Collaborative Learning with Social Robots – Reflections on the Novel Co-Learning Concepts Robocamp and Robotour

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Abstract. This article presents the Robostudio space for collaborative learning (co-learning) around and with social robots, and two novel co-learning concepts. The first concept, *Robocamp,* is a home-based one-month learning model for family members' co-learning with a robot. In this model, a social robot is borrowed for families, and weekly hands-on tasks to be conducted with the robot are provided. The second concept, a co-learning workshop called *Robotour*, takes place in Robostudio and there, university students and primary school pupils together gain an understanding of different aspects of social robots. Both concepts aim for the cooperation between different learner groups and increasing their knowledge about social robots, interaction with them, and how to operate or program them. We present the current state-of-the-art in the area of educational robots, as well as initial evaluations of our concepts with the authentic target groups. We also reflect on our concepts in light of their benefits and potential. According to the evaluation findings, Robocamp provided an encouraging environment that allowed all the participating family members to participate in the collaborative activity, as well as think critically about the limitations of the robots. Robotour successfully raised different learner groups' curiosity towards robots, which further resulted in the enhancement of their creativity. The knowledge from this article can be utilized by researchers, designers, and teachers, who are interested in the development and implementation of co-learning activities around and with social robots.

Keywords: Social Robots, Educational Robots, Co-learning, Co-learning Space

1 Introduction

In this article, we explore and reflect on collaborative learning with social robots. Collaborative learning (co-learning) refers to the learning model, where learners are learning and engaging actively together (Yuen et al., 2014). Our emphasis is on co-learning, where humans from different learner groups are learning together while utilizing social robots as tools or learning platforms. Learning with social robots is multidimensional. In addition to human-robot interaction (HRI) and social robotics, we can also learn many other skills, such as creativity and teamwork (Yuen et al., 2014; Kandlhofer & Steinbauer, 2016; Aris & Orcos, 2019; Ryokai et al., 2009). Generally, robotic projects benefit from multiple backgrounds and abilities of the team members (Yuen et al., 2014), which makes robots a potential platform to learn with. Social robots can also act as efficient icebreakers between learners (Chowdhury et al., 2019; Sun et al., 2017, Beheshtian et al., 2020), which can make them beneficial tools also to support the team formation phase. Co-learning with robots has started to gain interest (e.g., Relkin et al., 2020; Govind et al., 2020; Eck et al., 2014; Chung & Santos, 2018; Ahtinen et al., 2023). However, the prior work mainly focuses on constructing and programming a robot by utilizing robotic toolkits, not social robots. Social robots are interesting platforms because they have some human-like features, they are interactive and multimodal, and they can have several different form-factors, roles and tasks.

Robostudio[1] is a co-learning space, which was established in Tampere University in Finland in Spring 2022. Robostudio owns several types of social robots, such as Pepper[2], QTRobot[3], Nao[4], Cozmo[5], Alpha Mini[6,] and Alpha 1E[7]. There exist also some non-humanoid robots such as Temi[8] and Spot[9]. Knowing and being able to interact and operate social robots is related to *technological literacy*, i.e., the knowledge and understanding of what a robot is, how do the robots work, how do they look like and what do they do (Jäggle et al., 2019; Kandlhofer et al., 2019). As Björling and Rose (2019) aptly describe: *"Many North American teens are immersed in technology from the time they were born and are most likely to have long-lasting relationships with robotic technologies in their future work, education, and home settings"* (p. 2). We assume that this statement can be applied to many other nationalities as well.

The fundamental idea in Robostudio is to promote the knowledge of robots from multiple viewpoints by utilizing robots and co-learning between different learner groups, e.g., university students, school pupils and seniors. For example, school pupils and university students can join a robotic design project together, and both parties can bring in their own perspective for learning based on their interests, skills and worldviews. In addition to learning about HRI and social robotics, these shared projects aim at enhancing knowledge regarding different people and cultures, teamwork, creativity and problem solving. A regular annual activity in Robostudio is to run the "User Experience in Robotics" course, which is a master's level hands-on project course about social robotics. As part of the project, the university students organize workshops with school pupils. There, the pupils learn about robots, while the students learn about facilitation and get design-oriented knowledge for their robotic design projects. Additionally, and as the focus of this article, we have developed two novel co-learning concepts in Robostudio. *The contribution of this article appears from the presentation of these two different co-learning concepts, and their evaluation results.* The first concept is

