Collaboration Between Parents and Children Using Robots

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Abstract. In this paper we report from a study where families (children aged 10–15 and parents) work together in their own homes on programming tasks with an educational robot Robomaster S1. The purpose of the study is to improve the science, technology, engineering, mathematics (STEM) and computational thinking (CT) competencies for both parents and children. The data collection involves self-recording and self-assessment done by the families after each completed task. In this paper we present and evaluate the method along with preliminary results from the data collection. The preliminary results provided insights about the collaboration and interaction with the robot and initial feedback about the method and tasks. The preliminary results indicated that the family improved their understanding of technology and programming. Furthermore, the children in the study supported the parent with explaining the mathematics concepts. We hope that the future results and studies can contribute to understanding the children-parent collaboration and how children use STEM and CT to solve problems while working with robotics.

Keywords: Mathematics · Robotics · STEM · Out-off-school activities · learning Computational Thinking

1 Introduction

There are currently many experiments aiming at introducing programming and computational thinking (CT) to children in primary school to try to meet the growing needs and demands for science, technology, engineering, and mathematics (STEM) competencies. One way of introducing children to programming and STEM competences is through robotics (González and Muñoz-Repiso 2018; Bers 2012) and several different robots exists created for this purpose.

While most of these experiments take place during school hours there is also a huge potential in looking at out of school activities that foster STEM competences as children spend most of their time in out-of-school environments (Stevens and Bransford 2007). A study by Sheehan and colleagues (2019) have shown a positive effect on children's learning when parents engage in programming activities and according to Vygotsky

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(1978), parents play an important role in the scaffolding of children's learning, but is it also possible that children can influence parents' learning through social interaction? According to Bers (2019) the early introduction to STEM and CT should not be made to meet the requirement of the future workforce, but instead the future citizenry. Although a need to strengthen children's STEM competences still exists, there is an increased focus on learning STEM competencies in primary school, this does however, not help parents in becoming digital literate.

In this paper we report from a study where families (children and parents) work together in their own homes on programming tasks with an educational robot Robomaster S1 (DJI 2022). For the study, we developed a home kit for the families consisting of the robot, an iPad, a booklet with tasks, and different materials needed for the tasks. For each task, the families were asked to answer a number of questions to evaluate the process. In this paper, we present and evaluate the method used along with preliminary results about their collaboration and learning potential regarding STEM and CT for parents and children.

2 Background

The term CT was first used by Seymour Papert (1980) and later used by Jeanette Wings (2006), stating that CT is thinking like a computer scientist to solve problems, design systems and understanding human behavior, however, it a skill for everyone and not just fundamental for computer scientists. Later she defined it as: *"the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent"* (Wings 2011; p. 1). To uniform CT teaching in K-12 Barr and Stephenson (2011) identified a number of core computational thinking concepts including: Data collection, Data analysis, Data representation, Problem Decomposition, Abstraction, Algorithms & Procedures, Automation, Parallelization, Simulation.

According to Grover and Pea (2013) a good programming tool for learning about programming and CT in K-12 is one that provide "a low floor" and a "high ceiling" meaning a programming tool that is easy for beginners to start using and is powerful enough to satisfy advanced programmers. One way of providing the low floor is through graphical programming environments (e.g., block-based programming), allowing the user to focus on design and content creation rather than the syntax. One of the most widely used graphical programming environments is Scratch (Zhang and Nouri 2019; Brennan and Resnick 2012). Brennan and Resnick (2012) developed a framework for studying and assessing the development of CT with students programming in Scratch. The framework was divided into computational concepts that students engage with when they program (such as sequences, loops, and conditions), practices that students develop as they engage with the concept (e.g., Abstracting and modularizing, and testing and debugging) and computational thinking perspectives of how they understand themselves, their relationships to others, and the technological world around them.

While science, engineering, mathematics, and programming/CT are seen as distinct disciplines they are also intertwined and often borrow from each other's methods and approaches (Denning and Freeman 2009). It can be beneficial to keep the disciplines intertwined when teaching as e.g., CT and mathematics builds a reciprocal relation for learning between the two domains and because this way of teaching is closer to the professional practices (Weintrop et al. 2016). Likewise, the use of educational robots can foster learning within all the STEM disciplines as children engage in activities where they design, construct, program and interact with robots and in the process learn about gears, actuators, sensors, and programming. Furthermore, robotics projects can support other skills such as: collaborative work, creativity, self-esteem, and leadership (González and Muñoz-Repiso 2018). According to Bers (2012; p. 8) *"Children engage in social interactions and negotiations while playing to learn and learning to play (…) When making robots, children become engineers exploring with gears, levers, motors, sensors, and programming concepts"*.

