.bostondynamics.com/products/spot*

based on our experience from the last iteration of Robostudio co-learning workshops: teenagers seemed motivated and focused on the workshop. Another reason for choosing this age group was the research gap for the age group in co-learning studies. The other target group, Human-Technology Interaction students, was chosen for both practical and research gap reasons. The students would potentially need these facilitating experiences in work environments and are often eager to participate in each other's studies. The students being unfamiliar adults for the 8th graders were also a novel co-learning pairing.

In our research process we had three phases with participants involved. Furthermore, the pre-study and evaluation phases involved participants under 18 years old. When recruiting under 18 years old participants, we asked for consent from both the participants and their guardians. Concerning recruiting a whole pupil group, we also asked permission to participate in the study from the headmaster of their school.

In addition to acquiring participation consent, the participants, both pupils and students, had the option to give permission to be photographed in the workshop (under 18-year-olds' faces would not be shown). We asked the interviewed participants for permission to record the interviews. The consent form given to the students is in Appendix B. The consent forms for each participant group (pupils, students, teacher) are similar in content, but only the student version is in English. Participating in the study was voluntary, and the participants were free to quit the study without any explanation.

We provided the participants with a data privacy notice regarding collecting and handling private information, such as names. The names of the participants were only collected with the consent forms to know their willingness to participate. The data collected in consent forms are not connected with other collected data; therefore, the participants and the data they provide are anonymous.

We stored the collected data in a password-protected Microsoft Office platform (OneDrive, Forms), which Tampere University provides. We analysed the anonymous answers provided by the participants in the MURAL online platform, which is password protected.

4 PRE-STUDY

This chapter explains what was done in the pre-study phase of this thesis. The pre-study consists of an in-depth co-design week with a 9th-grade school pupil and an interview and evaluation session with a teacher. The studies are described separately in this chapter: first the study with the pupil and after that the teacher. Both studies were conducted in Finnish, therefore most of the notes, interview plan, and other study materials are in Finnish.

4.1 Co-design week with pupil

The co-design study was conducted in Robostudio at the Hervanta campus on 10.-14.10.2022. The study duration was 4 x 6-hour workdays, and Wednesday of that week was a break.

The purpose of the pre-study with the pupil was for us to familiarise with the target group, their goals, needs, and limitations. Additionally, the goal was to have a draft of the workshop task ideas, which would be co-designed with a member of target group.

During the week, all nine robots in Robostudio's collection were tested. The researchers in Robostudio and our colleague HTI student assisted with testing the robots. List of the robots is in Appendix A.

For providing written instructions for the participant and making co-designing and working more efficient, we used an online design/note tool called *Mural*. The instructions and templates were added to the Mural page daily. A screenshot from Mural is visible in Figure 4. below.

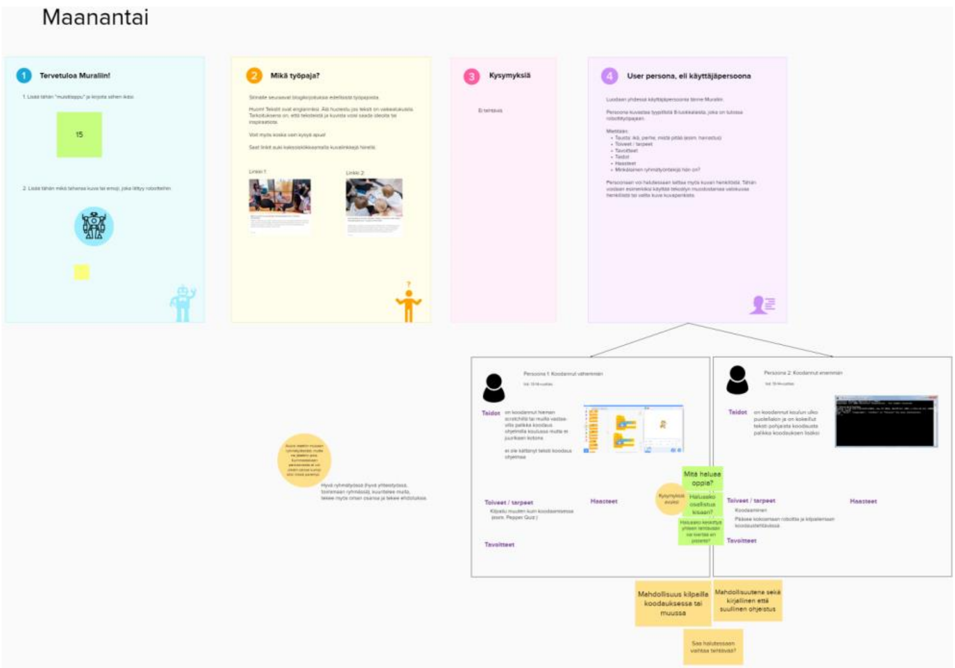

Figure 4. A view from Mural: First day tasks of the co-design week.

4.1.1 Participant

The supervisor of this thesis found the participant for the pre-study. The supervisor had been contacted by a colleague, who asked if it would be possible for a 9th-grader to do a mandatory work practice program (in Finnish TET = Työelämään tutustuminen) in Robostudio. They considered Robostudio because the pupil is interested in robots, which was ideal for a participant in the pre-study. They are also close to the target age group. More information regarding the participant is in Table 1. below.

The pupil did half of their work practice program (one week) in Robostudio, and four days of that week they participated in the pre-study. The participant brought their computer to use during the study.

Table 1. Information regarding the pupil participant

Attribute	Participant's info
Age	15
Studies	9th grade in secondary school
Interests (by interview and observation)	Using and building robots, technical problem solving
Programming experience	Has programmed more than average 9th-grade pupil. In addition to block programming (which is taught in school for all groups) with *Scratch*, knows some text-based programming with Python
Experience with robots	Lego Mastermind, some other robots

In the pre-study phase, there was only one pupil participant. However, the long duration of the study made it possible to break the ice and utilise many of the available robots extensively. We were able to familiarise ourselves with the available robots and explore their programming possibilities regarding the workshop tasks.

4.1.2 Methods

As the pre-study duration was long, we could utilise many research methods. The main method frame for design was *co-design***.** Co-design or participatory design means "*a design approach that attempts to actively involve all stakeholders (e.g., employees, partners, customers, citizens, end users) in the design process to help ensure that the outcome meets their needs"* (IGI Global, n.d.c). The participant is the target groups stakeholder and is collaborating with us to design a co-learning robot workshop for the target group.

A summary of pre-study week's tasks of each day is presented in Table 2.

Table 2. Co-design week tasks

Monday	Tuesday	Thursday	Friday
Introduction to the study	Taking Spot robot for a walk	QTrobot Demo	Programming Alpha robot
Interview: background and robots, programming	Building and programming Clicbot	Starting the rating of the Robostudio robots	Programming Pepper robot
Practising using Mural	Programming Cozmo (1)	Ideating and listing out ideas for workshops robot tasks	Programming Nao robot
Introducing robot workshops in Robostudio		Programming Alpha Mini robot	Finalising the robot rating
Interview: Discussing the workshop		Programming Cozmo (2)	Summarising workshop task ideas
Pepper robot demo: Tampere quiz			Interview about the pre-study experience in Robostudio
Demo of Temi robot following a person			
Creating personas of the target group			
Creating a catalog n Mural of Robostudio robots			

During the pre-study week, we observed and interviewed the participant three times. The first interview was the background interview, where we had pre-defined questions about the participant's knowledge of robots and programming. The second interview was about the previous iteration of the co-learning robot workshops and the initial idea of the workshops. The third interview was at the end of the co-design week, where we asked about the participant's experiences during the co-design week. In addition to these primary interviews (background, workshop idea, and final interview), we asked questions about each of the robots while the participant was testing the robots during the week.

Regarding the first day's interviews, we soon learned that the planned questions were too broad and challenging to answer, and the participant commented on some question that it was quite a broad question). We adjusted the style of working from extensive interviewing to include much more concrete, hands-on working with the robots, so that the participant could have better understanding of the possibilities of the robots in the workshop. We also learned we had underestimated the participants willingness to test out and program the robots.

The pre-study with a pupil participant included some anthropological study**,** as this was the first time, we have extensively worked with this age group. The pre-study with the pupil gives some understanding of how-to time tasks and how to give instructions.

To broaden the knowledge of the age group, we made two *personas* to represent the target group of the workshop. Persona in HTI means a fictional representation of a user or other target group person and it can include the person's behaviours and motivations (Aquino & Filgueiras, 2005). The persona often includes the person's goals and made-up personal details to make them feel real. The purpose of creating a persona is to focus on the target group's goals instead of the tasks (Blomkvist, 2002). The co-designed personas, which are in Finnish, are presented in Appendix C.

The first persona is more experienced in programming (as the participant), and the other has basic knowledge/skills in programming. We also tried to think about other skills needed in the workshop, such as teamwork skills, but we thought this would strengthen too much a common prejudice of the technically skilled people being more socially challenged. On the other hand, it would not have been realistic that the technical person was also better in all the other skills, such as social skills:

> "*The other cannot be objectively better in everything."* (Participant)

To have a "database" to work with, we created a mind map of the robots listing their names and features. The mind map made it easier to discuss and remember the available robots. Some robots may have data security issues, as it is not known where they might send data, so it was also beneficial to list these.

During the pre-study week, we ideated some tasks for the workshop.

After reviewing/testing most of the robots, we asked the pupil to give a rating to the robots either using 1-5 grade or a tool/template called a *Tier list:*

> *"A tier list is a ranking system that allows you to rank anything in tiers from the best to worst. Using a tier list allows you to group similar ranked items together and it's quick and easy to create a tier list."* (TierMaker, n.d.)

We gave Tier list as an option because it is popular in gaming culture and the participant was interested in video games. The participant chose the Tier list option. The purpose of the rating and reviewing was to make the participant consider the qualities of the robots and think about what makes the robots interesting/fun but also to inspire the participant to ideate more with the robots that seem interesting to them. Also, we asked the participant to explain the grading system: what is the rating based on? They explained that the rating is not based only on what is fun but also on what are technically advanced robots. We decided to use the default rating variables of the tier list (S being the best, D worst), but it was also possible to give them new descriptions. The created Tier list with the robots is shown in the findings.

After the pre-study week with the participant, we analysed the notes and Mural canvas using content analysis.

4.1.3 Findings

The following findings were made of the pre-study with the pupil participant:

Pupils most probably have previous experience of block-programming and robots.
The participant has used *Scratch* programming environment and thinks that many schools use it. They have also programmed with Lego Mindstorms and seen more robots in school.

"Malfunctioning" of the robots is fun.
The participant visibly enjoyed it when robots did something unexpected or appeared to malfunction. They programmed Alpha Mini to say a fake error message and found it amusing when QTrobot said English sentences in the wrong settings with a Finnish accent.

Informal tasks are engaging.
The participant was allowed to choose the way of reviewing the robots formally or informally. They chose the informal Tier list way and were engaged in doing the task. The freedom of making the decision may have also contributed to the engagement.

There should be options for programming tasks.
The participant was interested in programming and robotics but acknowledged that not everyone likes programming. It could be beneficial to have alternative tasks as well and have the option to switch tasks instead of having one task that would take the whole workshop duration.

Some pupils may be more courageous using robots.
When controlling the Spot robot outside, the participant made some risky movements against the instructions with the robot. No harm was done to the robot, but it is necessary to everyone to carefully handle the property that is in shared use.

Pupils expect technical guidance from the facilitator students.
When asked about the role of the students in the workshop, the participants expect them to provide technical guidance.

Spot and Temi were ranked the best.

The pupil ranked Spot and Temi, that are not traditionally educational robots, as the best, because they were fun and technologically advanced. The second-best robots were Nao, which could move well compared to other robots and Clicbot, which allowed more creativity. On the lowest ranking were Alpha, because it couldn't talk and Alpha Mini, because there were limitations to its programming (not being able to make facial expressions with movements). The whole ranking is shown in Figure 5.

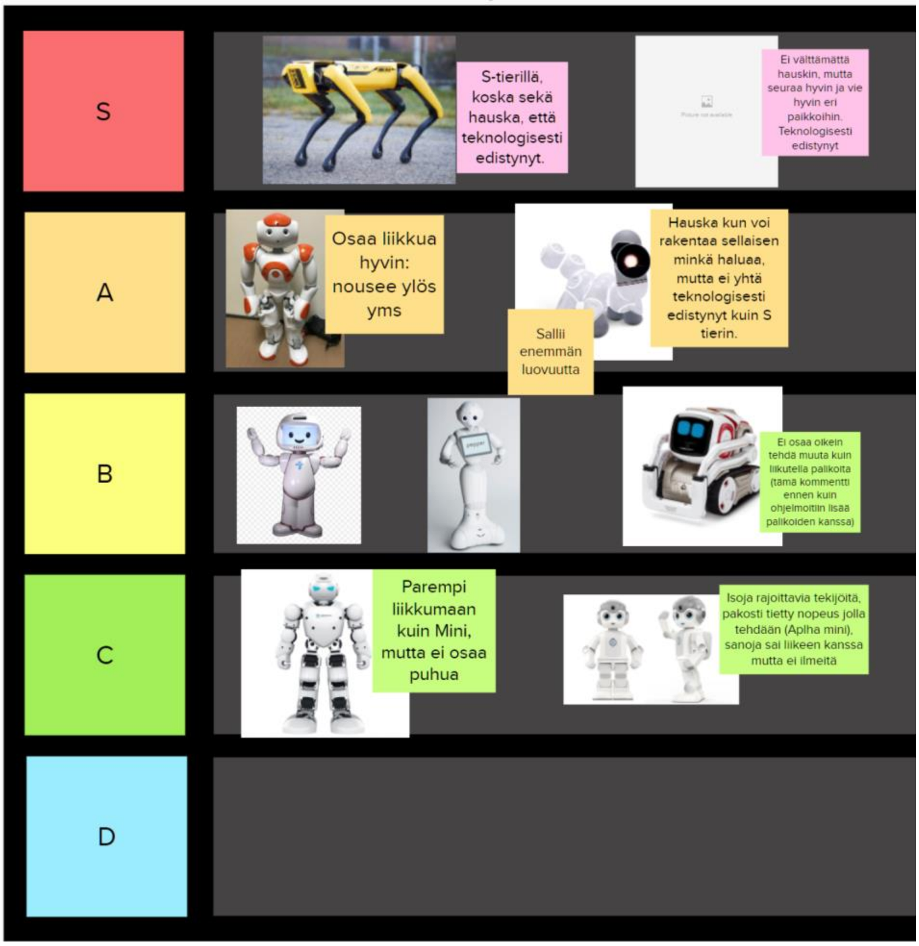

Figure 5. Robostudio robots ranked in Tier list by the pupil. Robots in upper rows are considered best.

Task ideas were versatile.

