Robocamp at Home: Exploring Families' Co-Learning with a Social Robot

Findings from a One-Month Study in the Wild

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Figure 1: Children interacting, operating and playing with Alpha Mini in the Robocamp co-learning study.

ABSTRACT

Social robots are becoming important agents in several sectors of people's lives. They can act in different contexts, e.g., public spaces, schools, and homes. Operating, programming and interacting with these robots will be an essential skill in the future. We present a qualitative and explorative study on how family members collaboratively learn (co-learn) about social robots at their homes. Our one-month in the wild study took place at homes of eight families (N=32) in Finland. We defined a novel model for co-learning about and with a social robot at home, Robocamp. In Robocamp, Alpha Mini robot was introduced and left within the families, who were then provided with weekly robotic challenges to be conducted with the robot. The research data was collected by semi-structured interviews and online diaries. This study provides novel insights about family-based co-learning with social robots in the home context. It also offers recommendations for implementing family-based co-learning with social robots at homes.

CCS CONCEPTS

• **Computer systems organization → Robotics**; • **Human-centered computing → Empirical studies in HCI**; **User studies**.

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1 INTRODUCTION

Robots can be considered as an essential area to learn and know in contemporary life [33]. *Social robots* are autonomous or semi-autonomous machines that have an ability to interact and communicate with human beings [8]. Operating and interacting with social robots will be an essential skill for humans in the future, as they are entering many sectors of life, like education [4],[9],[47], customer service [3],[43],[54] and healthcare [17],[18],[51]. Knowing, operating and interacting with social robots is related to robot literacy, in terms of knowledge and understanding of what a robot is and what are their mechanisms, how do the robots work, how do they look like and what do they do [28],[33],[46]. Robotics and programming of the robots are entering as educational subjects on the elementary school level [33]. Robots are also used in education for learning other subjects than robotics. This approach is called robot-assisted learning. For example, robots are used as a learning tool in STEM education (science, technology, engineering and mathematics) as described by, e.g., [6],[29],[30]. In addition to

STEM, robot-assisted language learning (RALL) is a widely spread area, which utilizes social robots as language learning companions [4],[10],[47]. The involvement of robotics in curricular education expresses their increasing role in people's life.

Chung and Santos [16] state that parents are an underutilized resource when children are learning about robotics. Researchers are increasingly interested in the informal settings for learning about robotics. Informal learning settings, e.g., robotic competitions, provide great potential for motivation, curiosity and creativity around the robots [6]. Several projects have now integrated parents and other family members as part of the co-learning model about and with robots. Typically, in these models, the family members collaboratively work and learn (co-learn) together towards solving the given robotic tasks related to robot construction and programming [16],[22],[26],[39]. Similarly, *co-learning* in this paper refers to learning together with a group of people, in our case within a family unit, by using a social robot as a learning tool.

Research goal and questions. The goal of our qualitative and explorative study was to gain understanding of families' experiences of co-learning with social robots, taking place at home. The research questions of this study were the following: *1) How do family members co-learn with a social robot in the home context? 2) What are the recommendations for implementing family-based co-learning with a social robot at home?* Our research was conducted as a one-month study with eight families including elementary school and younger children (N=16) and parents (N=16). The study was conducted by utilizing the Robocamp co-learning model, which has been developed by us. Robocamp is a co-learning concept, where the family members learn about the social robots together at home.

Contribution. The informal family-based co-learning projects around robotics have mostly taken place in event-based settings, such as workshops and camps [16],[22],[26],[39]. The former studies about in-home learning with the robots have mainly taken place as short-term co-design studies [13],[25] or as studies focusing only on children's learning [14],[56]. The previous work has not yet properly explored the home context as a co-learning environment for the family-based learning about robots. Home and family as a co-learning context can bring in different experiences, learnings, enabling factors and challenges than supervised learning contexts, such as school and event settings. Thus, *the novelty of this work emerges from the in the wild long-term research setting at home and exploration of the whole family as a co-learning unit with the social robot.* As a contribution, we report the discovered co-learning experiences of the families, and provide recommendations for researchers, designers and instructors who want to utilize social robots as co-learning tools of families in the home context.

2 RELATED WORK

This section presents relevant related work about educational robots in the home context, and family-based co-learning with robots.