Children's engineering interest, engineering knowledge and engineering abilities can also increase in out-of-school environments (Ehsan and Cardella 2017). In the study Ehsan and Cardella (2017) showed how children and their families engage in engineering design tasks and found that children can enact competencies such as: abstraction, algorithms, and procedures, debugging, problem decomposition, parallelization, pattern recognition, and simulation.

Studies of collaborative problem-solving have e.g., shown that students acquire more abstract knowledge when working collaboratively compared to working individually (Scwartz 1995). Studies of children and parents collaborating or doing things together have also shown positive effects on children's learning, such as co-viewing (Strouse et al. 2018) and co-reading (Lauricella et al. 2014) or programming together (Sheehan et al. 2019). Overall, there seem to be great benefits for children learning in collaborative settings with their parents but how about the parents learning potential?

According to Ploetzner and colleagues (1999), explaining things lead to the acquisition of new knowledge as the learner identifies missing information needed to explain things. When explaining or teaching others, the listeners will often point out missing information and inconsistencies or ask for clarification that will help the explainer to identify these (Ploetzner et al. 1999).

Thus, we presume that the parents also learn something in the process of working together with the children. As robotic programming is an unfamiliar domain for most children and parents, we do not expect the parents to only explain things, but rather to be part of a collaboration where the roles can change during the activities.

3 Method

In our research, we wanted to study how children aged 10–15 years and their parents in collaboration learn about STEM with a focus on mathematics and CT. For the study, the families received a package with the robot, an iPad and different materials needed for the tasks such as cones, tape, practice targets and a folding rule. The families were also asked to self-assess the process of solving the tasks using an approach inspired by a cultural probe approach (Gaver et al. 1999). In this section we first describe the Robomaster robot followed by a description of how we developed the tasks and finally the evaluation method and how we collected the data.

3.1 Robomaster Robot

The Robomaster S1 is a programmable educational robot created to support STEM-oriented activities. The robot is developed by DJI (DJI 2022). Robomaster's design resemble a tank (Fig. 1). It consists of four omnidirectional wheels, a chassis with build-in touch sensors and LED's. A gimbal-based cannon with a camera mounted on the chassis. The cannon can be used to shoot water pearls and laser. Robomaster can be remotely controlled using an app installed on a tablet or mobile phone. The app includes options for programming Robomaster either by using a block-based programming language (Scratch 3.0) or text-based programming language (Python). It can e.g., be programmed to drive in different directions, rotate the cannon, or change the color of the built-in LEDs. In addition, it can detect and follow various objects such as people, targets objects, and colored tape paths on the ground. It can also play and respond to sounds.

Fig. 1. Picture of the Robomaster S1 educational robot from DJI homepage: https://www.dji.com/dk/robomaster-s1.

3.2 Development of the Content

We invited three mathematics teachers to individual sessions to help us design age-appropriate tasks and support the teaching curriculum. We also received input on how they designed tasks for specific learning objectives as well as didactic and pedagogical considerations in relation to how we design and scaffold the different tasks. The teachers all had experience with teaching at primary school and experience with educational robots and block-based programming.

In the design sessions we first introduced Robomaster and gave a short demonstration of how you control it and the various options for programming it and the teachers were invited to try the robot themselves.

After introducing Robomaster we interviewed them about their teaching experience. We asked them to first list what their students were required to learn and to provide examples of how they teach, including their didactic and pedagogical considerations.

We then proceeded to a brainstorming phase with the teachers on how we could design tasks using the Robomaster that supported the learning objectives elicited in the previous phase. The authors discussed the input from the workshops and incorporated the input into 8 different tasks. Although the tasks were built around the input we received from the workshops, it has also been necessary for us to adapt the content and add subtasks to ensure a proper scaffolding of the content. One of the participants from the workshop reviewed the content and send us feedback on the tasks. The feedback was incorporated into the final version of the booklet. Most of it was suggestions for different wordings and a few misconceptions.

3.3 Tasks

In the following we provide a short overview of how each of the tasks are designed to give insights into how the programming and math concepts are incorporated into the tasks.