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1 https://www.tuni.fi/en/research/robostudio
2 https://www.aldebaran.com/en/pepper
3 https://luxai.com/robot-for-teaching-children-with-autism-at-home/
4 https://www.aldebaran.com/en/nao
5 https://www.digitaldreamlabs.com/pages/cozmo
6 https://www.ubtrobot.com/AlphaMini/index.aspx
7 https://www.ubtrobot.com/Alpha1E/index.aspx
8 https://www.robotemi.com/
9 https://www.bostondynamics.com/products/spot

called Robocamp, which is a home-based learning model, where a social robot is loaned to the families for one month. There, the family members act as co-learners. Our second concept is called Robotour. In Robotour, university students and some other learner groups, for example children or seniors, learn together in a co-learning workshop. This learning model includes co-learning stations, which are designed and facilitated by the university students. In this paper, we describe initial findings from the evaluations of these co-learning concepts based on two explorative field studies and qualitative data collection. Based on the findings and related work, we reflect on the benefits and potentials of co-learning between different learner groups with social robots.

2 Related work

This section about related work focuses on two different areas. First, in 2.1., we describe how and why social robots are currently utilized for educational purposes, and what are the special characteristics of the educational robots. This section provides a good grounding of the benefits of the social robots in education. Second, we present literature of the research about co-learning with robots (2.2. and 2.3.). That provides information about what is already known about using robots as tools for co-learning.

2.1 Educational robots and their benefits

Robots can be considered as an essential area to learn and know in contemporary life (Kandhofer et al., 2019). *Social robots* are autonomous or semi-autonomous machines that have the ability to interact and communicate with human beings and obey the behavioral norms set by humans (Bartneck & Forlizzi, 2004). Interacting and operating social robots is an essential skill for humans in the future, as the social robots are entering many parts of life, like education (e.g., Van den Berghe et al., 2019; Belpaeme et al., 2018; Ahtinen & Kaipainen, 2020), customer service (e.g., Zalama et al., 2014; Stock and Merkle, 2018; Aaltonen et al., 2017) and healthcare (Yang et al., 2017; Dawe et al., 2019; Cifuentes, 2020). *Human-robot interaction* (HRI) is a research field that is "*dedicated to understanding, designing, and evaluating robotic systems for use by or with humans*." (Goodrich & Schulz, 2008, pp. 1). Under HRI, a specific branch studies *child-robot interaction* (CRI). It focuses on children as the users of robots (e.g., Salter et al., 2008). Robots are typically motivational educational tools for children (Yuen et al., 2014; Petre & Price, 2004) and they can raise curiosity and creativity in the learners (Zawieska & Duffy, 2015). They can be utilized in various educational areas, such as STEM (science, technology, engineering and mathematics) (Anwar et al., 2019; Jung & Wong, 2018), languages (Van den Berghe et al., 2019; Belpaeme et al., 2018) and learning of general soft skills such as teamwork (Yuen et al., 2014; Kandlhofer & Steinbauer, 2016; Aris & Orcos, 2019). Alimisis and Kynigos (2009) explain that robotic activities in education can be divided into two broader categories: *robotics as a learning object* and *robotics as a learning tool*. Robotics as a learning object refers to education, where the learners learn about robotics by working with robots. Robotics as a learning tool, on the other hand, means that robots are used to assist the learning of some other subject, e.g., language or mathematics. In that case, we often speak about *robot-assisted learning.*