2.1 Educational robots at home

Previous research has explored the roles and interactions related to social robots that act at homes. Cagiltay et al. [13] explored the design space of in-home social robots with families by focusing on the perspective of children and parents. They organized co-design workshops with families, and found out different roles for the in-home robot, i.e., companion roles (playmate, reading companion, conversational companion) and assistant roles (cooking support, instrument support, homework support). Garg and Sengupta [25] studied families' expectations towards the conversational technologies for children's in-home learning. Their findings revealed that children expected the learning companion to have different learning modes, roles, personas, and intelligent human-like conversational skills to support different types of learners. Human-like characteristics, such as the adaptability based on the context, and emotional ability, were expected. The parents wished for social interaction around technology, and to be in control about the children's technology use. Garg and Sengupta [25] suggested the involvement of family members as co-learners in a technology-facilitated learning. Longitudinal in-home studies with social robots can be helpful to understand the human-robot interaction and user experience beyond the initial experience that is mostly affected by the novelty effect [24]. Such studies can help to design robots that people will interact at home over time even after the novelty is faded [45]. For example, Cagiltay et al. [14] explored the children's long-term engagement with an in-home learning companion robot in a one-month study at homes. They found that, e.g., the learning activity with the robot should be versatile, and that the robot's behavior should be adaptable to the user.

Employing social robots at homes can raise doubt and ethical concerns. Users' privacy is a crucial ethical aspect in the use of in-home social robots. In several studies, parents have raised concerns towards privacy matters when it comes the collected data and its use [13],[25]. Social robots are connected to sensors, cameras, range finders, and accelerometers [42]. Due to these sensors and their mobility, they can access people's personal and sensitive data, as well as personal spaces. One way to improve these privacy issues is for the user to be able to turn off the sensors, disable network connections, control the visibility of the camera or limit the robot's access to specific areas in the house [27]. Transparency aspect is also essential in interaction with social robots. The data collection, processing and storage should all be transparent to the user [27]. Confidentiality is another ethical consideration regarding the use of social robots in-home [27]. The users need to be informed that the data gathered by the robot remains confidential at all stages of collection, storage, and analysis. The user should have control over the data being recorded and the ways it is made available. An emerging area of privacy-sensitive robotics [15],[40] is now focusing on these important privacy and data security issues in robotics.

2.2 Family-based co-learning with robots

Recently, an increasing amount of research has focused on family-based co-learning about robots and robotics. Robotic projects can bring in family members with different interests and skills together. The previous research on this area has mainly conducted studies with robotic toolkits (i.e., not social robots), typically in informal workshop or camp settings (i.e., not at home). Bers et al. [11] presented the project called InterActions, which is a series of five workshops, where 4-7 years old children together with their parents build and program a robotic project by using LEGO MINDSTORMS robotics kit. They explored the challenges and opportunities related to multigenerational learning experiences for children and parents. Their results showed that both parties learned how to build and program the robot, and they also gained confidence and competence regarding technology. The families were provided with an opportunity to take the robotic kit to home. The families who took it home reported a better learning experience. However, they did not describe in detail the actual learning experiences taking place at home. Relkin et al. [39] studied how parents supported their children's informal learning experiences with robots. This study took place as KIBO Family Day workshops lasting for 1-2 hours, and it was targeting to children between 5-7 years and their parents. KIBO is a screen-free robot, which is programmed with the wooden blocks. Their findings were promising. The KIBO family events provided open-ended and collaborative ways for families to get familiar and interested with robotics and learn about it. These workshops significantly enhanced families' interest in coding. According to their findings, the parents adopted the role of coaches, while the children engaged as playmates and planners during the activity.

Chung and Santos [16] 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. It was found out that the parents were positively able to inspire and motivate their children by teaching and instructing them in the STEM challenges. Based on this research, the parents can have a valuable role in the co-learning about the robots. Positive findings about cross-generational co-learning have also been reported by Eck et al. [22]. In addition, von Wangenheim et al. [50] observed a reversion of the traditional roles between parents and children - the children leading and explaining the robotic activities to their parents.

3 METHODOLOGY

To approach our research goal and questions we arranged a one-month field study with eight families in Finland. The study took place at homes by utilizing the concept that we call Robocamp, a family-based co-learning model about social robots at homes. We adopted a user experience (UX) research approach [23] to explore the co-learning experiences of the family members with the robot based on the participants' reported perceptions, reactions and experiences. Studies in the naturalistic settings are still quite rare in the field of human-robot interaction [20]. Studies in the naturalistic context can provide rich qualitative data, and the analysis can lead to deep understanding of the human-robot interaction in this specific setting [20].