The co-designed ideas included tasks for six robots: Spot, Clicbot, QTrobot, Nao, Alpha Mini and Cozmo. Most of these robots had a good ranking in Tier list, which is why we tried to include tasks for them. Some tasks are designed for having more than one of the chosen robots, and two teams would use the robot to compete against each other (race competition) or to have one free form task and one instructed. Three task ideas involved using a maze or a track for navigating the robot through. The track tasks would have playful speed competition added. Some ideas concentrated on singular features of some robots ("picking an object from the floor with Nao robot"), which might not be enough for the whole workshop task. The pupil enjoyed building and programming a custom robot with Clicbot, so that was included as a task idea.

An overview of the task ideas is shown in Figure 6.

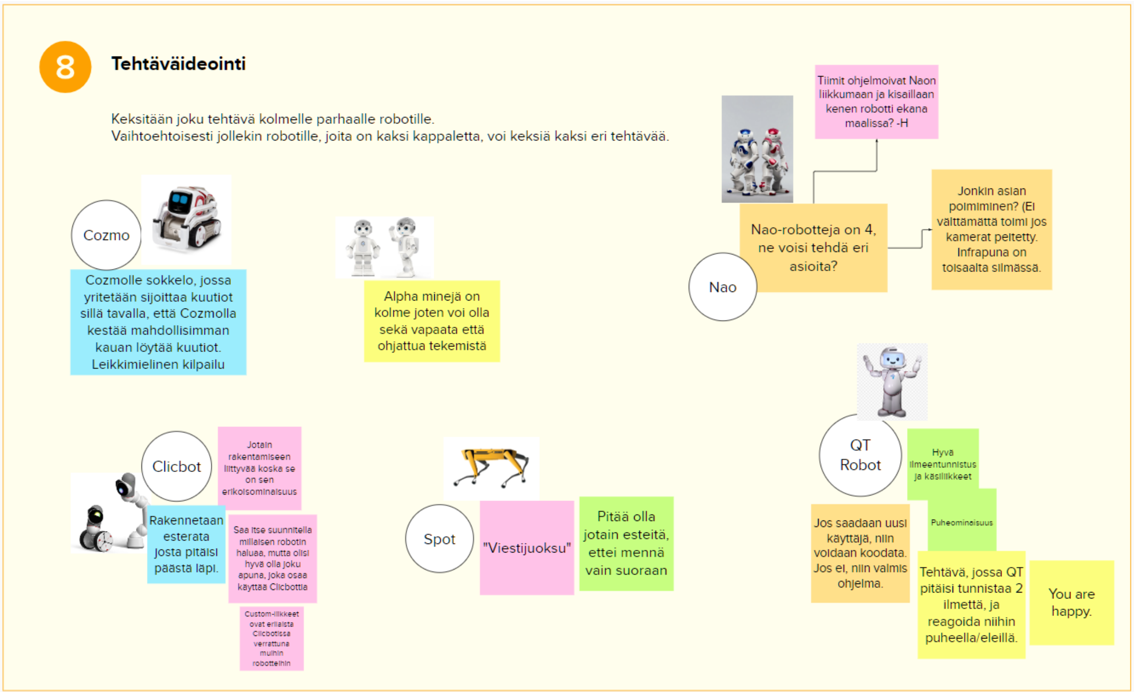

Figure 6. Screenshot of ideas for robot tasks.

4.2 Interview with the teacher

After the co-design week with the pupil participant, we interviewed the teacher who would bring their class to the workshop. The purpose of the interview was to find out the expectations and needs for the workshop from the teacher's point of view and to evaluate the possibilities of including programming the robots in the workshop.

4.2.1 Participant

The interviewed teacher participated in a previous workshop organized in Robostudio in the Spring of 2022 with a group studying in the same robotics class. The teacher already has some foreknowledge on the workshop, Robostudio co-working space, and some of the resources that are available there.

The teacher teaches classes from 7 to 9 (Finnish secondary school). Programming is taught as part of mathematics and robotics classes in weeklong periods a few times during 7-9 grades. The robotics class is an optional study that the pupils can select from different subjects, and this class will join the workshop.

Programming is taught with different tools: text-based programming with Python programming language, e.g., with math-related tasks, and block programming with Lego robots.

4.2.2 Methods

The interview type was the semi-structured interview. We transcribed the interview recording and conducted a thematic analysis of the transcription. The language of the interview was Finnish; therefore, the interview plan is in Finnish. The interview plan is in Appendix D. The quotations from the teacher are translated into English.

We divided the interview questions into four themes:

1. **Background:** This section focuses on how programming is taught: in which classes, and what tools are used. The section also includes questions of the opinions about the programming tools and programming itself, such as "How is pupils' attitude towards programming?".
2. **Expectations, needs, and wishes:** This section includes some reflection on the previous workshop in the Spring of 2022: what was good, and was there something missing? These questions were discussed both from teachers' and pupils' views. The purpose of discussing the previous workshop was to make some variations to the workshops. The section focuses on the expectations towards the workshop in general, the students, and the tasks.
3. **(Challenges:** This section gives question ideas for the interviewer if the challenges related to the suggested topics aren't otherwise discussed during the discussion of the other themes.)
4. **About workshop tasks:** In the last section of the interview, there is a brief evaluation of some of the ideas or thoughts that came from the 1st part of the pre-study: programming vs other types of tasks, 1 task for each small group vs circling between different tasks, and giving free hands with programming vs giving clear instructions on what should be done.

4.2.3 Findings

Here are the findings from the interview with a teacher:

Not everyone enjoys programming.
While conducting the pre-study with the pupil participant, there was a discussion on if all the participants were eager to do programming-related tasks in the workshop. The interview with the teacher reinforced this assumption. There could be other types of tasks with the robots, as the pupils have diverse programming skills.

Prioritizing a motivating and casual atmosphere.
The workshop should have a fun and inspiring experience with robots prioritized for every participant instead of limiting the workshop tasks solely to programming-related tasks using robots. The pupils might find the workshop more fun if they can choose which tasks they want to do.

The relaxed atmosphere motivates the pupils to try out new things and be active by themselves.

> *” I think there was a lot of good in the previous workshop, like the atmosphere was somehow really good. That may have been the most important thing for me because it kind of made the pupils motivated to work and to really try. That is perhaps the most important thing of all and the fact that the students themselves get to be active and participate*.”

Pupils may have different needs regarding instructions.
Some pupils enjoy working without specific instructions, and some need them to progress with robots. There could be options for both work styles, but the pupils can work either way.

> ”*Some of the groups definitely want to use ready-made instructions and we have searched those online. Then some want to do it themselves, that they don’t want the ready-made instructions at all. But they* (all pupils) *can work either way.”*

Some pupils might need help with progress.
Some pupils may need help progressing in tasks, as they might get too interested in more minor details. There are some tools to help with this. We can nudge the pupils when they are stuck and help them to accept the state of some part of the task by stating that it is ok as it is. Another hint is to provide some task information before the workshop so that pupils can prepare.

Wishes regarding the use of robots in the workshop.
The last time the teacher brought their class to the workshop, the pupils wished to interact more with the robots, which social robots are designed for. At that time, some interactions were limited because of data privacy issues.

> *” The pupils would have liked to discuss with the robots. It was probably because of the data protection and such, that it didn’t work out that time, but that would probably have been terribly nice for them."*

4.3 Summary

Both a pupil and a teacher participated in the pre-study and provided insights regarding a robot workshop. The initial idea of designing a robot programming workshop changed because some students might not like programming, and providing everyone with a positive experience using robots is more critical. Other choices than programming tasks should be given as well. The co-learning robot workshop should be a positive and motivating experience for everyone, and participants should be able to learn something new.

The informal and playful style of the task can motivate the pupil to participate, and the pupils are interested in interacting with the robots. Technical guidance and other help should be given when needed.

5 DESIGN

5.1 Defining the workshop tasks

In the pre-study phase, we learned that instead of pushing the idea of programming, the co-learning robot workshop should be a positive and motivating experience for everyone. The related work presents a policy that can help to provide a positive learning experience for the co-learners. The policy is giving the learners freedom to find a suitable way for them to learn and participate (Ahtinen et al., 2023a).

After the pre-study we were contemplating if the robot workshop should have one big task for each team or if the teams would switch tasks during the workshop. When including a programming task, it is crucial to allocate enough time for familiarizing with a new programming environment. The pre-study suggested that all the pupils do not like programming, so we made the decision to have multiple tasks that the pupil teams can choose from and one of the tasks does not involve any programming. Programming was still included in because it enables the learners to have the hands-on experience, which is one of the goals of educational robots (De Cristóforis et al., 2013).

In the pre-study phase, we co-designed some tasks or challenge ideas for the workshop with the pupil participant. Here is a summary of the ideated tasks:

1. Racing with robots: two similar robots racing each other or one robot that everyone controls individually for a round.
2. Building a maze or obstacles for a robot to navigate.
3. Building and programming a custom robot (from Clicbot parts).

The ratings given for the robots in the pre-study phase were utilised at this phase. We wanted to consider the robots that were ranked higher by the pupil in pre-study, but also consider the data privacy matter, and aim to choose robots that don’t have those issues.

The final task ideas are collected from the initial ideas and the decisions of robots, that were interesting to the target group and data secure. The final tasks for the robot workshop are presented with photos in the next chapter.

5.2 Robot stations

To structure the workshops tasks and resources, we divided them into *stations*. A station includes a robot, a task related to it, and other resources such as space, tech appliances and stationery. In total, three robot stations were designed for the workshop. The stations were all situated in Hervanta Campus in Robostudio or nearby rooms. Two of them, Clicbot and QTrobot stations, have block-programming tasks, and Spot station has a design task.

We were given one hour and 45 minutes for the whole workshop and we timed each station to last 35 minutes. Before the stations, we allocated time for giving instructions, dividing into groups, and explaining the stations. We also gathered after the workshop to go through the tasks done in the stations, to fill in a feedback questionnaire and to give an essay assignment for the pupils. The questionnaire and essay assignment are described in the chapter 6. Evaluation.

The workshop station tasks are shortly described in the following paragraphs. The photos illustrating the station descriptions are taken from the workshop.

5.2.1 Clicbot rally car competition

Clicbot stations idea is to build and program a simple rally car. The shape of the robot is defined beforehand. After building and programming the movements of the robot, the pupils have a playful racing competition. The idea of timing the rounds came from the facilitators of the workshop.

Instructions for Clicbot station are in Appendix E. Photos of the workshop are in Figure 7 and 8.

Figure 7. A group programming Clicbot.

Figure 8. Driving Clicbot rally car between obstacles.

5.2.2 QTrobot quiz programming

In QTrobot station, the pupils design and program a quiz using the QTrobot Visual Studio editor. In the quiz, the robot can read the questions out loud, and the answer to the question can be given by choosing a picture from the learner's tablet. To make the task motivating, the pupils can choose the topic of the quiz and then form a couple of questions about the topic. Instructions for QTrobot station are in Appendix F. A photo of the workshop is in Figure 9.

Figure 9. Facilitators and pupils viewing the QTrobot code. The code is visible on laptop and the TV screen.

5.2.3 Spot (Tassu) controlling and designing task

Spot station is the only station without programming, and it is a more design-oriented station compared to others. At first, the pupils control Spot in different environments inside the Hervanta campus, as outside is inconvenient in Finnish snowy December weather.

Controlling Spot gives the pupils some idea of how the robot moves and works. After testing out Spot, the pupils ideate different usage for Spot, and create a mindmap out of the ideas. If needed, the participants can use *Experience Design Cards for Social Robotics*, which are designed to help in the design of social robots (Islam, 2021).

Instructions for Spot station are in Appendix G. A photo of the workshop is in Figure 10.

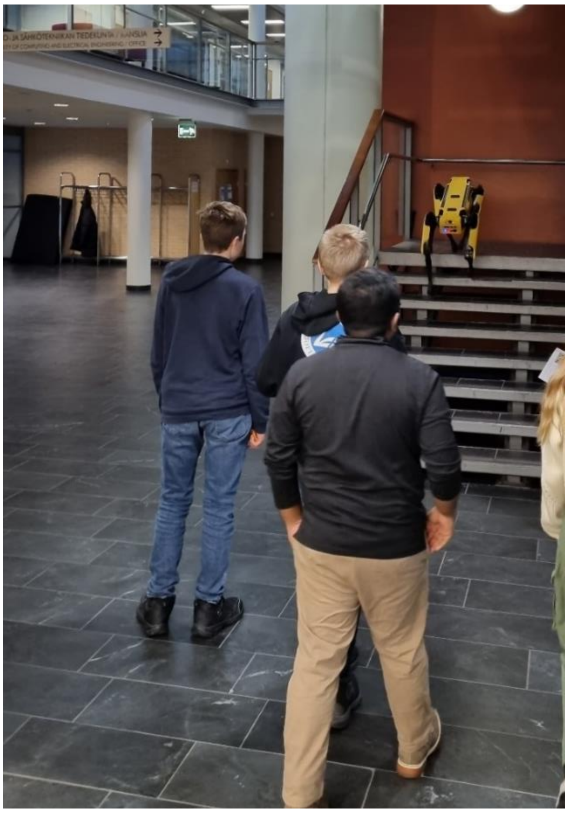

Figure 10. Pupils navigating Spot upstairs in Hervanta campus.

5.3 Visualising the workshop

To be in control of the entirety of the workshop, we visualised a mind map utilising Mural. The mind map is shown in Appendix H. Mind map is a type of diagram for organising information so that it is easier to use or remember (Cambridge Dictionary, 2023c). It enabled considering many resources or requirements, such as workshop goals, tasks, needs, participants, timing, and tools. According to Chen (2008, p. 1035), "*the mind map provides an effective graphic tool for designers, by the using of both picture and language techniques, in order to turn on the unlimited potential ofthe human's brain.*".

To share the content and idea of the workshop, we created a shared document. In the start of the document, we have the schedule of the workshop. The document includes the descriptions of the three robot stations: the facilitator, tasks, and tools. The document (facilitator identifications removed) in is Appendix I.

In addition to schedule and tasks, the document has a brief section for information about working with pupils, who experience *executive dysfunction*. We collected this data to make the workshop more accessible and it is an essential practise to consider diverse participants.

5.4 Organising a planning and practice session

Before the workshop, we asked the students who would facilitate the workshop to participate in a planning and practice session. We left some things to be solved and designed in this session. This was made to make the experience more motivating to the facilitators as co-learners. The session was organized for:

1. Making the final station assigning for the facilitators
2. Reviewing, adjusting and practicing the tasks
3. Listing and testing tools and spaces used in the workshop.

In the next chapters we describe the participants and how the planning/practice session was.

5.4.1 Participants

We recruited six students to be facilitators in the co-learning robot workshop. They were all master's students in the Human-Technology Interaction field. They were recruited among friend students and from a Human-Technology Interaction course *User Experience in Robotics*, which was ongoing during the workshop. The recruiting advertisement is in Appendix J. Some had participated in the previous workshops organised in the Spring of 2022. Most facilitators were in the age group of 25-29 years old, and their nationalities were diverse: they were from three different continents.

We divided the facilitators into three pairs, and the pairs were each assigned one robot station. The facilitators were assigned to the robot stations based on their previous experience of the chosen robots and their interests. We defined an id for all the facilitators (Table 3.), which are later used in the evaluation chapter when referring to the facilitators. The contents of the robot stations are described in previous chapters.