Social robots have an ability to raise curiosity in children towards learning, as noticed in many studies, e.g., Han et al. (2005); Ahtinen & Kaipainen (2020), and Zawieska & Duffy (2015). There are many reasons why children typically consider robots interesting and motivational (Tanaka et al, 2015; Zaga et al., 2015). Some of the reasons are their playfulness and their ability to give feedback and be reactive (Ahtinen & Kaipainen, 2020). Yuen et al. (2014) mention that robots provide concrete, authentic, accessible and motivating learning experiences for children. Social robots are designed to be human-like, social and physically present (Belpaeme et al., 2018; Leite et al., 2014). In addition to verbal interaction, social robots have abilities for non-verbal communication, e.g., using gestures, expressions, movements and proximity. This is due to their physical embodiment. Physical embodiment increases the feeling of social presence and thus improves multimodal communication, perceived trust, pleasurable experiences, attractiveness and perception of how helpful the robot is (Deng et al., 2019). The physical embodiment of the robot enables the movements and expressions to be designed for the robot. For example, De Wit et al. (2018) found higher level of engagement during the children's learning activities when the robot used gestures. Also, Leite et al. (2014) found that the use of facial expressions on robots had a positive impact on long-term interaction with robots.

2.2 Co-learning about robots in families

Robot-related learning projects are mostly diverse, and they have potential to bring people with different interests, ideas and skills to work together (Yuen et al., 2014). For example, one project can include activities such as programming, constructing and designing (Yuen et al., 2014). So, they can naturally enable collaboration between different learners and team members. Generally, in collaborative robotics projects presented so far, group members have worked together in constructing and programming a robot by utilizing the robotic toolkits (Yuen et al., 2014; Relkin et al., 2020; Eck et al., 2014). The general characteristics of robotics projects are the hands-on tasks, and the learners work with tangible objects, i.e., robots.

Lately, the number of studies targeting family-based co-learning about robots and robotics has increased. Robotic projects benefit from different interests and skills of the family members – the family can form a multi-faceted team to work in a robotics project. Previous research on this area has mainly studied co-learning with robotic toolkits (i.e., not social robots), and how children and parents build and program them collaboratively, typically in informal workshop or camp settings (i.e., not at home). The InterActions project presented by Bers (2007) conducted a series of five workshops, in which 4-7 years old kids and their parents were instructed to use LEGO MINDSTORMS robotics kit for building a robotic project. They explored the challenges and opportunities related to multigenerational learning experiences for children and parents. They found lots of potential in this type of cross-generational learning. The study result indicated that both parties gained knowledge of robot programming. Additionally, their confidence and competence regarding technology was enhanced. The families were provided an opportunity to take the robotic kit home. However, the authors did not describe the actual learning experiences in home settings. Relkin et al. (2020) studied how parents supported their children's informal learning experiences with robots. The study invited children between 5-7 years and their parents to participate in a 1-2 hours KIBO Family Day workshops. The KIBO robot used in the study is screen-free and can be programmed with wooden blocks. Families who participated in the workshops had the chance to get familiar with and interested in robotics through open-ended and collaborative approaches. These workshops successfully raised families' curiosity in programming. The study summarized that during the activity, parents played the role as coaches, while kids engaged as playmates and planners.

Eck et al. (2013) studied cross-generational learning about robotics in a scientific kindergarten experiment day. There, the participating children visited several hands-on experiment stations with their grandparents. They recognized the value of discovery and experimentation in learning by stating that "in general the concept of discovering and experimenting represents a valuable pedagogical approach within the area of preschool education, fostering the learning process of children in a holistic way." (p. 15). According to their findings, the cross-generational concept worked out well. Some children were motivated to even build their own robots at home after the event by using, e.g., Lego Mindstorms. Yet another study by Chung and Santos (2018) explored the Robofest Carnival, which is an informal learning program with multiple learning stations with robotic tasks. The parents were integrated into the program to manage the learning stations. The study showed that parents can enhance children's learning motivation and aspiration by providing instructions in the STEM challenges. The research concluded that parents indeed have a valuable role in robotic co-learning projects.

We have started exploring the family members' co-learning with social robots in the home context (Ahtinen et al., 2023). Based on our study with eight families we have noticed that home is a unique context for co-learning. It provides freedom for all family members as learners to adopt their personal perspective for learning based on their interest, level of knowledge about robots, and willingness to learn. In addition, home feels like a safe space for learning, thus providing comfortable settings to learn together.