3.1 Robocamp co-learning and the robot model

To structure our research study, we developed the co-learning model called Robocamp. In Robocamp, the family members interacted with the robot together at home by conducting several open-ended hands-on tasks to learn about social robots, their possible roles and tasks, their programming, and their design. A social robot called Alpha Mini [1] with an external tablet including a data sim card and Alpha Mini app were provided for the participating families to be used during the trial. Alpha Mini is about 24 cm tall social robot with voice interaction, several kinds of movements, expressions and face recognition. It can be operated with a graphical interface and programmed in uCode block-based environment with a mobile device by using the Alpha Mini app. 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 well for the children's education. We explained in the study introduction that Alpha Mini is just one example of social robots. By providing it for the participants to be used in the authentic home settings, we were able to collect information about its usage, interaction and programming, as well as the family members' robotic learning experiences in the naturalistic settings. Several research papers emphasize the role of hands-on tasks on robotics learning [21],[44]. In Robocamp, the participating families got weekly hands-on tasks (challenges) that related to the Alpha Mini robot, and they were asked to solve the tasks together as a family. The challenges and instructions were provided on the online canvas in Mural tool [2]. We revealed the challenges in a weekly basis. The first week challenges dealt with familiarizing with Alpha Mini. The second week was about the basic programming of it. On the third week, the families ideated their own robot application and implemented it on Alpha Mini. On the final week, they ideated a robotic game and implemented it on Alpha Mini. There was not only one correct way to solve the tasks, as they were designed to be creative and open-ended tasks that required experimenting and discovering according to the constructivist approach for learning. In addition to the weekly challenges, the families were allowed to freely explore the robot as much as they wanted and make as many additional programming tasks as they were willing to.

3.2 Participants and research ethics

Eight voluntary families participated the study in Finland. The participants were recruited through the advertisement on the local university's webpage, and through the personal networks. To participate in the study, families were required to have children of elementary school age (6-15 years) and to have basic knowledge about technology. Basic knowledge about technology was needed in the families for them to be able to handle the robot, even though it was quite straightforward to use. There were three rounds in the study – the first round was running with three families in February-March 2021, the second round with three new families in April-May 2021, and the third round with two additional families in June 2021. The total amount of families was eight, including all together 32 participants, out of which 16 adults and 16 children. All families had two parents. The number of children/family varied from one to three. All families had children of elementary school age, but four families had also younger children. The average age of the children was 8,4 years. Some of the families were more technologically oriented than the others. Three families were international, and five families were Finnish.

Participation to the study was voluntary, and all the activities and the strict research data security policy (data sets collected, data storing and deletion) was explained to the participants prior to the study. They were also informed that they can quit the study at any point by informing the researchers. Adults were provided with an in-depth information sheet and they signed a consent form. The children were provided with a simpler version of the information sheet to be understandable for them. The parents were advised to discuss the study procedure with their children and ask if they want to participate. The researchers did not communicate with the children independently, but the communication took place under the supervision of the parents in the family interviews. All the research data collected from the families was controlled by the parents. In the online interviews, the children were present if they wanted to be, and the parents allowed. The family could decide whether to keep the camera on. The parents filled in the diary together with the children. The data was pseudonymized, i.e. all identification information was removed from the data during the transcription and analysis phase, and all the data was stored in the secure drive of the university. The families were informed that the research data would be deleted after five years of finishing the study. It was advised for the families to keep the camera of Alpha Mini covered when operating the robot for the data security reasons. The families had a possibility to contact the researchers and ask any question through the phone, email and diary canvas. All of the possible concerns could have been discussed also during the kickoff and both interviews.

3.3 Data collecting methods

First, the representative family member was introduced to the study and the robot in the kickoff session, where the Alpha Mini robot and other materials (tablet, instructions and information sheets) were delivered. This meeting took place as a face-to-face meeting at the university with one family member, who shared the contents with the rest of the family afterwards. The data was collected by utilizing online methods due to the Covid-19 pandemics. *Two rounds of semi-structured online interview* were conducted with the families. The interviews were conducted in Microsoft Teams. The interviewer had a pre-defined script of open-ended questions, which was slightly adapted during the interview based on the possible emerging themes and topics appearing. Ideally, the whole family was present, but this varied between the families. The interviews were video recorded, and the participants could select whether to keep the camera open. Each interview lasted about 45 minutes. Interviews acted as the main data source in this article, as they provided a very in-depth and rich qualitative data set. An initial interview about the expectations and initial learning experiences was conducted on the first week of the trial. The initial interview covered, e.g., the following themes: family's experience and interest in robots, first experiences with Alpha Mini and expectations towards the Robocamp. The second interview was conducted in the end of the trial to discuss the co-learning experiences during 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. During the whole research period, we asked the families to keep an *online diary* about the pre-defined themes on Mural canvas tool [2]. We had prepared a structured diary template for each week (e.g., how was their co-learning, how did the programming feel, did they face any challenges) but there was also an open slot where they could add any additional ideas, experiences, images and screenshots of their program code. The families added their responses to the diary by using digital sticky notes. The diary notes were generated by the family members collectively. Each family had their own diary, which just the family members and researchers could access.