Table 3. The IDs of facilitators and their station.

ID	Station
F1	Spot
F2	Spot
F3	QTrobot
F4	QTrobot
F5	Clicbot
F6	Clicbot

5.4.2 Agenda and solutions in planning and practise session

The first thing in the planning/practice session was to decide the ice-breaking methods in the beginning of the workshop. As icebreaking with the pupils, we decided to use Spot robot for bringing candy to the pupils. It would also provide a small preview of one of the station's contents.

Another issue to solve together was the data privacy actions for one of the stations. Instead of taking Clicbot behind a glass, it was decided to use background music to avoid potential clear audio data to be transferred to unknown location. The camera of the robot was covered since it was only needed to read a single QR code at the start of programming the robot.

After the common matters were reviewed and agreed on, the pairs of facilitators practiced their station. The facilitators evaluated how much time would be needed for each task and, if needed, what should be added to the 30min stations. Spot station seemed short of tasks, as it only included steering Spot robot and a small design task for ideating usage for Spot. The facilitators gave their insights on the tasks regarding what kind of tasks were age appropriate for teenagers and not too juvenile. They helped structure Spot station, which had too vague content, by defining its motive: the pupils control Spot because they need to understand its possibilities and limitations before designing its usage. Clicbot station's facilitators prepared additional props to the rally car track, which was a welcome way to make the experience more motivating for them.

After the session, we made sure that the needed equipment was charged and available and that there were written instructions for each robot station to provide an alternative to spoken instructions. Some facilitators continued practising with the robots.

6 EVALUATION

The following chapters provide more detailed information regarding the evaluation. During the evaluation phase, we used the following methods in Figure 11. to gather data from each of the participant groups:

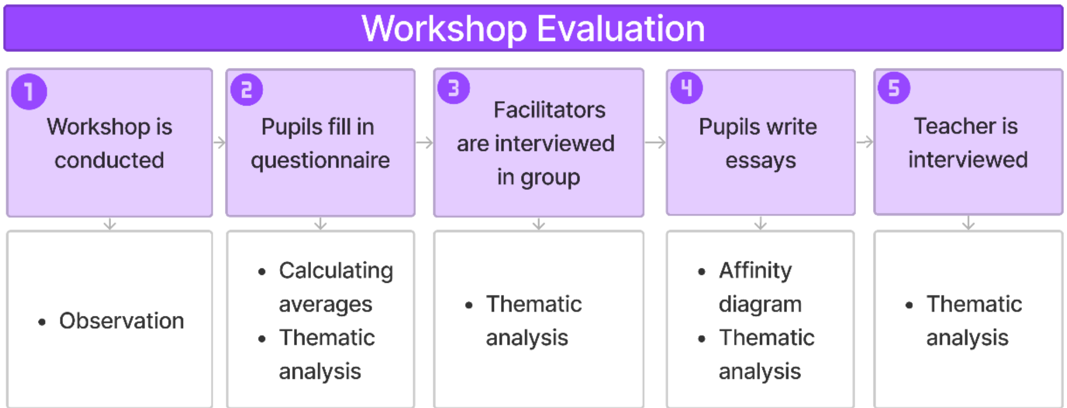

Figure 11. Phases of the evaluation. Questionnaire and essays from the pupils are presented together in the chapter.

The evaluation starts from conducting the workshop. We observed the participants in this step. After the workshop, the pupils filled in a feedback questionnaire, and they were assigned to write an essay as homework. Then we interviewed the facilitators in a group interview and a couple weeks later, we interviewed the teacher.

6.1 Participants

Nine pupils, six university students and a teacher participated in the co-learning robot workshop and the evaluation of it.

The university students are previously presented in Design chapter 5.4.1. and the teacher is presented in Pre-study chapter 4.2.1 and

Pupils

Nine 8th-grader pupils in total participated in the workshop. The pupils are studying in a voluntary course where they learn about robots. Seven of the pupils had permission from themselves and their guardians to participate in the study, so we only utilised these pupils' comments or thoughts in this thesis.

We divided the pupils into three groups of three pupils, and the teacher made the division before the workshop. At the beginning of the workshop, we gave group numbers to the pupils as post-it tags.

6.2 Notes and observations from the workshop

In this chapter we present the observations and notes we did during the workshop.

When the workshop started, we gave the pupil groups a chance to go to a station they found interesting based on a short introductory description of the station. Some pupils expressed their willingness to go to a certain station and other went to what is left. Spot seemed to gain interest from the start.

In the stations the pupils appeared shy at first, but they warmed when the time passed. Pupils working in the stations gave turns to others politely, they provided hints for others, and they asked translation help from each other. The pupils often spoke Finnish with each other.

In Clicbot station the pupils struggled to build the robot, but both teams were able to build and program it, so that the goal of the station was fulfilled. The pupils did not seem very excited about the racing competition, that the facilitators organised, but everyone participated.

The stations had quite different atmospheres: Clicbot stations had background music of current Finnish radio hits to as a data privacy measure, but it may have had an alternative role as icebreaker. The music seemed to make the pupils more relaxed. The effect of background music as an icebreaker in the co-learning workshop context could be a potential topic for further research.

In comparison, QTrobot station, which is the other programming station, was very quiet. The teams seemed to struggle with the programming task, which turned out to be too challenging and the QTrobot was not functioning properly. For the second group of the station, the content of the station was altered. The facilitators showed pre-programmed demo, which could detect the gender of the user by facial recognition AI. It did not work properly with multiple users and gave false definitions which was funny to the pupils. Still, after the change, the pupils were able to see and learn more about the robot.

Spot station did not seem to have any problems. The pupils shared turns testing the robot and ideated a lot of versatile usage for it. The ideas included: a guard dog, checking people’s suitcases in airport, food delivery, finding and rescuing people, and aiding elderly people to go outside during winter. Some ideas seemed to be familiar for the pupils from previous knowledge about Spot, but there were some novel ideas as well.

6.3 Pupils evaluating the workshop

After the workshop, we asked the pupils to fill in a feedback questionnaire and gave them an essay assignment regarding the workshop. The questionnaire is in Appendix K and the Finnish essay instructions are in Appendix L.

6.3.1 Questionnaire

The purpose of the questionnaire was to collect the initial thoughts and opinions about the workshop. The questionnaire had three questions, which the participant gave a rating of 1-5 (where 1 = disagree and 5 = agree):

1. I liked the workshop.
3. I learned something new in the robot workshop.
5. I thought that the robot workshop was inspiring/exciting (in Finnish *innostava*).

The rating questions also had additional questions for explaining the rating and giving feedback. All the pupils provided written justifications for each question/claim.

The questionnaire was in physical, printed format to be easy to fill out after the workshop. The answers were digitised afterwards by typing them in Microsoft Forms.

We analysed the digitised data by calculating the ratings' averages and doing a thematic analysis of the text-written feedback. We did the thematic analysis using an online affinity diagram in Mural.

6.3.2 Essay assignment

We gave the pupils a set of questions about the workshop experience, and they had one week to write the essays. The essays were written in electronic format. From nine essays, we analysed the ones for which we had research consent: seven essays. On average, the essays were 158 words long.

We analysed the essays by making an affinity diagram, shown in Figure 12. First, we colour-coded the essays. After that, we clipped smaller notes from the essay content according to different topics and gathered similar notes together. We formed four broad topics: Learning, Atmosphere, Tasks and Communicating. Inside these topics there are themes that one or more pupils wrote about.

The pupils are referred to as codes P1-P7, where P means a pupil. The coding is different to the questionnaire chapter.

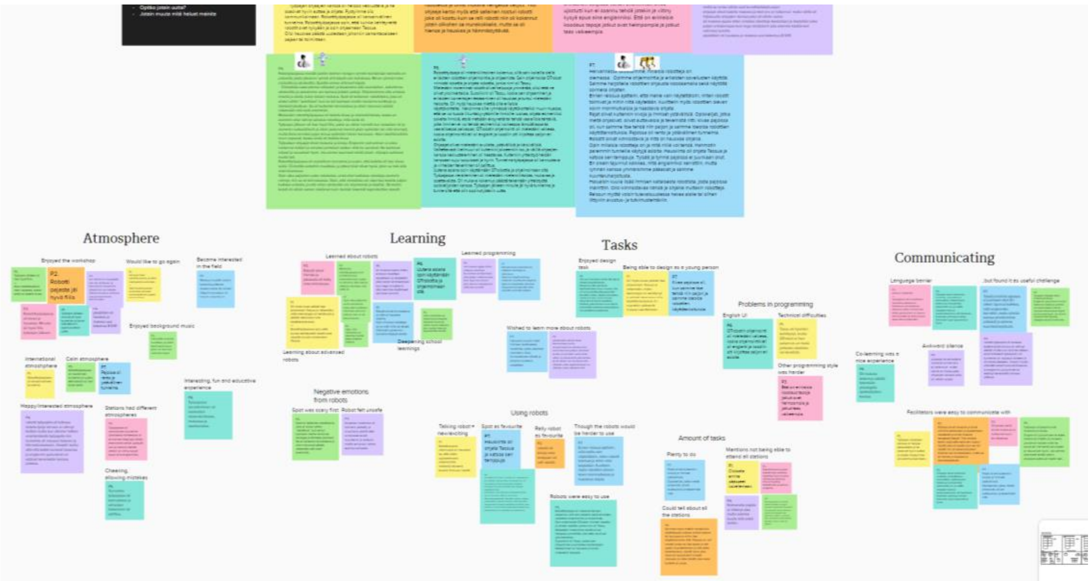

Figure 12. Screenshot of the affinity diagram of pupil essays. Each essay has assigned one colour.

6.3.3 Results from questionnaire

The results of the questionnaire answers were positive. On average, the pupils agreed that they liked the workshop, learned something new, and thought the workshop was inspiring/exciting. The averages are presented in Table 5.

Table 4. The averages of questionnaire questions

ID	Question	Average (1=disagree, 5=agree)
Q1	I liked the workshop	4,86
Q3	I learned something new in the robot workshop.	4,43
Q5	I thought that the robot workshop was inspiring/exciting	4,71

The comments given by the pupils provide justifications for their ratings.

The participant pupils are referred to as P1-P7 in this section. These ids are only valid for this questionnaire part of the evaluation, and the essay part has different coding.

Q1: "I liked the workshop"

+ The workshop was inclusive/participatory
P1, P2 and P4 mentioned inclusiveness related things, such as the pupils were able to ideate, make decisions and influence. They were able to do a lot, were spoken to and everyone was able to try out things. P3 (Liked the workshop, rating 5) wrote that the workshop was easy, but they did not like the aspect that they had to speak English.

+ Positive experiences of learning and robots
There were comments from P2, P5 and P7 about learning new things, about new robots and seeing how robots work.

- Not seeing all stations and speaking in English
P7 mentions in the answer that they would have liked to attend all of the robot stations in the workshop. As mentioned previously, P3 did not like speaking in English.

Q3: "I learned something new in the robot workshop"

+ Learned about robots and programming
P1, P2, P5, P6 and P7 wrote about using (new) robots in new way or doing new things. P3 and P2 mentioned learning programming in the workshop.

- Already familiar robots
P4 (neutral rating 3 on learning) wrote that they had seen many things about Spot already online and heard about one robot before.

Q5: "I thought that the robot workshop was inspiring/exciting"

+ Suitable tasks
P1 wrote about the tasks of the workshop. They mention that the quiz programming task provided enough challenge and that the Spot design task was interesting.

+ Interesting robots
P1, P3 and P6 wrote about the robots in this part. They mentioned being able to control the robots and that there were different kinds of robots.

+ Had fun in the workshop
P1, P2 and P5 wrote that they had fun in the workshop.

6.3.4 Findings from the essays

The co-learning workshop was an enjoyable experience

All the pupils wrote about the workshop in a positive tone and that they felt positive after the workshop. P1 mentions that they would like to go again in a similar workshop. P7 wrote that they would like to work in the field in future. P6 says that getting to collaborate with students was a pleasant experience.

Pupils learned about new robots and programming

The robots of the workshop were generally new to the pupils. They thought the robots were advanced and had interesting features. They learned to use and program new robots. P7 says they learned about different robots and their usage, and that the experience helped them to better understand things learned in school. P5 found similarities in QTrobot's code to Lego robot's code.

Wished to learn more about robots

Some students wished to learn more about robots. P4 says they would have wanted to know more about a robot, but it was new, and they felt they would have been able to know more if the robot came earlier to the university. P7 wanted to know more about human-like robots, which were mentioned in the workshop, and see other robots in general.

Appreciated the inclusivity of the workshop

Three pupils wrote positively about being included in the decision making in the workshop. P1, P6 and P7 enjoyed designing usage for Spot robot. P1 mentions controlling Spot by themselves as a nice thing and that they appreciated young people being included in a development process. P6 describes the atmosphere of the workshop as supportive, and it was ok to make mistakes.

Wished to visit all stations → too little time?

Four out of seven pupils mention not being able to attend one of the stations. P5 mentions their group not having enough time to attend Spot station and says that they would have wanted to see more of it. The comments imply that the participants would have liked to attend all of them, and the workshop schedule should allow attending all stations.

Programming task was may have been too hard

Two out of seven pupils mention about problems in QTrobot task. P6 says that it was hard to program because the programming language was in English and they had to write a lot. P1 says QTrobot did not work, but they were not sure if it was the robot or the code. These comments are in line with the observations of the problems in the station and it appears that the programming task with QTrobot was too challenging.

English language is a positive challenge

The workshop was multicultural from the facilitator side, which made English the main language of the workshop. P1 said the workshop had an international atmosphere. We did not specifically ask about the language, but P3, P4, P5, P6, and P7 write about speaking and listening English in the workshop. All but P3 found it as a challenge, but not a too hard one.

> P7: *"I didn't really understand everything what was said in English, but with my group we understood the main things and got listening practice."*

A pupil felt unsafe using a robot

One pupil, who attended a station with data privacy protection elements (camera and background music), felt unsafe. It is unclear how the protective measures were explained, but concluding from this comment, the explanation or the safety measures should be more extensive.

6.4 Group interview with facilitating students

After the workshop, the students (facilitators) were interviewed as a group. The interview plan is in Appendix M. The interview was semi-structured, and it was recorded. The facilitators are referred and quoted as F1-F6, F meaning a facilitator.

6.4.1 Findings

Facilitators learned versatile things

F2, F5 and F6 discussed learning how to interact, moderate and instruct 8^{th}-graders. F4 mentioned learning about programming and was inspired by the pupils' inner motivation to program. F3 learned about the target group's behaviour of not wanting to read instructions. Facilitators F1 and F4 were positively surprised to learn how active the pupils were, when they asked many questions and put effort on the programming tasks.