2.3 Co-learning between school children and adults

Previous research has also explored collaborative robotic activities between children and adults, who do not belong to the same family (Angel-Fernandez & Vincze, 2018; Arnold et al., 2016; Wegner et al., 2013). Angel-Fernandez and Vincze (2018) have conducted a study with children between 6-18 years old and two master's students to identify the significance of storytelling session with children. The master's students were responsible for running the workshops with children, where the children learned about the robot and implemented a story for it. First, all children were introduced to the basic programming of the robot, and they carried out a short driving task with it, including activities like starting, stopping and avoiding obstacles. After the initial introduction, the bigger group was divided into subgroups: first group was responsible for creating the story and props, second group was responsible for implementing the story on the robot, and the third group was responsible for coordinating the work of the prior groups. According to their findings, although the young participants faced difficulty with programming and adult participants faced difficulty in collaborating for the story telling part, most of the participants strongly agreed that they learned best in teams and liked working with other people. In addition, more than half of the participants had fun working with the robots. The authors also mentioned that the participants seemed to be engaged during the activity.

Arnold et al. (2016) conducted a study with children (6-11 years old) and researchers to explore the expectations and needs of the children in the context of social robot as a friend. They conducted a four-stage study session. During the *coming together*, the researchers provided a space for the children to interact with adults to create openness and equality among children and adults. During *circle time*, the director of the sessions asked, "question of the day" (a question related to the design activity of the day) to get participants to think about the design problem. During the *design activity,* groups of 2-3 children and 1-2 researchers were formed. These groups were provided with a bag of art supplies to build a low fidelity prototype of their robot friend. The researchers collaborated with the children by asking them questions about their design decisions and providing suggestions. During the *presenting and wrapping up*, the children presented their designs, and the director wrote down the presented ideas and features. According to their findings, the children preferred to work on individual designs rather than working in groups. However, the children would enthusiastically explain the story behind making their friend robot. On the other hand, the adults could gain deep understanding about children's needs and wants towards the robot, which changed their existing perception of children's expectations and wants from the robots. Children being the active designers opened an opportunity for the adults to see the difference and similarities in children's design requirements.

2.4 Insights from the related work

Based on the related work, social robots seem to be a potential learning tool for various learners. They can raise interest and curiosity of the learners, they are tangible and present in physical space together with the learners, and they provide good opportunities to work in hands-on tasks around them. In addition, robots are useful in group-based learning, such as collaborative learning, because they seem to have a natural tendency to break ice between people. Robotics projects also benefit from multidisciplinary teams including people from different disciplines and backgrounds, thus bringing in different skills, competences and perspectives. Thus, we wanted to generate novel concepts for robotic co-learning, which could be utilized also by other researchers and instructors. Collaborative learning about robots either at home or in the co-learning spaces would be beneficial because as robots are entering many sectors of life, such as education, health care and customer service, the knowledge about robots can be an essential skill for everybody in the future.

3 Co-Learning concepts and evaluation methodology

We have developed two novel co-learning concepts in Robostudio. They include different learner groups learning about robots together. Next, we present these co-learning concepts and their evaluation methods.

3.1 Robocamp co-learning and it's evaluation

The first concept is called Robocamp. It was developed and evaluated during Covid pandemics in 2021. Robocamp is a home-based learning model, where a social robot is loaned to a family's home for one month. There, the family members act as co-learners. Home can act as a comfortable learning space for different family members learning together. In Robocamp, we provide the families with instructions and weekly tasks around the robot, including, e.g., familiarizing themselves with the robot, basic programming of the robot, and designing applications for the robot. The idea is to collaboratively learn about robots and their programming, so that all family members can participate in learning.

We have evaluated the Robocamp co-learning concept with eight voluntary families in Finland in 2021. The trial lasted for 4 weeks, and during this time period the families used Alpha Mini robot[6] and its block-based programming environment uCode. Alpha Mini was selected to represent a social robot in the Robocamp, because it is interactive, easy to use and transport and it has a friendly appearance, thus suiting very well for the children's education. We explained in the study introduction that Alpha Mini is just one example of social robots. In the beginning of each week, the families received new hands-on tasks to be conducted with Alpha Mini. The tasks are described in Table 1.

Table 1. The weekly topics and challenges of Robocamp.