3.4 Data analysis methods

We collected qualitative in-depth data in this study. The qualitative data consisted of the semi-structured interview transcriptions, which acted as the main data source, and the online diary notes, which acted as a supporting data source. The interview records were transcribed word for word, resulting in totally 39 400 words long transcript, on average 4925 words/family. In the transcription, the data was pseudonymized - all the identification information was removed at this phase from the whole data, and a code was given for each of the families (F1-F8). The family members were marked by "mother", father", "girl 12 y." etc. An inductive content analysis [36] was conducted to analyze the data. First, the interview and diary data were coded in spreadsheets and grouped into themes. The first and second author discussed the identified themes throughout the whole analysis phase, although the coding of the data was conducted by the first author. The analysis resulted in more than 20 themes, for example, approachability of the robot, learner roles, limitations of the robot, learning of programming, robot's embodiment and family dynamics in learning. Screenshots of the programs done by the families, as well as other materials such as photos, were also observed on the online diaries. We have excluded irrelevant themes from this article, based on the article's focus. We have included authentic participant comments with the family codes to illustrate the findings, e.g. F1 = family 1.

4 FINDINGS

In this section, we report the co-learning experiences of the families.

4.1 Families' co-learning and learner roles

Multifaceted hands-on learning about the social robots. During the Robocamp, all family members were flexibly adopting their own personal approach and perspective for learning, and making their own insights about the social robots. The learning about the social robots in Robocamp was versatile. Based on the final interviews, all families learned about social robots, for example what is a social robot, what are their benefits and tasks, how to interact with them, but also challenges and limitations. According to the families' comments, participation in the Robocamp succeeded in raising their awareness about social robots. The following quote describes how the families got a better view of what are the social robots, and what tasks they can actually do, as described by one mother: *"Now I know that these kinds of robots exist, and on which level they are, and that those are available in reasonable consumer price, and what they can do in general. So, now I have some sort of touch of them."* (Mother, F1). The same mother continued her explanation by saying that now she thinks to be more aware of what kind of robots teach languages at their kids' school. One aspect about Alpha Mini, which was wondered by one father (F2), was how the robot has been actually made. The context of learning in Robocamp (having a robot at home, long-term period, home context, family members as co-learners) enabled unique and personal learnings and insights for all family members as they all adopted own approach for learning: *"This is collaborative and determined activity, this is* *good, this provides something for many people, not necessarily the same things for everybody, but one can participate in many ways – planning, implementation and ideation."* (Father, F3). The family members had plenty of freedom to adopt their own perspective for learning, as there was enough time, space and flexibility in the Robocamp learning setting. Each family member explored Alpha Mini from their own perspective and age, as the home setting enabled a safe and comfortable learning context with freedom to explore in own speed. The hands-on tasks with the robot were appreciated by the participants: *"First, we think that learning about something by working around it as a practical use of it, it is a good thing as first thing."* (Mother, F6).

Co-learning as a positive experience. Many families described the co-learning experience with Alpha Mini as a positive collaborative experience. The father of F1 described the family acting and making things with the robot together. Their children wanted to take Alpha Mini even to the holiday trip. The father commented that in Robocamp, they could freely think when and how they make things together, and what do they actually want to do. In this family, the siblings collaborated when they were exploring the robot. For example, the older one helped the younger one with the language of the robot, and the younger one explained some things about the robot to the older one. F2 described that in Robocamp, they could have collaborative activity within the family, and they could get familiar with the robot, and what it can do, and also what it cannot do. So, they got to know about the limitations as well. Siblings' collaboration was also present in this family, as the older sibling was launching the applications from Alpha Mini for the 3-years-old little sister. F3 described the Robocamp activity as *"collaborative activity between parents and kids, and collaborative learning"*, as well as F4 commented how the Robocamp activity was nice time spent together. F6 explained that the whole family collaborated when some technical problems appeared on the robot; they tried to solve the problems together. F7 explicitly defined the robotic activity as a whole family activity, and they only worked with the robot when all family members were present: *"The challenges were all different and that gave possibilities to use it, and we had a big group on ideation, we got lots of ideas, and then we had the main programmer, who could then harness the good ideas, so he was really implementing the technical work. We had a great team."* (Father, F7). F7 also said that they gave tips and supported each other.