> *F2: "It was like a part of the ideas of them giving how we can use this, but I think also like how we interact with them. Like also giving this time for them to think and all that."*

Facilitators felt like teachers/guiders and senior friends

There were two different types of roles defined among the facilitators. Mostly facilitators said they felt like teachers or guiders, and they gave many instructions to the pupils and motivated them. F1 mentions being like the pupils' senior friend who may have more knowledge, but also that the pupils may have more knowledge, as they are 8^{th}-graders.

> F5: *"More like motivating them and just like cheering them on and sometimes giving a hint."*

Some pupils were scared of handling the robots

There were some examples of the pupils showing fear of interacting with the robots or breaking them. The Clicbot station had a building task where the pupils had to use some force to join the parts together. Spot is a big robot that moves fast, which may be scary to control and move around.

To avoid having these fears, the facilitators should more actively give instructions about handling the robots. F2 told about a pupil who asked if they could practice away from the stairs first and then try Spot climbing them. Some other pupils might not think of requesting this, so it could be offered as well.

The Clicbot group also adjusted the building task to avoid the pupils being scared of breaking Clicbot. After that, the second group did not mention any problems with the building part of the task.

> F2: *"I said this comment that when I see Spot, I see that it's so fancy, that I am kind of afraid to break it, and two of them* (pupils) *said: Oh yeah, that is exactly what*

happens to me. And that was one of the persons that didn't want to interact with the robot at all. -- That person was watching and was super excited about everything that the Spot was doing, but didn't want to control it."

F6: *"For Clicbot, because when you are trying to detach the joint or attach them, you need some force and if someone is not familiar with the robot they will be scared to break it."*

Visual instructions are more appealing than textual

Many facilitators said the written instructions did not seem motivating to follow for the pupils and F3 noticed the pupils ignored the written instructions. F6 and F1 proposed showing video tutorials or using more screenshots or other visual guidance.

F1: *"I guess if they're a bit shy to start with the programming and stuff like that, a simple video showing a very simple, maybe programming might help."*

QTrobot station was too challenging

The quiz task of QTrobot station was considered too challenging. The groups were not able to fully complete the quiz, which seemed to leave some pupils unencouraged. F4 noticed a pupil being sad about not completing the task. F3 mentioned that even though the pupils said the task was easy, they were not able to complete it and they were reluctant to do it. F3 also suggests simplifying the task, showing the strong points of QTrobot and utilising them in the task. Adjustments were made for the other group, and they were shown some finished programs made with QTrobot.

F3: *"First we need to show the strong points of QT like, the facial, the display of emotions and stuff and maybe having the task of storytelling or something that could be more suitable. Like different emotions and the ability of the QT to speak. They find it interesting that QT can speak different sentences and show emotions and gestures."*

Technical problems that could have been avoided

When using the Spot robot at Tampere university, the obstacle avoidance sensor is usually turned on, but on this occasion, it had been turned off earlier. Spot, unlike other robots, takes more time to turn on, which left no time to adjust the settings during the workshop.

Background music might help motivate the pupils

Clicbot station had background music playing as a data privacy solution to avoid audio files of pupils and students talking. Some pupils seemed to enjoy the background music and it made them seem more motivated. QTrobot station was the calmest one, and it might have benefited from the background sound.

F5: "*They weren't shy in our group. They were dancing and partying.*" From Clicbot group.

F2: "*And when you were making Spot dance, they said we are missing some music here, it would be even better.*"

F3: "*Ours was a bit too calm for them.*"

F1: *"So if there was any background music, I'm quite sure we wouldn't have understood the single word."*

Pupils were shy to communicate in English but can be encouraged to

The QTrobot group spoke about difficulties in using English, but the Spot group facilitators spoke about overcoming language difficulties by allowing writing in Finnish and then they asked more questions about the Finnish answers. F1 also talked about telling the pupils that the students themselves are also learning, which made them more approachable.

F3: "*They seem quite shy to communicate in English, like whenever they discuss they use Finnish among themselves.*"

Teenagers are more critical with ideating than children

Many of the facilitators had previous experience working with pupils, who are younger than 8th graders. They had noticed that the younger pupils are not as critical when ideating. In the workshop, the facilitators noticed that the pupils use more time on simple creative tasks, such as naming a robot.

F1: *"That's why they (children) are fearless to give any ideas and when kids get a bit older at a certain age they are they are like OK maybe he or she will judge me."*

6.5 Interview with the teacher

After the workshop we interviewed the teacher of the group that attended the workshop. The duration of the interview was about 15 minutes. The interview was semi-structured and the (Finnish) interview plan is in Appendix N. The purpose of the interview was to evaluate the workshop: how it was and whether it provided what was needed. There were questions about the tasks, facilitators, and the atmosphere of the workshop, but also questions about the pupils and how they reacted to the workshop.

We transcribed and conducted a thematic analysis of the transcription. Quotations from the interview are translated to English.

6.5.1 Findings

The workshop was a positive experience

According to the teacher, the atmosphere of the workshop was positive and relaxed. The pupils were participating actively, and they would like to attend a similar workshop again.

Teenagers warm up toward the end of the workshop

The teacher said that the pupils this age warm up towards the end of the workshop and in that sense, the workshop could have been longer.

> *"It was clearly noticeable that the pupils warm up towards the end. The workshop could be even longer, because then, in a way, maybe they would be more involved."*

Spot was everyone's favourite

The teacher had noticed and heard from the pupils that Spot station was the pupils' favourite. The pupils seemed relaxed working in the station. The teacher thinks it is because the station or the robot was easy to approach. One group had been building a dog-shaped robot in school and they may have seen familiarity to dogs in Spot, which made it more appealing to them.

The teacher also says that one of the Spot facilitators was specifically mentioned as someone whom the pupils liked, which may have been one of the reasons for Spot being the pupils' favourite.

> *"In my opinion or what I discussed with the pupils, Tassu (Spot) was everyone's favorite. It was perhaps easy to approach and as I watched the pupils working in that station, they were the easiest and most liberated of all of them to work together in a way that somehow it worked."*

QTrobot's programming task was hard

In the QTrobot station, the teacher noticed that the first group in the QTrobot station was struggling to get inside the programming task. It was unclear what the assignment was and how it can be done. For the second group, the station was altered to use more time on presenting the ready facial recognition programs with the robot. According to the teacher, the second group enjoyed the station a lot. It appears that the original programming task was unsuccessful.

> *"They can like it (programming), but it may have been the thing that it is challenging to start from something that is hard."*

QTrobot facial recognition was liked by the pupils

The second QTrobot group got to see more of the QTrobot features, such as facial recognition, which can detect the user's gender by using artificial intelligence. This feature was interesting to the pupils and they were enthusiastic to try it out.

> *"When they got past the beginning, they liked it a lot. It was fun and surprising to follow how enthusiastic the pupils were about facial recognition and if the robot recognized their gender. Somehow it is a very simple thing, but it was terribly interesting and impressive."*

Pupils were scared to build with Clicbot parts

The teacher noticed that the pupils seemed scared to touch the Clicbot parts, which was challenging at first. The task went fine after the initial challenges.

Background music divides pupils preferences

In mathematics classes in school, the pupils have the option to listen to music while working, but some pupils prefer silence when working. The music might help to make a relaxed atmosphere and it can work in some situations, but for some pupils, it can be a distraction. The teacher thought the pupils enjoyed hearing the music in the workshop, but sometimes it may have been a distraction.

6.6 Summary

Combining the input from the participants of the co-learning robot workshop, the overall experience was positive for everyone. The pupil participants reported about learning robotics and programming, and the facilitators learned about interacting, moderating, and instructing the pupils. However, there were comments from pupils that they would have wanted to learn more about some robots.

It took some time from the beginning for the pupils to "warm up" and in that sense the workshop could have been longer. The facilitators suspect teenagers, compared to younger children, are more cautious. For some measure, the background music in the workshop might help to break ice. There were some occasions where pupils felt scared or otherwise uneasy. The occasions related to being afraid of breaking robot or data privacy questions. The facilitators reported that the written instructions were not engaging for the pupils to follow, and instead, they recommended visual instructions.

The pupils appreciated the freedom given to them in making decisions about which station to attend and being creative in the ideation task. Not being able to attend all stations turned out to be an unfulfilling experience for some, when a pupil could not interact with a robot that was most interesting to them.

There were some issues related to the technology, but it did not prevent anyone from learning about robotics. On the other hand, technological issues may have provided more experience to the facilitators, when they had to handle difficult situations with the robots and the pupils. In case of technical difficulties, that cannot be solved right away, alter the task or its goal. In the workshop we made some alterations to the QTrobot task because the robot was not working as intended and the programming task was too challenging for the time limit. Changing the task to showcase the robots pre-programmed features was more engaging for the pupils.

7 DISCUSSION AND CONCLUSIONS

This chapter presents the key findings from the studies, proposes design implications for co-learning robot workshops for elementary school and university students, answers the research questions, discusses the limitations of the study, and covers the conclusions.

7.1 Summary of findings

We wanted to research the experiences when 8th-graders would co-learn with unfamiliar adults (university students) and formed the research question: **1. What are the co-learning experiences on the social robot activities for school pupils and University students when learning together?**

Based on our findings, the co-learning workshop was a mainly positive experience for the participants. The tasks of building, programming, and designing robots provided learning experiences for both the 8th-graders and the university students. The pupils learned about new robots and programming, and the facilitators learned about interacting with the pupils in a facilitating situation.

When starting this thesis project, we planned to make the workshop solely programming-themed. The idea came from the previous iteration of Robostudio workshops, the Robotour model (Ahtinen et al., 2023b), from which we got the impression that the pupils wanted to interact more with the robots themselves. When using ready-made demos, the pupils would be limited to the chosen features. If they programmed themselves, they could utilise any features the robots have. In the pre-study phase, it became evident that programming would not be ideal for all the pupils. In the workshop, inspiring the pupils to learn about robots was more important than making the pupils program.

The non-programming robot station, controlling Spot and designing usages for it, was the most liked. There were several possible explanations for it: the robot itself, the task enabled using creativity, and the task enabled using more creativity. The pupils appreciated that they were included in a design process in the Spot station and that they could make decisions regarding the stations to attend. On the other hand, not being able to attend all stations was disappointing for the pupils.

Based on the pupils' feedback, the robots themselves were more interesting than the tasks. They reported learning about new robots and what features they have. Some pupils would have wanted to know more about some robots. The experiences from QTrobot station backs up this finding. The original programming task turned out to be too challenging, which did not seem to engage the pupils. The station task was changed for the second group, and the pupils got to test out pre-programmed demos of QTrobots features. They visibly enjoyed the testing of it.

In addition to negative experiences with QTrobot programming task, the pupils experienced challenges speaking in English. Mostly they reported understanding the main things, and some thought it was a positive challenge. On some occasions, the pupils felt scared or uneasy using the robots, and the occasions related to data privacy using and operating a robot in fear of breaking it.

We, the facilitators, and the teacher, all noticed it took some time for the pupils to warm up, but it is natural for teenagers. Background music and funny experiences with QTrobot's occasionally faulty gender recognition made the pupils more relaxed and enjoy the workshop.

7.2 Design implications for co-learning robot workshop for elementary school and university students

Our other research question was: **2. What are the design implications for a co-learning robot workshop for school pupils and University students?** We are answering the question in this chapter. Based on the findings in the evaluation, we propose some design implications or workshop practices that can make the workshop more successful and avoid negative experiences:

1. We suggest putting effort into ice-breaking but also accepting that it may take time for teenagers to warm up.
2. Consider using background music. The background music may ease the co-learning experience by relaxing the event.
3. Give the participants the freedom to make decisions regarding their work to make the participants of the co-learning workshop feel more relaxed and in control of the situation.
4. Put effort into the safety instructions in the co-learning robot workshops. The purpose is to protect the people and the equipment. When using safety measures, be straight about them and assure the participants about their safety. Give hands-on instructions on handling the robots so the participant gets encouraged.
5. When facilitating a co-learning workshop, prioritize visual instructions, such as video tutorials, pictures and showing things in practice. The unfamiliar, busy environment might be too distracting to focus on reading instructions.
6. Enable everyone to participate in all the tasks. Otherwise, the participants may feel they did not finish everything, or they miss something interesting.
7. When ideating the tasks, focus on the primary features of the robots. The robots and their features are presumably new and exciting to the learners, which is already a lot of information in a short period of time.

8. Before the workshop, double-check the tasks and tools. Are the tasks doable in the given time? Do the robots work as intended? The checking can prevent some unexpected problems.

7.3 Discussion

When writing this thesis, the topic of children co-learning about robots was studied before (Ahtinen et al., 2023a; Bers, 2007). The previously studied robotics co-learning experiences presented children mainly co-learning with their family members (Chung & Santos, 2018; Kandlhofer et al., 2014; Relkin et al., 2020) or older children (Angel-Fernandez & Vincze, 2018). The co-learning experiences with said co-learner groups were successful and positive, and the co-learners in the studies learned about robotics and became interested in robots. We studied the experiences of 8th-graders and university students in a co-learning robotics workshop. Our choice of co-learners is a novel pairing. We applied a Human-Centred Design research process in designing a co-learning robot workshop for elementary school and university students. We conducted a pre-study with a target group pupil and a teacher and used the findings and the knowledge gained from the related work to design the workshop. The workshop design was evaluated with nine pupils, six students and one teacher.

The experiences of co-learners from the workshop were mainly positive. Our findings from the co-learning workshop evaluation and both elementary school pupils and university students can learn together about robotics. In addition to robots, they can learn about interacting with diverse people. The pupils appreciated freedom and being able to make decisions, similarly to co-learners in study made by Ahtinen et al., 2023a.

Similar to a study conducted by Angel-Fernandez & Vincze (2018), in which older children had difficulties co-learning with younger children, the pupils and students experienced some difficulties while co-learning. In our study, there were mentions of a language barrier, and some pupils experienced uncertainties regarding using robots, which could have been prevented by communicating. It would be beneficial to research how to make co-learning more seamless for people unfamiliar with each other and how to make them more comfortable working together. What ice-breaking methods could help the participants feel comfortable in a workshop? Could background music help to make the co-learning experience comfortable without being disruptive? If so, what kind of music? These are questions that would be interesting topics for further research.

As of the time of writing this thesis, there are no clear design implications for designing a co-learning robot workshop for elementary school pupils and university students. Based on our findings throughout the research process of this thesis, we propose eight design implications for a co-learning workshop. The implications aim to provide participants with a more comfortable, safe, and fulfilling co-learning experience. On the other hand, some challenges also provide learning experiences and might be beneficial to face them.

7.4 Limitations

There are some shortcomings related to conducting this thesis, some related to the methods used and some using the methods.

In the pre-study, our number of participants was limited to one pupil and a teacher. The whole age group should not be generalised based on one pupil, and by involving more pupils, we would have been able to form a more diverse picture of the target group and their needs and goals. Increasing the number of participants would have also helped to ideate and test out more versatile robot tasks for the workshop.

In the evaluation phase of the workshop, we asked the pupils to fill in a questionnaire and write an essay. When we checked the questionnaire answers, we realised we should have added checkboxes for each robot station. By doing so, the participant could have easily reported which two stations they had visited, which could have given more context for the feedback. We considered this learning when assigning the pupils the essay task: We asked them to briefly describe what they did in the workshop.