Week number	Topic of the week	Challenges
1	Familiarizing with Alpha Mini and other social robots	1) Connecting Alpha Mini to the network and application, 2) exploring and trying out the skills and features of Alpha Mini, 3) searching for other social robots online
2	Programming Alpha Mini	1) Familiarizing with the programming environment and trying out some pre-defined programming tasks, e.g., Alpha Mini introducing itself, walking and doing yoga, 2) ideating own programs and programming those
3	Social robot as an encourager for sustainable behavior	1) Exploring the idea of a social robots as an encourager for sustainable behavior, 2) ideating and storyboarding family's own scenarios for such a robot, 3) programming part of the idea on Alpha Mini
4	Sustainability game design on social robot	1) Ideating a creative game for Alpha Mini to support sustainable behavior, 2) programming part of the game on Alpha Mini

The eight voluntary families were composed of 32 participants, which included 16 adults and 16 children. Each family had two parents, while the number of children varied from one to three. There were elementary school-aged children (6-15) in all families, however, four families had children's participants at younger age. The children's participants in this study had an average age of 8,4 years.

The data was collected by utilizing online methods due to the pandemic situation. Two rounds of *semi-structured online interview* were conducted with the families. The interviews were conducted in Teams. The interviewer had a pre-defined script of the open-ended questions, which was slightly adapted during the interview based on the possible emerging themes and topics appearing. The first interview focused on the family's experience and interest in robots, initial experiences with Alpha Mini and expectations towards the Robocamp. At the end of the trial, the second interview was carried out to discuss the family's co-learning experiences throughout the one-month Robocamp. This interview included, e.g., the following themes: family's co-learning experiences, collaboration between the family members, as well as benefits and challenges in learning. The participating families were asked to write *an online diary* about the pre-defined themes on Mural canvas (Mural) during the entire research period. The provided Mural included a structured diary template for each week to report, for instance, how was their co-learning, how did the programming feel, and did they face any challenges. Besides, the Mural has an open section for recording additional ideas, experiences, images, and screenshots of their program code. We had a separate diary view for each week of the trial. The families recorded their diary on Mural with digital sticky notes. An inductive content analysis (Mayring, 2000) was conducted to analyze the qualitative data. The transcribed interview and diary data were coded in spreadsheets and grouped into emerging themes. The analysis resulted in more than 20 themes, for example, approachability of the robot, learner roles, limitations of the robot, robot's embodiment and family dynamics in learning. Some of the themes have already been reported elsewhere (Ahtinen et al., 2023), and here we are focusing on some basic evaluation findings related to Robocamp.

3.2 Robotour co-learning workshop and it's evaluation

Our second concept is called Robotour. There, the university students and some other learner group, for example children or seniors, learn together. This learning model includes co-learning stations, which are facilitated by the university students. In co-learning stations, there is at least one robot involved, and some collaborative learning tasks around it. The learning tasks can include, for example, programming, story creation, responding to the quiz, or doing physical exercises with the robot. In addition, we encourage facilitators to undertake data security measures for safe and responsible human-robot interaction, such as taking care of the audio and image data acquired and stored by robots. These data security aspects are also learned and discussed on each learning station. An essential part of the co-learning station is reflective discussion about robots and the learnings. In this learning model, the learners have the possibility to interact with several robots, as they visit several stations. The basic structure of the workshops is the following: 1) welcome and intro, 2) hands-on learning activities with the robots, 3) wrap-up.

We evaluated this co-learning model in spring 2022, when we arranged three workshop sessions with university students and school pupils from different levels (4th, 6th and 8th grade, age-range of pupils 10-14 years). The workshops were arranged in the university's robotic co-learning space Robostudio. The first workshop with 8th grade (9 pupils, 1 teacher, 6 university students) was 1,5 hours long. The second workshop with the 4th grade (15 pupils, 1 teacher, 10 university students) was 2 hours long. The third workshop with 4th grade (18 pupils, 1 teacher, 10 university students) was similar to the second one.

The research data was collected by hand-written observations during the workshops, the materials produced by the learners in the learning tasks, audio recorded focus group discussion with the university students after the workshop, essay text written by the pupils as homework, and an audio recorded semi-structured interview with the schoolteachers. The data was analyzed with the qualitative content analysis (Mayring, 2000), similarly as Robocamp data. In this article, we report the findings from the school pupils' perspective based on the content analysis of their written essays, while the perspectives of other parties will be reported elsewhere.