It was recognized, however, that in most families the tight schedules and everyday activities taking place in the family context often prevented the whole family being present in the robotic learning moments. As it will be explained in more detail in the next section, some family members took more passive role in Robocamp, and acted as an observer. Even though they had more passive role in hands-on activities, they were still participating on the background. All the family members participated in exploration of Alpha Mini, discussions about the robotic activities and ideation of the programs, even though some members were not equally active in working with Alpha Mini than others. Sometimes, the family members were collaborating in smaller units, such as pairs. Thus, we can call Robocamp learning as collaborative learning, where all of the family members could participate based on their own willingness, interest and perspective.

Learner roles and collaboration in learning. In many of the participating families, similar kinds of learner role divisions between the family members were visible during the Robocamp. Typically, the school age children were the most active ones who worked with Alpha Mini and did most of the programming tasks. We call this role as a *Main programmer*. For example, a 13-years-old boy acted as the main programmer in one family (F2). His mother described that she was present in the programming tasks by watching what the robot did, but the programs were made independently by the son. An 11-years-old boy was the main programmer in another family (F7), and the following quote describes how this boy described himself as a programmer-type-of-a-person, and thus, his high interest towards the programming: *"In general, I am a programmer type of person. I attended a programming club for one year and I learned the basics."* (Boy, 11 years, F7). Yet in another family (F8), a 6-years-old girl acted as the main programmer. Her mother described how interested this girl was about the robot, and how happy the mother was about it. The mother also described how patiently the girl learned by trying things out - she played and removed something, and added new blocks, and then removed again. In one family (F5), there was a couple of main programmers in the family, as the 8-years-old daughter was actively working with her mother in the programming tasks, and they discussed the tasks together as well. In most cases, the main programmers worked quite independently with the robot's programming tasks, without much support. Sometimes it was noticed by the parents that it is better to let the child work independently in programming, because of the child's strong willingness to implement things in a specific way. F5 mother commented how she let the child to program independently based on her own will, because the child had very strong opinions. The main programmer was typically the family's main enthusiastic person towards Alpha Mini and its programming, and the main programmer needed to have reached a specific age or level in order to be able to program. So, the youngest family members (2-3 years) were not programming even though they were very enthusiastic about interacting with Alpha Mini.

Typically, the main programmers had one parent who supported them when needed, as expressed by a mother of a 14-years-old girl: *"But I definitely helped her when things were not working, I tried to figure out how to do things… In programming yes [mother had assisting role], but I assisted very briefly, not every time, whenever is needed."* (Mother, F6). The main programmers sometimes needed support for example with the code, or with the network connection of Alpha Mini. Especially the younger schoolkids also sometimes needed language support, as Alpha Mini worked only in English. We call this supporting role as an *Assistant*. The additional tasks of the assistants were to explain the Robocamp challenges for the children, and sometimes think about what would be realistic to do timewise and content wise. Also, the assisting parent sometimes explained some basic things about the system. Sometimes the assistants also made some suggestions for the programs that the children implemented: *"Especially the Welcome program that we made with our son for our friends. We made it together, but it was nicer that the kids used the tablet and my role was more like making suggestions about different features or gestures on some parts of the program, and then the kids searched for a suitable gesture."* (Mother, F4). In most cases, the other-than-assisting-parent adopted a more passive role and acted as an *Observer*. For the observing parent, the kids were showing what they made with the robot, and the programs they coded: *"There was this specific Kungfu dance that our daughter wanted to show me."* (Mother, F1). The observers did not typically participate the programming activities, but they were the persons for whom the programs were proudly shown, and who were asked to try out the programs. The fourth role established during Robocamp related to the youngest family members (2-3-year-old children). The youngest family members were actively involved in the activities and very naturally adopted the role of a *Player*. They were very enthusiastic about interacting with Alpha Mini, and most of them approached Alpha Mini naturally and without hesitation. One 3-year-old girl (F2) was extremely enthusiastic about playing, interacting and dancing with Alpha Mini. When she noticed that Alpha Mini cannot speak Finnish, she tried out to speak English with it, even though she had not learned English before. Her mother commented that the shape and movements of the robot encouraged the play aspect on this girl, who was willing to interact with Alpha Mini as long as the battery lasted: *"Alpha Mini was really striking for our 3-year-old. She can empty the battery all the time as long as we manage to listen and follow the interaction. We need to check that the robot does not fall from the table. We can observe unbelievable long-term enthusiasm towards acting with the robot, and she tries to speak with it… Clearly it is the shape and embodiment of the robot, which encourage the play. I don't believe that this kid would talk with Alexa for one hour."* (Mother, F2). Similar findings were visible also in other families that had a 2-3-year-old child, as they were all very enthusiastic about interacting and playing with Alpha Mini until the end of the trial.