When collecting data from the participants, we sometimes were too careful regarding data privacy. We did not give each pupil participant a personal, anonymous code, which could have been written on the questionnaire paper and in the essay. This way, the answers could have been connected and compared with the essays, but the data privacy would still be fulfilled. The questionnaire could have also been a standardised questionnaire for evaluating a workshop or experience. We made both the questionnaire mistakes out of worry of using too much of the participants' time.

Another example of fear of consuming the participants' time was made when we did not properly interview the facilitators nor their teachers before the workshop. Defining their needs and goals regarding the workshop would have been beneficial. The facilitators' opinions might have also been unheard in the group interview, as it was challenging to moderate the discussion and ensure that all the participants had their turn.

7.5 Conclusions

This thesis presents the learning experiences of elementary school pupils and university students who gathered at Robostudio of Tampere University to co-learn about robotics. We designed a co-learning robotics workshop, where the university students facilitated robot-related programming and design tasks for 8^{th}-grade pupils. In the design process, we utilised the Human-Centred Design approach. We based the design decisions of the workshop on the pre-study data gathered from a co-design week conducted with a 15-

year-old participant and an interview with a teacher. We evaluated the co-learning robot workshop with nine 8th-grade pupils, six university students and a teacher of the 8th-graders (same teacher as in pre-study).

Despite the limitations of the study, we designed and conducted a successful co-learning robotics workshop. The co-learners' experiences were mostly positive. The pupils learned about robots Spot, Clicbot, and QTrobot, and how to program or operate them. The robots and their features were interesting to them, and they would have liked to learn more about them. The pupils faced a positive challenge in using English, as the facilitators of the workshop were multinational. The facilitator students learned about interacting with the pupils. However, the co-learning experiences between the co-learner groups were not seamless. Among the pupils, there were experiences of fearing the robots or using them, and one pupil was worried about the robot using their personal data.

Based on our findings from the evaluation of the workshop, we formed eight design implications for designing a co-learning robot workshop for elementary school pupils and university students. The implications may be helpful in the design of robotics co-learning experiences where the co-learners are unfamiliar and dissimilar with each other. In future, it is essential to understand how the collaborative learning experience about robotics can be made comfortable and relaxed for each participant.

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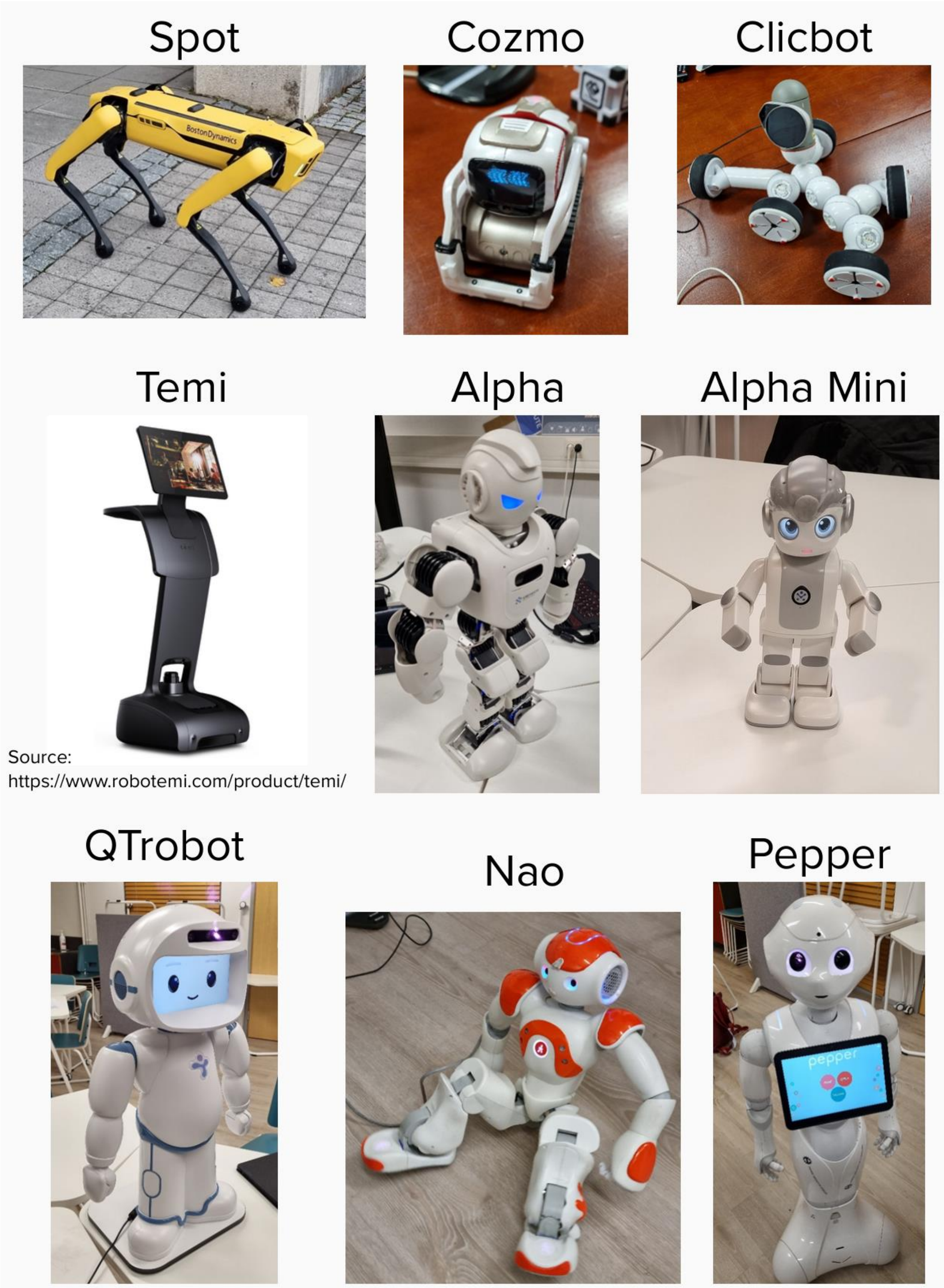
9 APPENDICES

Appendix A. Robots of Robostudio

All photos except Temi are taken by Hilkka Lammi.



Appendix B. Consent form (students)

Consent to participate co-learning (social) robot workshop

My name is Hilkka Lammi and I'm doing a master's thesis on a (social) robot co-learning workshop. The purpose of the study is to evaluate a robot workshop plan that is designed for 8th-grade pupils.

I'm looking for (HTI) student participants to join the workshop on 14.12.2022. Your task would be to facilitate a small group of 8th-grade pupils (aged 13 to 14) with a robot task/challenge. The tasks will include easy block programming or other use of robots. Each group would have 2-4 pupils and 1-2 students.

The workshop will be held in Robostudio.

The workshop tasks will be confirmed with the participants, and we will organize a practice session in 12.12.2022.

The estimated duration of the workshop is 1h 45 minutes, but you'll be asked to come earlier for preparing the workshop. During the workshop, I will be making notes by observing, and after the workshop session, I will collect feedback.

I would really like to encourage anyone to take part in this study. It is a great opportunity to engage with a possibly different group of people (13-14 year olds) when often you might do the studies with your peers. All the safety measures and protocols will be strictly followed to ensure the safety and data security of the participants.

If you have any questions, please send me an email: **credentials**

If you know someone, who could be interested to join the workshop, feel free to forward this invitation to them. 😊

Best regards, Hilkka

1. I want to participate the co-learning robot workshop 14.12.2022 at 9-11 (you might have to come earlier and leave later)
2. Name:
3. E-mail:

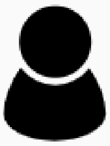
Separate form for audio/photo consent:

You can read more about the purpose of the study and data privacy from the information sheet and privacy notice sent attached to the same email that included the link to this form.

Consent to audio and photos

1. Name:
2. I give consent to record my audio in the group interview.: Yes/No
3. I give my consent to be visible in photos in the workshop. (Identification details, such as names, will not be attached to any photos. The photos may be used in the thesis and other scientific articles written on the topic.): Yes/No

Appendix C. Personas created in pre-study with the pupil participant



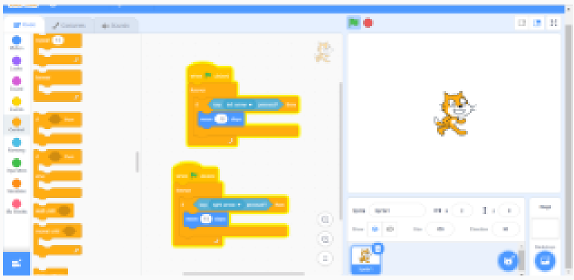
Persoona 1: Koodannut vähemmän

Ikä: 13-14-vuotias

Taidot

on koodannut hieman scratchillä tai muilla vastaa-villa palikka koodaus ohjelmilla koulussa mutta ei juurikaan kotona.

ei ole kättänyt teksti koodaus ohjelmaa

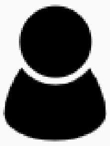


Toiveet / tarpeet

Kilpailu muuten kuin koodaamisessa (esim. Pepper Quiz)

Tavoitteet

Haasteet

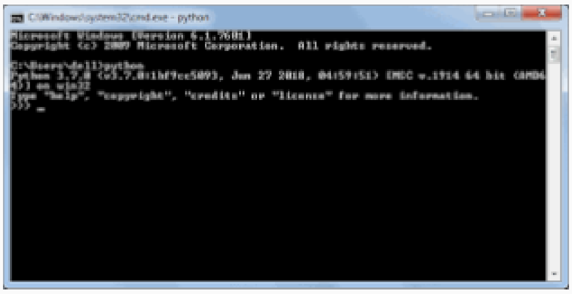


Persoona 2: Koodannut enemmän

Ikä: 13-14-vuotias

Taidot

on koodannut koulun ulko puolellakin ja on kokeillut teksti pohjaista koodausta palikka koodauksen lisäksi



Toiveet / tarpeet

Koodaaminen

Pääsee kokoamaan robottia ja kilpailemaan koodaustehtävässä.

Tavoitteet

Haasteet

Appendix D. Interview plan (teacher expectations)

Haastattelurunko

Tässä haastattelussa kerättyjä tietoja käsitellään anonyymisti ja tulen poistamaan tallenteet kun olen saanut tämän esitutkintavaiheen valmiiksi. Voisin tässä vaiheessa laittaa haastattelun tallennuksen päälle.

—Laita ruudulle näkyviin robottilistaus—

Tämän haastattelun tarkoituksena on, että minä ymmärtäisin paremmin robottityöpajoihin osallistuvien tarpeita ja haasteita. Olen tosiaan aikaisemmin pitänyt TET-viikon yhdelle 9.-luokkalaiselle ja opin paljon sen viikon aikana. Testasimme silloin kaikkia näitä Robostudiosta löytyviä robotteja.

Taustatiedot

1. Mitä ikäluokkia opetat?
2. Opetatko ohjelmointia?
   a. Opetan matikan osana ja robotiikkakurssilla
   a. Kuinka kauan olet opettanut ohjelmointia?
   b. Millä kursseilla opetat ohjelmointia?
   c. Minkä tyylisiä tehtäviä oppilailla on ohjelmoinnissa?
   d. Onko koululla ohjelmointihaasteita tai -kilpailuita?
   e. Millä välineillä opetat ohjelmointi? Palikkaohjelmointia? Robotteja?
      i. Mitä mieltä olet näistä käytössä olevista välineistä?
   f. Kuinka kauan oppilaat ovat opetelleen ohjelmointia?
      i. Millainen suhtautuminen heillä on ohjelmointiin?

Odotukset, tarpeet, toiveet

3. Oletko osallistunut aikaisemmin luokan kanssa Robostudion robotti-työpajaan?
4. Mitä mieltä olit niistä?
5. Mikä niissä oli hyvää?
6. Voisiko niissä tehdä jotain paremmin? Puuttuiko niistä jotakin?
7. Oliko jotain mitä oppilaat toivoivat enemmän?
   a. Tuliko sinulle kokemus, että oppilaat olisivat halunneet itse ohjelmoida tai koota robotteja?
      i. Onko tälle jotain esteitä?
8. Mitä toivot tulevalta työpajalta?
   a. Mitä toivoisit oppilaiden saavan/oppivan työpajasta?
9. Ohjelmointi?
10. Mitä toivoisit yliopisto-opiskelijoilta, jotka osallistuvat työpajaan?
    a. Millainen rooli heillä tulisi olla?

Haasteet

11. Millaisia haasteita 8-luokkalaisella voi olla
    a. Ohjelmoinnin suhteen?
    b. Ryhmätyöskentelyn suhteen?
    c. Toiminnanohjaushaasteet? Miten tulee huomioida?
    d. Englanninkielisyys?

Tehtävistä

Ruudulla tehtäväideointinäkymä Muralista

12. Mitä mieltä näistä tehtävistä?
13. Erilaisia haasteita vai saman tyylisiä?
14. Ohjelmointi vai muu haaste? Osa roboteista on sellaisia, mitä ei voi koodata palikkakoodaamalla.
15. Vaihtuva vai pysyvä haaste?
16. Luovuuden käyttäminen? Esim. Clicbot. Vapaat kädet vai joku tietty muoto?
17. Tuleeko tästä erimielisyyttä luokassa? Jotkin robotit saattavat olla suositumpia.

Loppukysymykset

18. Tuleeko mieleen jotain aihetta mistä en hoksannut kysyä?
19. Haluaisitko lisätä jotain?

Kiitos paljon ajastasi!