4 Findings

Here, we describe evaluation findings concerning both co-learning concepts, Robocamp and Robotour.

4.1 Robocamp findings

Co-learning experience. Most of the participating families mentioned that co-learning with Alpha Mini was a positive experience. Family 1 (F1) described that the family collaborated in working with the robot. Their children wanted to take Alpha Mini even on holiday trips. The siblings collaborated while they were exploring the robot. For example, the older child helped the younger one with the language of the robot, and the younger child explained some things about the robot to the older one. F2 described that they had collaborative activity within the family to get familiar with the robot's' capabilities and limitations. Siblings collaborated in this family as well - the older sibling was launching applications from Alpha Mini for his 3-year-old sibling. F3 considered the Robocamp activity to be "*collaborative learning between parents and kids,*". F4 commented that the Robocamp activity was a pleasant time they spent together. F6 explained that the whole family collaborated to fix the robot's technical problems. F7 defined the robotic activity as a whole family activity, and they only worked with the robot when all family members were present: "*We had a big group on ideation with lots of ideas and we had the main programmer, who implemented the technical work.*" (Father, F7). In most families, busy schedules often prevented the whole family from attending the robotic learning time. However, all family members participated in the exploration of the Alpha Mini, discussions about the robotic activities and ideation of the programs. Sometimes, the family members collaborated in pairs. Thus, we can call Robocamp learning as collaborative learning, where all the family members could participate based on their own willingness, interest and perspective.

Learning about the limitations and potentials. Another perspective about social robots raised during Robocamp was the robots' technical issues and limitations: *"Somehow an engineer inside me arose, and it was a must to check for example the voice control in the robot."* (Mother, F2). The families realized that there is still quite a lot of technical development required for these robots to become more intelligent: "*I did a couple of tasks [with Alpha Mini]. For me this appears to be a little bit like a toy. Maybe for me, a more interesting device would be more intelligent one, and not like a telephone's answering machine.*" (Father, F2). Some parents also questioned the enthusiasm towards the robot for longer period*:" Still, I am a bit suspicious about for how long it [Alpha Mini] can raise interest and if it made sense to purchase one for us, but I believe there are some occasions when they are beneficial*." (Mother, F3). When having the robot as part of life for a longer time, it enabled the participants to figure out the possible practical challenges as well, such as when to charge the robot for it to be ready for use, and where to store it.

On the other hand, some parents who were critical towards the robot's current limitations, still saw the potential of them for the further development: *"But I agree that there is a huge potential on them, and I can understand they are an important key forward. Time will show the direction, towards which they will be developed."* (Father, F3). Some parents also perceived the role of social robots in society, especially their valuable role in education and learning. Some mothers (F2, F7 and F8) had noticed that children were eager to listen to what Alpha Mini asks them to do: *"They are quite happy with the robot, and they are already following what Mini can do, so I think it would add some value to teach something to the kids."* (Mother, F8). Thus, having a social robot in children's education was considered beneficial and valuable.

4.2 Robotour findings

Overall Robostudio experience. Based on the essays, most pupils described the Robostudio workshop as a pleasant and positive experience. They described the Robostudio as "*nice*", "*interesting*" and "*fun*". On their writings, pupils mentioned it was interesting to see a great variety of social robots and their capabilities. Overall, many pupils stated they were able to learn new things about robots and their features. The pupils came up with good improvement ideas, for example the interaction could last longer, and there could be more activities on each learning station. They also wished for an opportunity to see how each robot is programmed, how they are built, and they were interested in having an opportunity to ask questions about robots. Some pupils wished to see more different robots, like industry robots. Two pupils mentioned that they did not consider Robostudio workshop a really good experience, and a few students stated that it would have been more interesting if everybody could see all the robots.

Learnings about robots. On the essays, pupils emphasized the variety of different robots they met and worked with*: "There were many robots, and they all were very different, and it was nice to see what they are capable of."* (Pupil, 6th grade); *"I find it interesting that there exists so many different kinds of robots 😅!!"* (Pupil, 4th grade).