4.2 Challenges, critique, and unexpected occasions

Learning about the robot's limitations and challenges. Even though most of the participants were positive towards Alpha Mini, especially the parents with strong technical background expressed quite critical perspectives on it. In many comments since the beginning, it was visible that they thought it was mainly a toy, and not capable of doing intelligent things. The technical limitations of Alpha Mini were raised by three parents, and also the purpose of it was questioned by them. One father (F1) commented he had noticed how far we still are from the perfect social robot. Also, some parents' expectations concerning Alpha Mini were not met, for example one father thought it should be livelier, and many parents mentioned that they were expecting it to have more intelligent features on it. Also, the voice of the robot was considered not to match with its appearance. As the appearance was cute looking, but the voice belonged to an older woman, it was considered irritating by one participant. One father (F4) mentioned the overload of technologies nowadays, which caused the robot to feel like just another gadget at their home. The children did not raise any critique at the initial interview. In the final interview, some children were talking about some limitations of Alpha Mini, like its inability to speak Finnish or limited speech recognition.

Unexpected experiences with the robot. One family (F4) experienced some weird behavior of Alpha Mini, when some bugs affected on its behavior, and it suddenly spoke with a strange male voice in the middle of the interaction. They felt that this kind of behavior was intimidating, as if someone was listening to them through the robot: *"It suddenly said 'okay' with completely different kind of voice, like male's voice. There were just me and the kids at home and I got very scared about what is gonna happen now. It sounded like the 'okay' was recorded voice. It felt as if some guy would be there and listen to us."* (Mother, F4). Based on the mother's further comments the family was able to calm down and consider the weird behaviors as the bugs of the robot. However, this is valuable finding and needs to be recognized and taken care when the robot is provided to homes. These kinds of experiences may raise intimidating feelings and make the robot feel unreliable.

5 DISCUSSION

We have presented a novel co-learning concept Robocamp for families in the home context, and a one-month explorative study focusing on the families' collaborative learning with the social robot at home. Based on the qualitative findings, several benefits and potentials, as well as challenges and ethical considerations, seem to be visible in the explored model. Next, we will discuss and reflect on both sides, and make recommendations for implementing robotic co-learning with families at homes.

Freedom for different learners and insights. Our Robocamp trial revealed that the hands-on Robocamp co-learning model with the social robot at home provided a very flexible and comfortable learning setting for the families. It offered a lot of freedom for the learners to explore the authentic robot and the interaction with it, try things out, and adopt an own personal angle for learning. The freedom and comfortable learning context (home) seemed to encourage for explorations and insights. Thus, *we recommend that the co-learning tasks will be designed to include freedom to conduct them according to the family's preferences*. The tasks can include basic, structured tasks and more open-ended tasks after the basic ones, and the family could be encouraged to use their own imagination and creativity in the tasks. It was fascinating to observe what kind of different roles the family members adopted as learners. Based on our research, they naturally formed four different kinds of roles: main programmer, assistant, player and observer. Typically, the children adopted the more active roles (main programmer and player) while the parents adopted the supportive roles (assistant and observer). In the former shorter-term research with the KIBO robot (screenless robot programmed with tangible wooden blocks) [39], it was found out that the parents engaged in the robotic activities adopting the role of coach, while children acted as playmates and planners. The research by Relkin et al. [39] and our research emphasize the active roles of the children in the robotic activities, and the activity being child-centered rather than adult-centered. In our research we were seeing how the children of the families sometimes became experts instead of parents, and they were able to solve, for example, the programming challenges and encountered problems independently, thus bringing in the experiences of competence and successfulness for the children working with the robots. This insight is in line with the previous findings by von Wangenheim et al. [50]. They observed a reversion of the traditional roles between parents and children in their robotic family workshops - the children leading and explaining the activities to their parents. In our study, we also found that some children felt proud of the programs they made and eagerly showed them to the adults. We also saw that the parents were very proud of their children conducting the robotic tasks.