Appendix E. Instructions for Clicbot station

Making your own rally car

1. First we are going to build the robot from these parts.

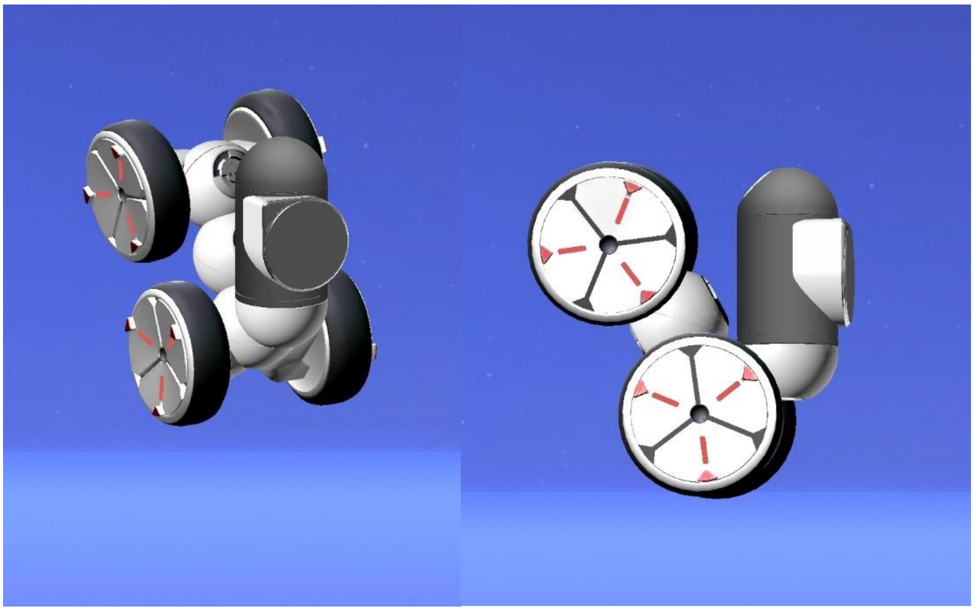
   You need:

1 x Brain

4 x Wheel

3 x Joint

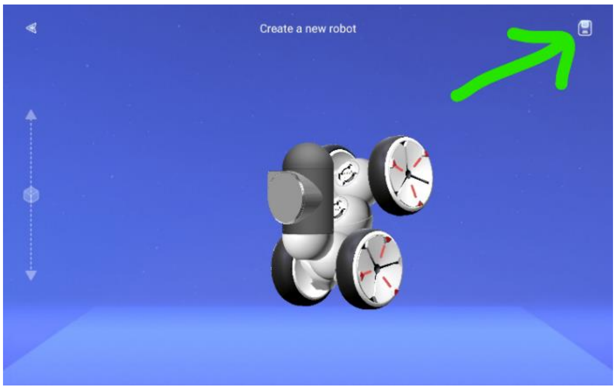
2. Build **a robot** according to these pictures:

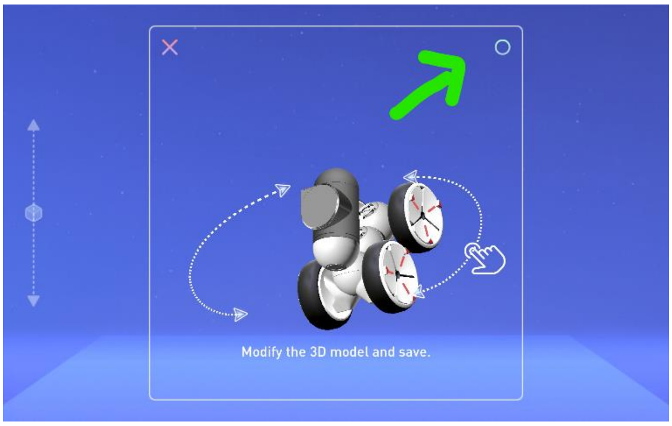


3. When you have put all the parts together, the robot needs to be connected to the tablet.

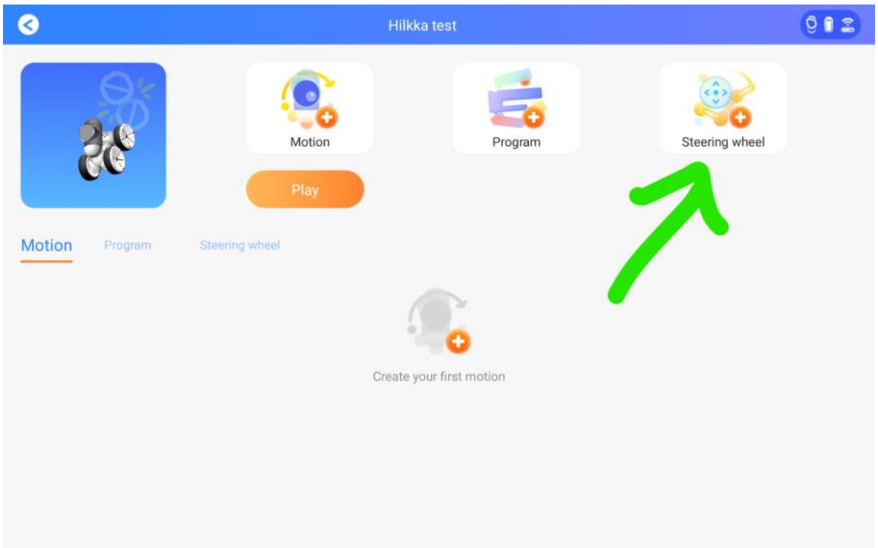
** In this part, we will start playing background music. ** ♪♫

4. Press **Go create** and then the button on the right bottom corner.
5. Name and save your robot

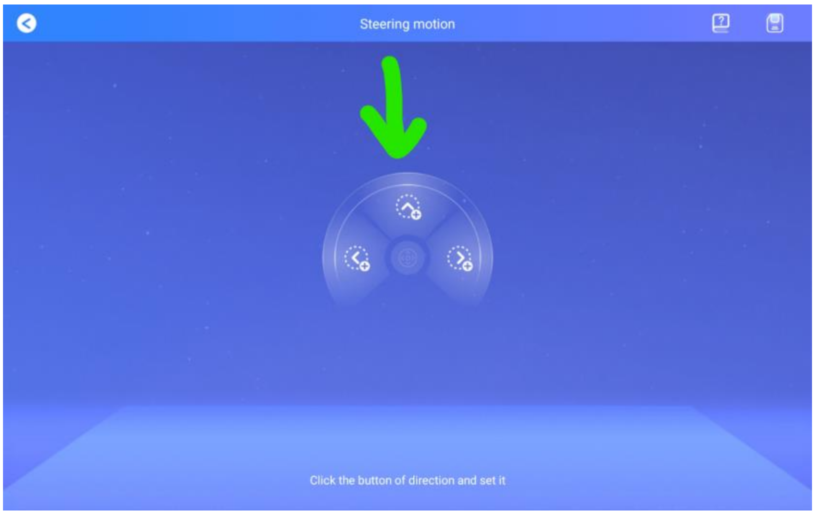




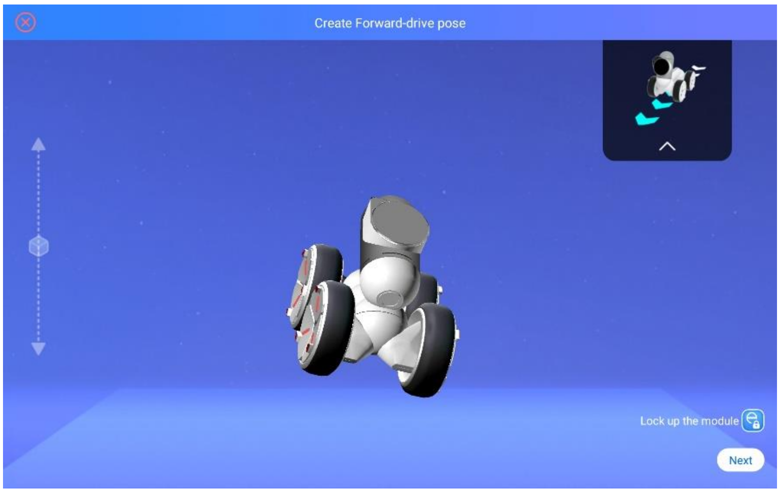
6. After saving the robot you can program the movements to the laptop:



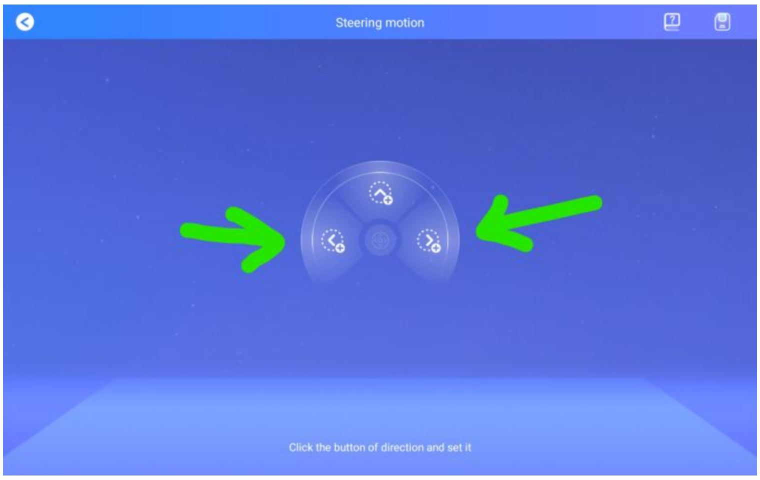
7. First choose the forward movement:



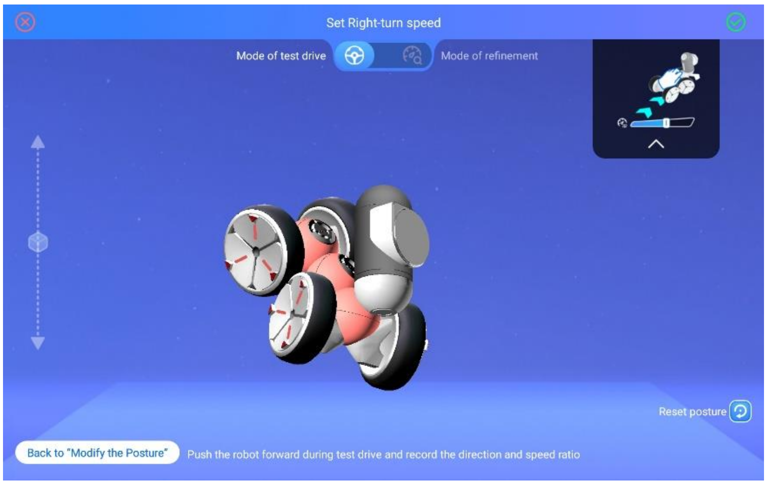
8. Put the robot into normal position and press **Next**.
9. Move the robot physically forward:



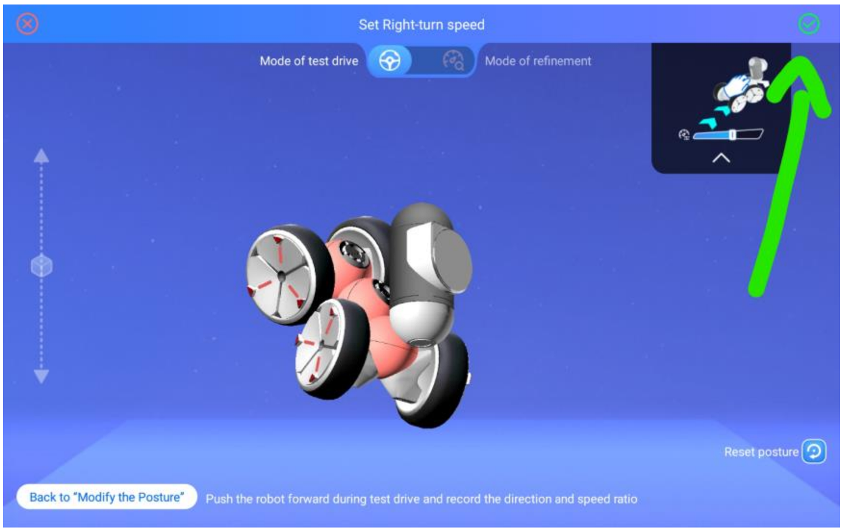
10. Save the movement by pressing the green check button on the upper right corner.
11. Now add positions for turning left or right:



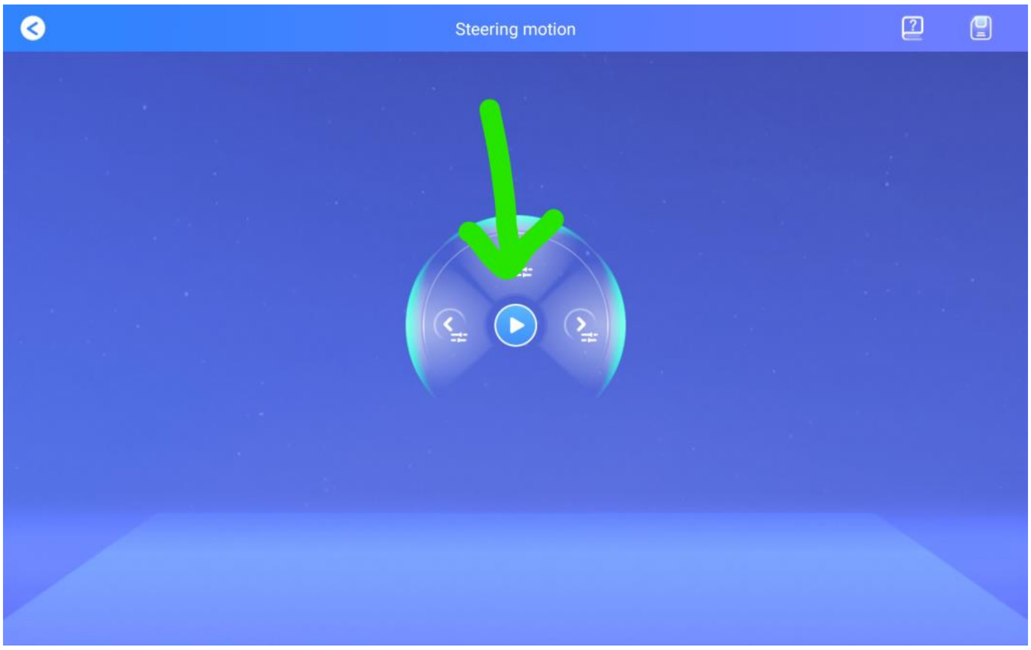
12. Change the position of the robot as if it was turning left/right:

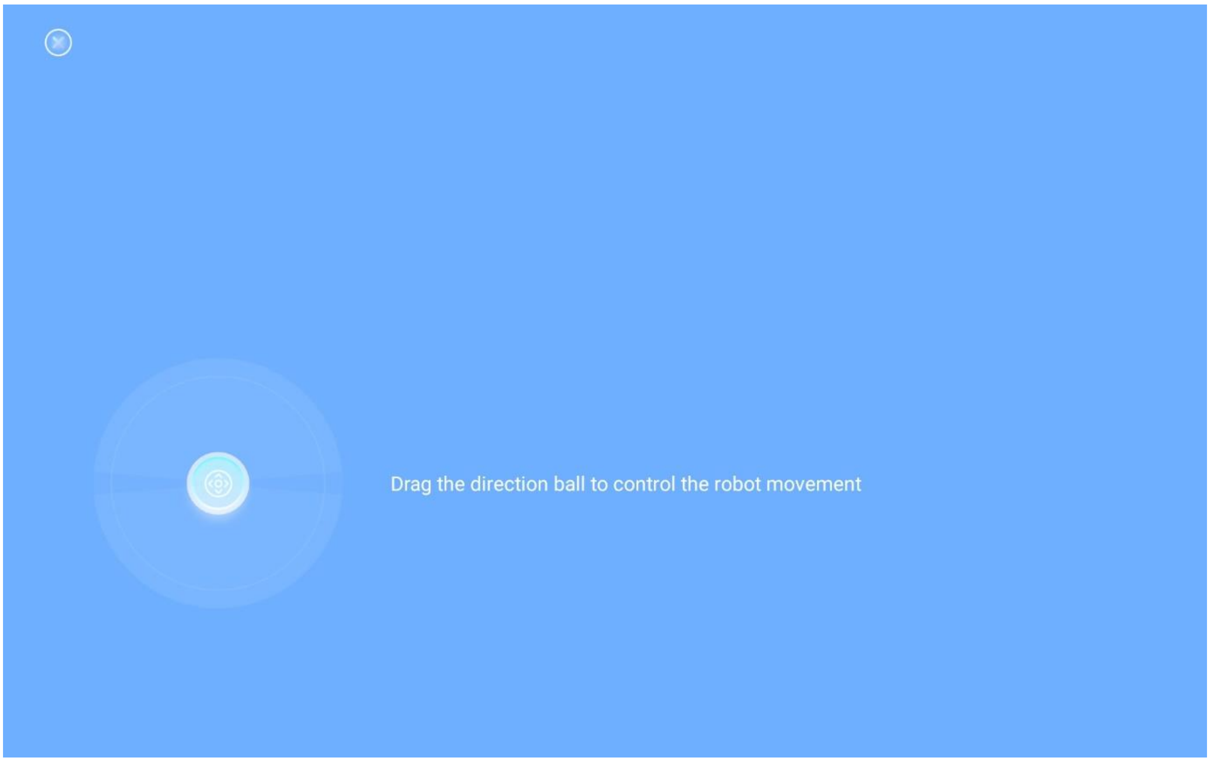


13. Move the robot in the chosen direction (left/right).
14. Save the turning posture by pressing Next and the green check button:



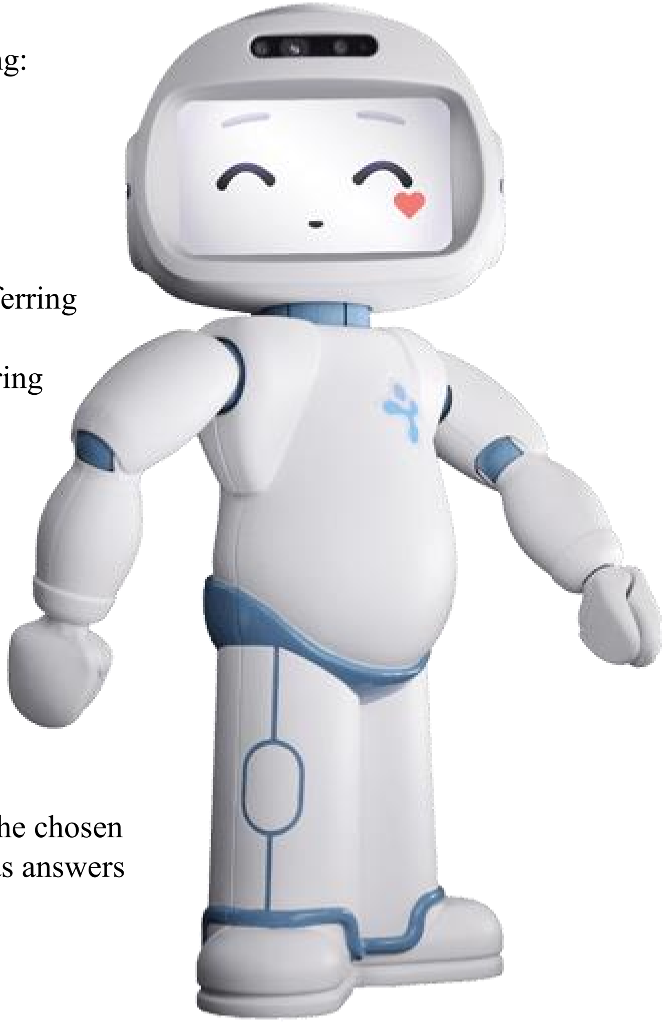
15. Repeat the turning position setting to other direction.
16. Start racing! 





Appendix F. Instructions for QTrobot station

Making your own quiz



Instructions for QT Robot graphical programming:
https://docs.luxai.com/docs/intro_graphical

When programming QTrobot, you need:

- Laptop
- 2 tablets:
  - Titled "Educator" (used for transferring the program to QTrobot)
  - Titled "Learner" (used for answering the quiz questions)

Task

1. Now you can choose the topic for your quiz. It can be something you all like.
   a. favourite school subject
   b. hobby
   c. movie/series/game

2. Each of you forms a question regarding the chosen topic. The questions must have pictures as answers but they can include text.

   For example:
   "What is December in Finnish?"

Joulukuu	Marraskuu

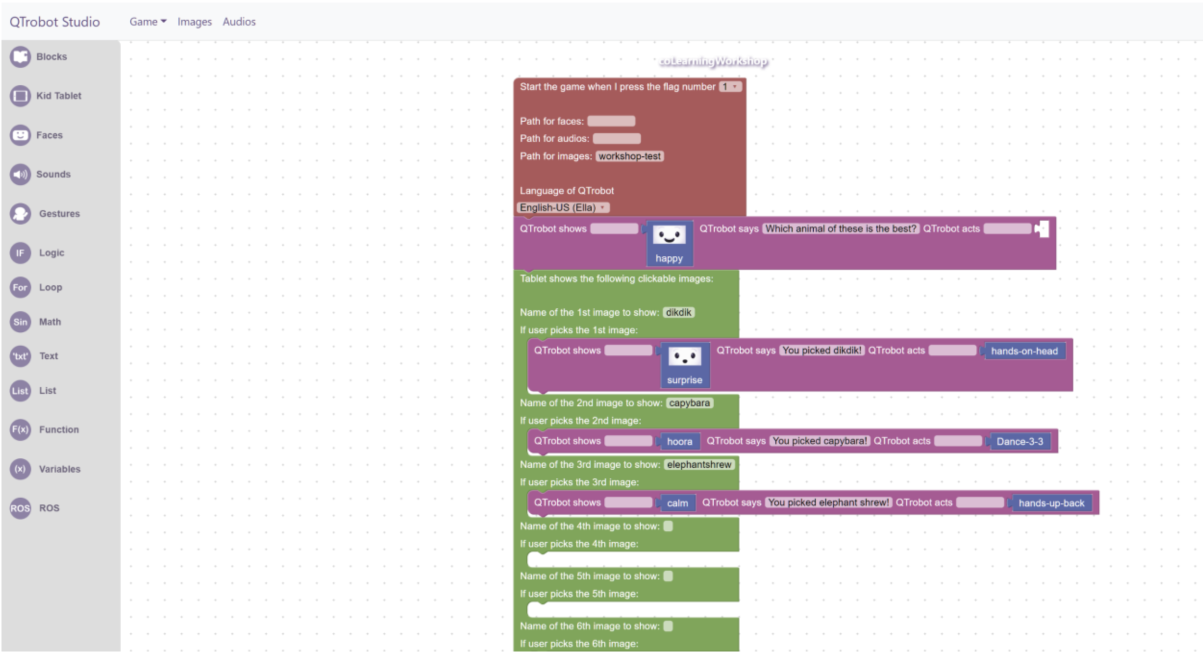
   "Which one of these is a robot?"

After/while forming questions, let's put them into the program.

Go to QTrobot Studio: *https://qtrobot.luxai.com/admin/*

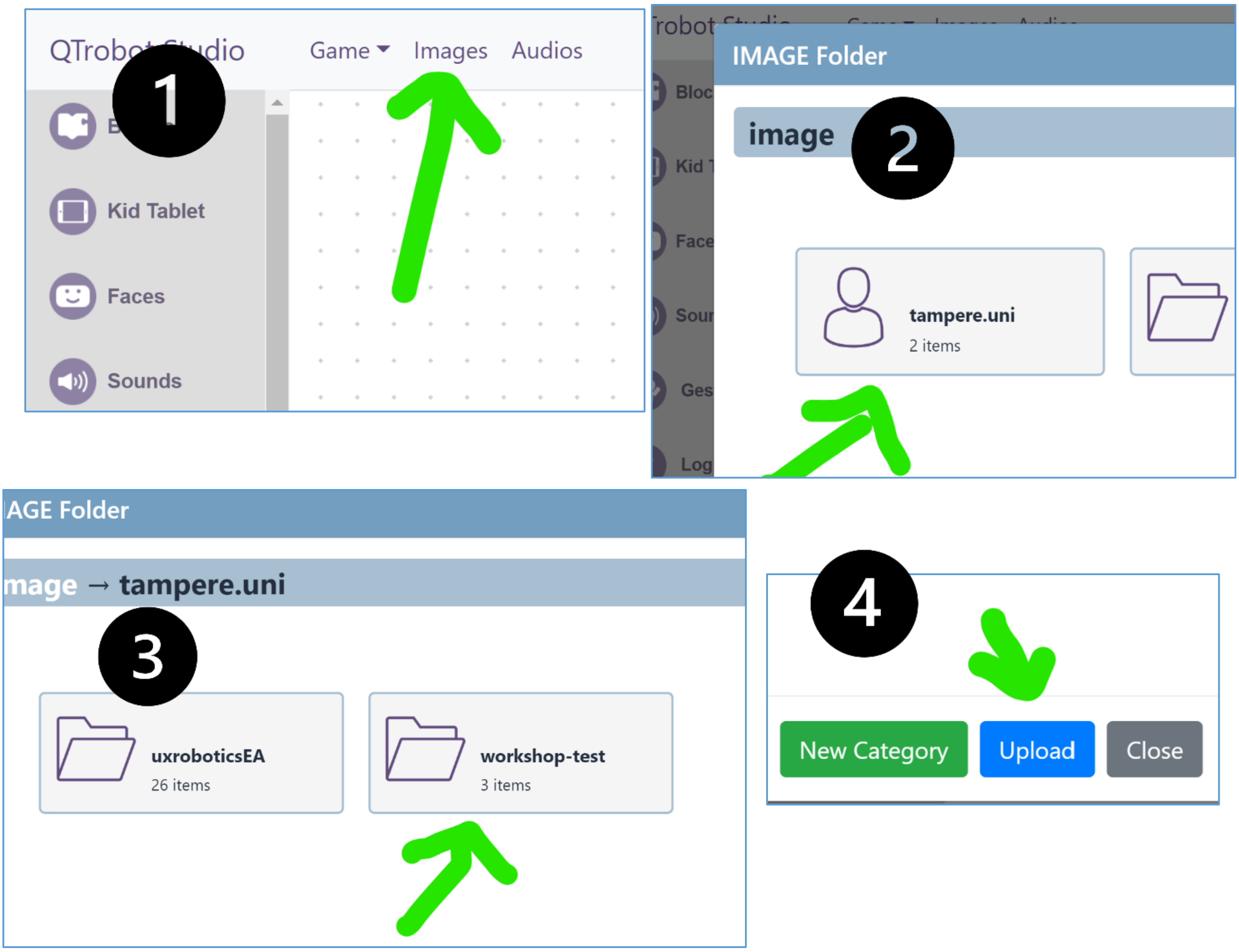
Choose game template called: **coLearningWorkshop**



Running the Quiz on QTrobot

1. First the quiz (game) has to be saved.
2. On the Educator tablet:
    a. Go to Settings
    b. Press **Update with cloud**
    c. Press **Synch with QTrobot**
    d. Go to **Lessons**
    e. Choose your game
    f. Press **Start**
3. Play the quiz!

Adding images



Appendix G. Instructions for Tassu station

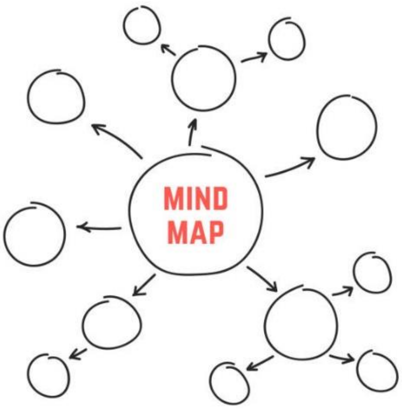
What could Tassu do?

1. Let’s start with going for a walk with Tassu.

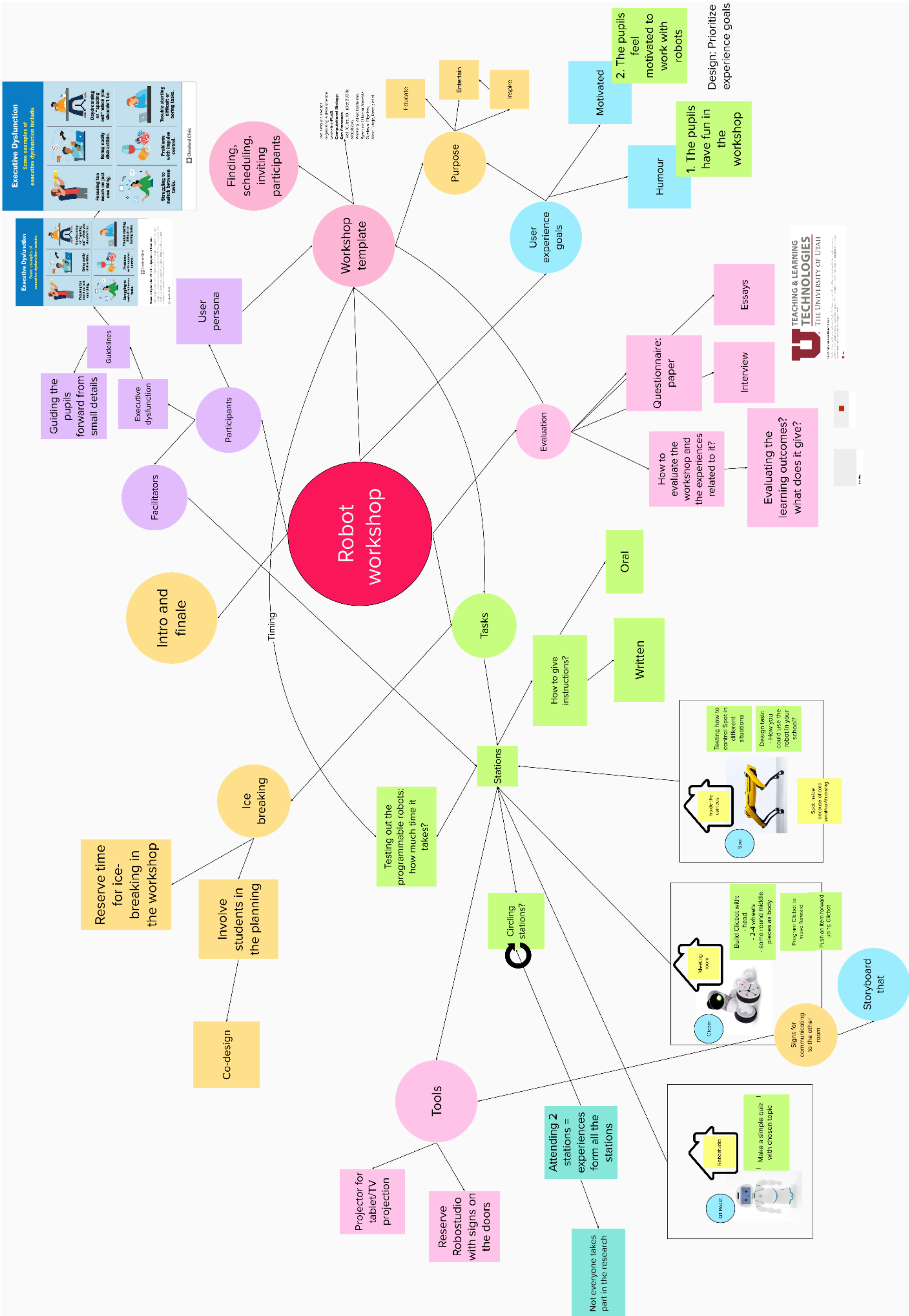
After that we have a small design task for you.