Overall, pupils found the robots interesting, and they liked to work with them. Clicbot and Pepper robots seemed to raise the most interest among the pupils, most probably because they were novel to them. About the Clicbot robot, pupils stated that they liked it because they were able to drive it by themselves and do a small transportation task with it. They also wrote that it is interesting to build different shapes for Clicbot. The Clicbot's ability to climb on the glass wall was also considered impressive: *"All robots were very interesting, but above all was the robot, which could climb on the wall with small support."* (Pupil, 8th grade). The size of the Pepper robot was liked, as well as its appearance, which was considered as *"very cute"*, *"friendly"* and *"human-like"*. One pupil considered Pepper's body and eyes cute: *"Pepper's hands were lovely! The body was cute, as well as the eyes. So handsome 😉."* (Pupil, 6th grade).

Pupils got many insights and ideas related to the usage of robots, for example they raised some ideas about how robots could be used as part of learning, everyday purposes, and for entertainment. One 4th grade pupil commented that social robots are our future. An 8th grade pupil was wondering if robots could help in learning complicated topics, such as physics and math. One 8th grade pupil commented that even though robots are impressive, they do not reach the same level as in sci-fi movies. Some pupils mentioned that they learned about the programming of robots and their sensors.

5 Discussion

Robostudio is a novel space for collaborative learning with social robots, where the usual mode of work is to work together with different learner groups in robot-related hands-on tasks. Similar to the findings by Yuen et al. (2014), we have also noticed that robot-related learning projects are diverse, and they have potential to bring learners with different interests, ideas and skills to work together. Additionally, we have realized that working around social robots through co-learning activities can create a positive team cohesion since the hands-on approach and tangibility of the objects can naturally make the learners become active in their tasks. Robots seem to have the ability to break the ice between the learners, as also noticed previously by Chowdhury et al., (2019), Sun et al., (2017) and Beheshtian et al., (2020). This aspect can be helpful in the initial phase of the co-learning, when the learners from different groups are forming the team and start collaboration.

Co-learning workshop Robotour – Raising curiosity towards robots. Co-learning workshops arranged in the co-learning space such as Robostudio, are a good opportunity for school pupils *to get to know different robots* and try out interaction with them. Similar to previous research (Yuen et. al., 2014; Petre & Price, 2004; Zawieska & Duffy, 2015), we also believe that learning with robots can enhance pupils' sense of *curiosity and creativity*. The co-learning model provides opportunities for participation in tasks, which may not be possible in everyday school settings. The model is responsible in the sense that *the data security aspects* are taken care of by minimizing the robots' data collecting and storing. The model is responsible also from the perspective of participation, as it allows for opportunities to take *the role of observer*. This means that the participants are not forced to do any activities with the robots, but they can choose the level of participation from the very active hands-on participation to quieter observer in the background. For many pupils, the co-learning workshops may be the first time they meet robots, so it is important to provide an opportunity for them to watch from a distance if they do not feel comfortable about robots. In addition, the reflective nature of the co-learning workshops allows for all kinds of discussions and questions, including the discussion on possible risks and threats, or fears towards the robot. This approach can result in enhancing pupils' sense of discovery and experimentation (Eck et.al, 2013) as they can learn about different aspects of robots during the discussions. Based on our observations, the model where younger pupils and university students are working together seems to provide good opportunities for creation of great group dynamics. Bers (2007) explored families as multigenerational robotics-based communities of practice. Similarly, we believe different learner groups in a robotic co-learning workshop can form a well-functioning community of practice for learning. In the future, it would be beneficial to arrange a series of co-learning workshops to strengthen the group dynamics as well as provide more opportunities for going beyond the very basic level of learning. For example, the first workshop could deal with the basic getting together and interaction with different robots, and the second session could focus on robotic programming or construction. We also like to emphasize the role of creativity as part of these co-learning workshops. First, it is beneficial to give freedom for the university students to design and organize the learning tasks and stations, because then they can use their own creativity and thinking for planning, and it also raises motivation in arranging the activity. Second, the co-learning tasks can be designed in a way that includes, for example, ideation or design, which will make the participating pupils think innovatively and creatively.