Inclusive learning for all family members. Our co-learning model provided a great opportunity for each family member to participate from their own perspective, which included their skills, approaches, age, willingness and time resources. This kind of co-learning can be described as inclusive learning, as everybody from the participating family could participate equally, or select to take more supportive role. The children were working with Alpha Mini very naturally, and it was interesting to see how interested the school age children were in the programming tasks. For the youngest children of the families (2-3 years), the Robocamp's co-learning model provided a safe and comfortable way of getting to know Alpha Mini and play with it, and make own age-specific learnings about social robots, for example what one can do with the robot, and what kind of creatures robots are in general. For the youngest children, Alpha Mini seemed to be a very fascinating creature and they were enjoying dances and other activities with it until the end of the Robocamp period. The youngest family members very naturally started to play with Alpha Mini, and through this creative robotic play they adopted their own age-specific way for learning about and with the robot. The childrens' naturally adopted role of player is in line with the findings from Cagiltay et al. [13], where one of the roles for the in-home robot was defined being a playmate. There, the participants expected that the robot would occupy a peer and playful role in the interactions related to games and entertainment. It seems that social robots can very naturally encourage young children for the robotic play, and there are great potentials for learning different things about the robots while playing. As it is assumable that the children will adopt the more active roles in co-learning, *we suggest that the learning tasks, instructions, feedback and rewards would be designed from the childrens' perspective by utilizing playful elements, hands-on approach and robot's special features such as jokes, dancing and tricks.*

Family as a multi-faceted co-learning team. We can conclude that families can act as great multi-faceted co-learning teams about and with the social robots. With our learning model, learning is open-ended and versatile, resulting in a variety of learnings and insights about robot's design, interaction, role in society, and limitations. Even though all of the family members would not participate equally actively, the learnings are discussed inside the families, and even the members with supportive roles can get their own insights and learnings. It is also possible to form smaller learning and collaboration units inside the families, for example one child-one parent unit, or the unit of siblings. This is in line with the findings by Bers [11], who explored families as multigenerational robotics-based communities of practice. Her research showed that the participating families felt that they gained confidence and competence regarding technology. We need to accept that all family members may not participate equally. Some family members may be more enthusiastic than some others, and different learner roles will be established, out of which some are more active and some more supporting roles. However, we can still call this as collaborative learning, because even the learners with supporting roles can learn despite staying more on the background. The supporting roles also have important role in sense that the more enthusiastic learners can present to them their outcomes, and then they can discuss and reflect on them together. *We recommend that the co-learning tasks would include explicit tasks of reflection and discussion, which would ask for children and adults to ponder the learnings together.*

Beyond the novelty effect of the robots, towards critical thinking. Social robots typically have a very strong novelty effect, which can have a strong impact on the user experience results in short-term studies [24]. Typically, the intial user experience about and with the robot is very positive, because they seem to be interesting emerging technology for people, but over the time the novelty effect can wear off [31],[35]. Sometimes even the perceptions from science fiction and media have an effect on how people experience the robots [12]. With our longer-term co-learning setup and having the robot at home we were able to get beyond the immediate novelty effect caused by the robot, or perceptions and attitudes caused by popular media and science fiction. 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 as well. Some participants even expressed their critical perspective on Alpha Mini robot, and on the social robots in general. In the short-term 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 flaws and restrictions may not appear in the mediated short-term interaction. Thus, *long-term learning period is beneficial for adopting critical view.* However, *we also recommend to include more that one example of robot in the co-learning model, because that would provide more variety for learning about robot literacy.*

Ethical considerations. Related to home-based co-learning with the robots, some ethical considerations do emerge. The first ethical consideration relates to the role "Player". Especially the youngest learners (2-3-year-old children) seemed to act with the robot with high enthusiasm ("as long as the battery lasted"), and even create some social bond with the robot. As this can be considered as harmful result [25],[37],[41],[48], *the researchers would need to design the co-learning activities in a way that the family members would discuss the robot's role as a technical tool with the children.* As part of the co-learning model, some discussion material about this could be provided, for example visual cartoons or video clips explaining that robots are not living creatures but technical tools. In addition, *it would also be good to limit the time with the robot for the children.* For example, Ahtinen and Kaipainen [4] report the learning sessions of 5-15 minutes designed for children, and that seemed to be a feasible solution in classroom settings, so that the pupil would not interact with the robot for long time at once, but the learning tasks would be done as short sessions. *We would also recommend that the parents are instructed not to leave the smallest children to act alone with the robot, but always in supervision of adults.* This is due to the safety, as robots are electrical devices with the capability of making, for example, sudden movements. This is also in line with the findings of the study by Garg and Sengupta [25], where the parents wished to be in control of their children's technology use.