2. Where could you use Tassu?
    a. What would Tassu do?
    b. You can use these cards for inspiration:

3. Make a small mind map for your design using post-its



Appendix H. Mural mind map for planning the workshop



Appendix I. Workshop plan and schedule

Robot workshop 14.12.2022

Workshop schedule

Time	Task	Notes
8:30	Arrive to workshop	
9:00	Pupils arrive	
9:05	Introduction	
9:13	Dividing into groups	
9:15	The workshop begins: ice-breaking with the group, tasks	
9:50	*Switch the groups to other stations*	
10:25	Finale: presenting what was done in workshop	
10:40	Paper questionnaire for pupils	
10:45	Pupils leave*	
	Group interview	

* The pupil groups' bus leaves at 11:00

Before workshop

- Arrive early at 8:30
- Check you have everything you need for your station (robot, laptop/tablet, etc. Listed in the station description)
- Set up robot (Clicbot needs to be disassembled)
- Preparations in Robostudio: arrange tables away and have chairs in front of the TV.

Intro

Ice-breaking with Tassu

What is Robostudio and who are the people in there? (Aino)

What are we going to do today? (Hilkka)

- Each small group will join 2/3 stations.
- Tassu station has more operating Tassu and a design task, Clicbot programming a rally car and QTrobot programming a small quiz.

Finale

- We could show the result briefly from each station: Clicbot built and moving with a tablet, QTrobot quiz (or both), and Tassu designs

Tips for facilitating

- Collaborate aloud, what the pupils are doing (think aloud)
- encourage independent problem-solving, but give instructions if they're stuck

Questions you can ask:

1. Have you used robots before?
    a. What kind of robots?
    b. What did you do with them?

Clicbot

Space

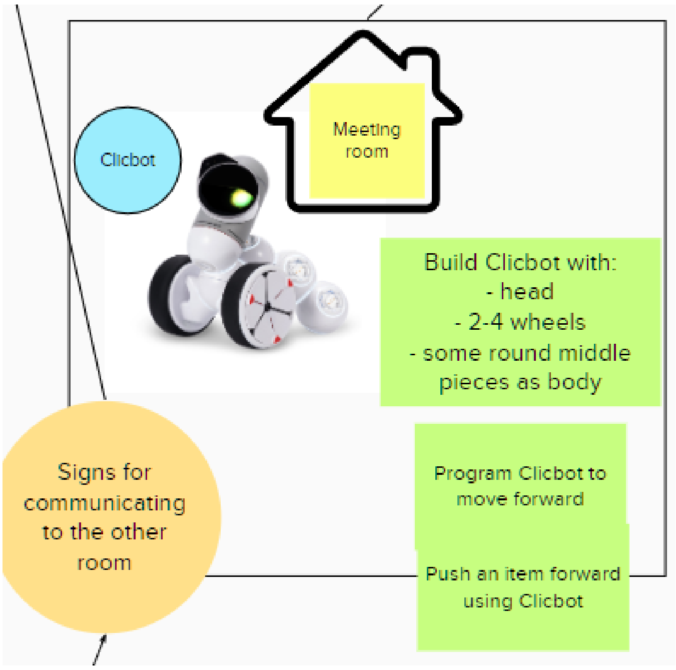
- meeting room C114

Tools

- Written instructions
- ~~Face masks~~
- Background music (Hilkka brings a speaker that uses Bluetooth)
- Tablet (white Samsung)
- Clicbot brains (camera has to be covered), 4 wheels, 3 (?) round pieces = joints?
- ~~Broadcasting the code view from the tablet to the TV so everyone can see it well (Hilkka checks the adapter on Tuesday)~~

Tasks

- Introduction about Clicbot
- Programming task:
    - Check the detailed description of the task:
    - build a robot with brains, 4 wheels, and 3 joints (picture)
    - program the controls to move around with a tablet



Tassu Spot Robonen

Space

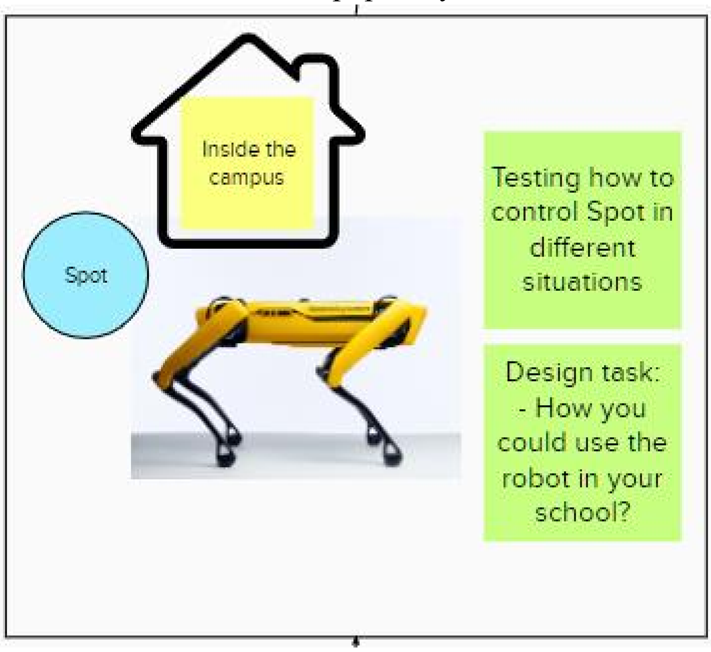
- Coffee room and walk route in Tietotalo

Tools

- Written instructions
- Tassu and the basket
- Tablet
- Canvas for mindmap, post-its, pens, UXRO cards (pink ones)

Tasks

- Introduction to Spot
- Show the controls and let pupils try to control the robot around Tietotalo.



-

QTrobot

Space

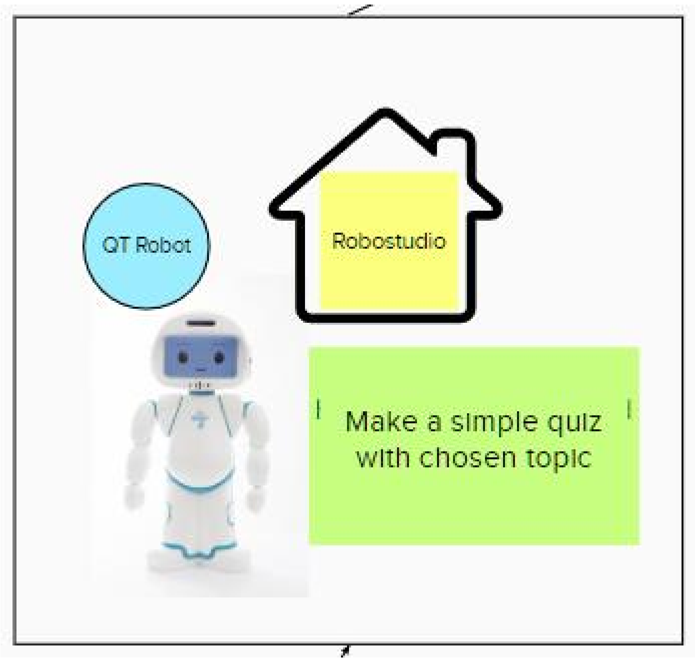
- Robostudio

Tools

- Written instructions
- QTrobot, tablets (teacher and learner)
- Laptop for programming (Robostudio laptop)
- HDMI for code view from laptop to TV so everyone can see the code well
- ~~Printed paper template for deciding the quiz questions: pupils can write the questions on a template with pencil~~ post-its for planning the quiz questions
- Hint template for block coding

Tasks

- Introduction about QTrobot
- Make a small quiz utilizing the learner tablet



Pupils with executive dysfunction

Disclaimer: I'm not a medical professional and my thesis work is not related to a medical topic. It is still important to try to make the workshop accessible for most participants and as I'm aware there will be participants who have executive dysfunction, I am doing lite research on the topic and using the tips that the interviewed teacher provided.

There may be some pupils in the group who experience executive dysfunction. There are some ways we can help them to move forward in the tasks. The picture below (Picture 1.) describes how executive dysfunction affects a person. The first example, "*Focusing too much on just one thing.*", was also mentioned by the teacher.

Picture 1. Cleveland Clinic, fetched 10.12.2022: *https://my.clevelandclinic.org/health/symptoms/23224-executive-dysfunction*

The picture below (Picture 2.) describes some strategies that teachers can use with executive functioning needs pupils. It is more advanced than we need, but we can utilize some of them.

1. Give clear instructions.
2. Give time to process.
3. If you notice that the pupils are stuck in small details, you can nudge them forward: "I think we could now focus more on thing X than thing Y."
4. You can ask the pupils to gather somewhere (movement, encouragement)

Picture 2. The Pathway 2 Success, fetched 10.12.2022: *https://www.thepathway2success.com/executive-functioning-skills/*

Appendix J. Invitation to participate in A co-learning (social) robot workshop

My name is Hilkka Lammi and I'm doing a master's thesis on a (social) robot co-learning workshop. The purpose of the study is to evaluate a robot workshop plan that is designed for 8th-grade pupils.

I'm looking for **1 more (HTI) student participants to join the workshop on 14.12.2022**. Your task would be to facilitate a small group of 8th-grade pupils (aged 13 to 14) with a robot task/challenge. The tasks will include easy block programming or other use of robots. Each group would have 2-4 pupils and 1-2 students.

The workshop will be held in **Robostudio.**

The workshop tasks will be confirmed with the participants, and we will organize **a practice session** in 12.12.2022.

The estimated duration of the workshop is 1h 45 minutes, but you'll be asked to come earlier for preparing the workshop. During the workshop, I will be making notes by observing, and after the workshop session, I will collect feedback.

I would really like to encourage anyone to take part in this study. It is a great opportunity to engage with a possibly different group of people (13-14 year olds) when often you might do the studies with your peers. All the safety measures and protocols will be strictly followed to ensure the safety and data security of the participants.

What: Co-learning robot workshop with a small group of 8thgraders (2-4 pupils each group)

Language: Mixed (English, Finnish)

Where: Robostudio

When: Wednesday 14.12.2022 at 9-11

(+ planning session 12.12.2022)

How to join: *link*

If you have any questions, please send me an email: *credentials*
If you know someone, who could be interested to join the workshop, feel free to forward this invitation to them. 😊

Best regards,

Hilkka

Appendix K. Feedback questionnaire for pupils

Feedback questionnaire for pupils

Palautekysely

Mielipiteesi kiinnostaa meitä! Merkitse numero, joka vastaa mielipidettäsi ja jätä kommentteja. Ethän kirjoita nimeäsi paperiin.

1. Pidin robottityöpajasta (1 eri mieltä - 5 samaa mieltä)

1	2	3	4	5

2. Mikä oli hyvää/huonoa robottityöpajassa?

3. Opin jotain uutta robottityöpajassa (1 eri mieltä - 5 samaa mieltä)

1	2	3	4	5

4. Perustelu:

5. Robottityöpaja oli minusta innostava (1 eri mieltä - 5 samaa mieltä)

1	2	3	4	5

6. Perustelu:

Kiitos osallistumisestasi robottityöpajaan! 😊

Appendix L. Essay instructions for pupils

Essay instructions

Liitteenä mukana kuvat kaikista roboteista ja niiden nimet. Kaikkiin kysymyksiin ei ole pakko vastata, mikäli niitä on liian paljon.

Ainekirjoituksessa voit kertoa mm. seuraavista asioista:

- Lyhyesti: Mitä teitte robottityöpajassa?
- Minkälaista robottityöpajassa oli?
- Minkälainen "fiilis" sinulle jäi työpajan jälkeen?
- Mitä mieltä olit roboteista?
- Mitä mieltä olit työpajan ohjaajista?
- Minkälainen tunnelma robottityöpajassa oli?
- Opitko jotain uutta?
- Jotain muuta mitä haluat mainita

Työpajassa käytetyt robotit: QTrobot (ihmisen kaltainen robotti), Tassu (tai Spot, keltainen robotti) ja Clicbot (se, joka kulki pyörillä).



Appendix M. Interview plan (facilitators after workshop)

Group interview after the workshop

I will record this interview and the recording will be removed after I have made a transcript.

1. How did the workshop go?
2. Did you learn something?
3. How did the pupils seem in the workshop?
    a. Were they interested/active?
    b. Did they seem motivated to work on the tasks?
    c. Did they seem to enjoy the workshop?
4. Was there something that went well?
5. Was there something that didn't go well?
6. Was there something that didn't go as planned?
7. Was there something that should have been done differently? Was something missing?
8. Did you have enough time for the workshop?
9. Have you participated in similar workshops before?

Appendix N. Interview plan (teacher after workshop)

Teacher interview after the workshop

Tässä haastattelussa kerättyjä tietoja käsitellään anonyymisti ja tulen poistamaan tallenteen, kun olen saanut tämän työpajan arviointivaiheen valmiiksi. Voisin tässä vaiheessa laittaa haastattelun tallennuksen päälle.

Laita ruudulle näkyviin robottilistaus: Käytetyt robotit ja niiden nimet

Tämän haastattelun tarkoitus on arvioida työpajaa.

1. Miten työpaja meni sinun mielestäsi?
    a. Mikä oli hyvää?
    b. Mikä olisi voinut mennä paremmin? Puuttuiko jotain?
2. Mitä mieltä olit työpajan tehtävistä? (Ralliauton ohjelmointi ja kisailu, kyselyn teko QTrobotilla/robotin ilmeentunnistusominaisuuden testaus, Spotin ohjaaminen ja suunnittelutehtävä)
3. Miltä oppilaat vaikuttivat työpajassa?
    a. Minkälainen fiilis työpajasta jäi ryhmälle? Vaikutelma ryhmästä
4. Vaikuttiko heillä olevan haasteita?
    a. Ohjelmoinnin suhteen?
    b. Ryhmätyöskentelyn suhteen?
    c. Englanninkielisyys?
5. Millainen tunnelma työpajassa oli?
6. Yhdessä robottipisteessä oli taustamusiikkia. Mitä mieltä olit taustamusiikista?
    a. Oliko musiikilla vaikutusta oppilaiden työskentelyyn?
7. Mitä mieltä olit työpajan ohjaajista?
8. Edellisellä haastattelukerralla pohdittiin työpajan tavoitteita. Päädyttiin silloin siihen, että työpajan tulisi innostaa robottinen kanssa työskentelyyn muullakin tavoin kuin koodaamisella. Toteutuiko tämä tavoite: oppilaiden innostaminen
9. Haluaisitko lisätä jotain?

Kiitos paljon ajastasi!