Robocamp at home - Beyond the novelty effect of robots, towards critical thinking. Social robots have a very strong novelty effect, which can have a high impact on the user experience results in short-term studies. In most cases, the initial user experience with the robot is very positive, because they seem to be interesting technology for people, but over time the novelty effect can wear off (e.g., Leite et al., 2009; Kanda, 2004). With our longer co-learning setup and having the robot at home we were able to get beyond the immediate novelty effect caused by the robot. While the family members were allowed to explore the robot flexibly in the open-ended tasks, they were able to *learn and discuss the challenges and limitations* related to the robot. Some participants draw attention to *the critical perspective* on Alpha Mini robot and social robots in general. The longer co-learning at home can be a beneficial learning model concerning *technological literacy skills*, which is essential knowledge about the emerging technologies such as social robots. In shorter interactions with these robots, especially when a human supports the interaction, the experience and learnings from the robot can be very limited and biased towards the positive direction, because the issues and restrictions may not appear. For example, Jäggle et al. (2019) studied the technological literacy related to educational robots in the setup where young people visited the three-hour program in the technical university to get to know the robots, the robots' applications, and the robots’ capabilities. It is important to get to know the limitations of these technologies in addition to the potential and benefits to adopt some level of critical thinking. Critical thinking and limitations may not appear in the shorter interactions with the robots, and thus, longer learning period can be beneficial. We can conclude that families can act as great *multi-faceted co-learning teams* with social robots. With our learning model, learning is open-ended and versatile, resulting in *multi-faceted learnings and insights* about robot's design, interaction, role in society, and limitations. Even though all family members may not actively participate equally, the learnings are discussed inside the families, and even the members with supportive roles can get their own insights and learnings. It is plausible to arrange small learning and collaboration units within the families, e.g., one to one unit of child and parent or the unit of siblings. This discovery corresponds to the findings by Bers (2007), who explored families as multigenerational robotics-based communities of practice.

All in all, collaborative learning between different learner groups seems to be a meaningful learning concept in robotic projects as every learner can adopt their *own personal perspective for learning;* everybody included have a possibility to participate and learn from one another. The main benefits include learning from others, getting different points of view, getting help for ice breaking from robots, possibilities to improve technological literacy, and offering a great platform for creative projects. We also see a great benefit of robots that are physically embodied and tangible. Working around these robots brings *people to act on hands-on tasks together in the same physical space*, which has benefits for getting to know each other, interaction, and understanding each other.

Limitations and future work. The qualitative and explorative nature of our research enabled us to investigate different phenomena around co-learning with social robots in the authentic home context as well as in co-learning space context. We were able to explore these phenomena in-depth with real social robots. Our setting offered possibilities to explore co-learning in the natural environments. Characteristics to the qualitative in-depth study, the limited number of participants affects the generalizability of the findings and conclusions. Thus, the generalizations of the findings need to be made cautiously. We recruited the participant samples considering their willingness to contribute to the study, therefore, the participants may have possessed a greater interest in robotic activities. In addition, providing specific types of robots based on which robots were available in Robostudio, may have affected the experiences and learnings about social robots due to their capabilities and restrictions. A study with different robots might have provided different learnings and experiences for the participants. In the future, the Robocamp co-learning model could include different types of robots to be explored by more versatile samples of families to get more insights about different robots. More research is needed about the Robotour co-learning workshops including different tasks and more sessions.

6 Conclusion

In this paper, we have presented and evaluated two novel co-learning concepts in the home context (Robocamp concept) and in collaborative learning space called Robostudio (Robotour concept). Robocamp was a one-month long study, where families used and programmed Alpha Mini robot at home using block-based programming. The families received new tasks and challenges each week, and two rounds of semi-structured interviews were conducted with each family. According to the findings, Robocamp encouraged families to work collaboratively as a team. However, families expressed their concerns about the limitations of the robot and its capabilities of engagement in long-term interaction. Robotour, on the other hand, was a pop-up co-learning activity where school pupils and university students participated in co-learning activity. The co-learning stations were managed by the university students and each station involved at least one robot and some collaborative tasks around it. According to the findings, the event raised curiosity and awareness towards robots. In addition, the children started to come up with ideas about the usage of robots in different areas, such as education and entertainment, which enhanced their creativity. This article provides insights for researchers, designers and teachers who are willing to design and implement co-learning activities around social robots.

Acknowledgment. We express our gratitude to our study participants and thank the Faculty of Information Technology and Communication Sciences at Tampere University for providing funding for this research.

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