It is important to *provide freedom to quit the co-learning activity at any point if the situations, willingness and available resources* *inside the family changes on the way.* The co-learning model should also be designed in the way that it provides *flexibility to give more time to complete the tasks with robots, if the family would need more time.* Schedules are typically quite hectic for the families and many unexpected things can happen suddenly, which might prevent the families to work with the given tasks. It would also be important *to design the robot related tasks in the way that the family can adjust them to their schedules and time available,* for example that they can make less tasks or more light-weight tasks if they do not have enough time on specific weeks.

Data security considerations. One interesting observation during the Robocamp were some unexpected occassions with the robot. These were rare, but important to discuss, as they may raise some ethical and data security concerns. The unexpected situations can happen when robots are delivered for people's authentic contexts, and when the researchers' control on what is happening is missing. In our case, we observed some intimidating occassions, when the robot suddenly started speaking with a strange voice. Even though these occassions could be explained with the existing bugs on the robot, these kinds of experiences can be very scary for people, and they might want to stop using the robot. When delivering the robots to the users' authentic context, *it is very essential to guarantee the data privacy of the users and select reliable robots to be used.* The organizers of robotic co-learning would need to understand, which personal data the robot is collecting, using, storing and sharing, and which parties are involved in the personal data processing. The privacy notice forms of the robot companies should be studied and understood carefully before utilizing any robot model at homes. The robots are machines, which include a lot of sensors and machine learning, and thus, the data collection and security of the users need to be dealt with carefully. Based on the previous research, data security issues are one of the major concerns of the parents, when considering the in-home robots. Cagiltay et al. [13] explored the design space of in-home robots and found out that families expressed their concerns towards the potential risk of an in-home robot's leakage of personal conversations or other information to other family members, users, or third-party services. Similar worries were expressed by the parents in the co-design study of in-home robots conducted by Garg and Sengupta [25]. It is a positive sign that users seem start being aware of the data security concerning the robots, and with the longer term interactions with the authentic robots we may even face some critical situations. This area would definitely need further research and considerations. Fortunately, an emerging area of privacy-sensitive robotics [15],[40] has started to emphasize the data security matters in robotics. *We suggest that privacy-sensitive robotics approach will be adopted on every robotic project that is dealing with especially home contexts and vulnerable user groups.* In fact, data security of the social robots would be a good learning topic for the co-learning activity at home, and thus, *data security could be added as a learning topic on the model.* With the actual social robot at home, the data security learnings would become more concrete and could be explained by using the social robot as a concrete example. To be on the safe side, *it would be recommended to instruct the participants to keep the camera of the robot covered, as well as switch the robot off when it is not in use.*

Another consideration related to the unexpected matters with the social robot at home is to *make sure that the researchers or instructors of the home-based co-learning are easy to contact whenever the participants need to ask something or have some challenge.* In our case, we had several ways to be in contact with the participants, and they could make small questions for example by writing on the canvas diary, and we could easily respond to their queries. More in-depth discussions and ponderings were available on the interview sessions.

Limitations of the study and future work. The qualitative and explorative study enabled us to investigate different phenomena around the families' co-learning about a social robot in the authentic home context. However, the limited number of participating families (eight families) affect to the generalizability of the findings and conclusions. For sure, the cultural background of the participating families was mostly western, as we had Finnish families and international families living in Finland involved. We had only nuclear families with two parents participating. In addition, the sample of families was recruited based on their willingness to participate in the study, so the families may have had strong interest in the robotic activities. Due to the pandemic restrictions, we did not observe the interactions with the robot, but used interviews and diary method for the data collection, which set limitations to the data accuracy. In addition, providing one specific type of robot for the families, in our case Alpha Mini, affected the experiences and learnings about the social robots due to it's capabilities and restrictions. In the future, more research would be needed about the family-based co-learning at the authentic home context by offering different kinds of robots, learning tasks and by recruiting a larger number of families with different demographics.

6 CONCLUSION

We have conducted an explorative one-month study about family-based collaborative learning (co-learning) with a social robot. For that we developed a co-learning model called Robocamp. Based on our exploration, we have presented the discovered characteristics of family-based co-learning with the social robot. The main characteristics are the freedom for all learners to adopt their personal perspective for learning based on their interest, willingness and level of knowledge. In addition, the safe space for learning, home, enables this kind of co-learning with and about the robot being inclusive and providing comfortable settings to learn together. On the other hand, there are several ethical and privacy aspects that need to be carefully considered and instructed for the learners who are using robots in the home context. We have formulated recommendations for implementation of family-based co-learning with social robots in the home context based on our study findings. These recommendations can be used by the researchers, designers and teachers who are utilizing educational robots in the home context. We will continue our work in co-learning with social robots, especially from the perspective of privacy-sensitive robotics.

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