Task 1

The purpose of this task is to introduce the programming environment and block-based programming (see Fig. 2). To complete the first task an example from the booklet must be copied by connecting the correct coding blocks and afterward change the parameters in the code. The robot can be programmed to translate in X and Y directions (Fig. 3) and rotate left and right (Fig. 4). In the coding example the robot must be programmed to translate in a given direction and later to rotate. The purpose of this coding example is to introduce to mathematical concepts such as coordinate systems, translation, and rotation.

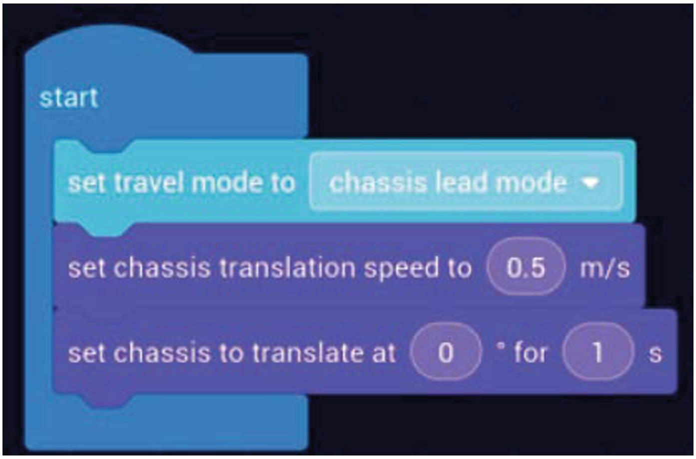

Fig. 2. Coding example from task 1.

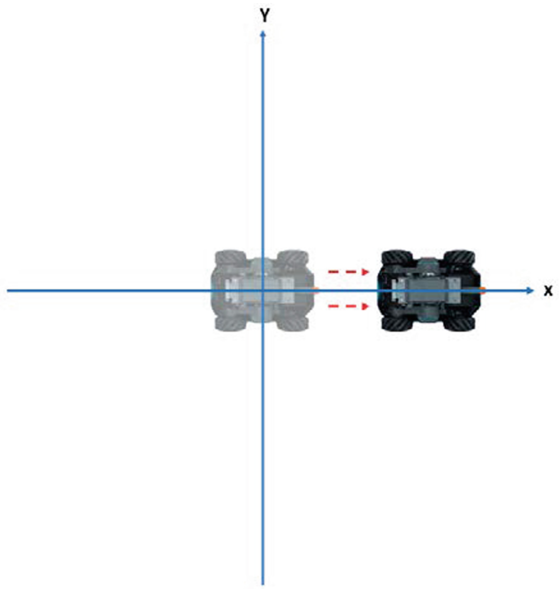

Fig. 3. Representation of translation in the booklet from task 1.

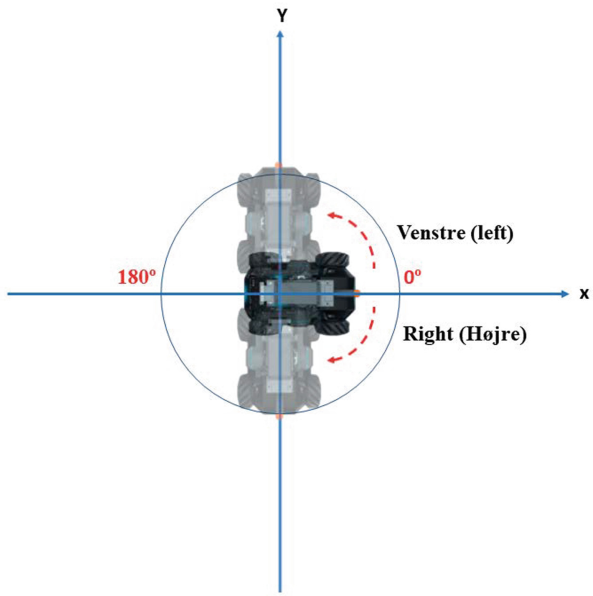

Fig. 4. Representation of rotation in the booklet from task 1.

Task 2

This task built on what was learned in the introduction of the programming environment and coding. In this task more blocks of codes have to be combined and loops are introduced in order to change the color of the LEDs.

Task 3

In this task the robot must be programmed to move in different geometric shapes (squares and rectangles) with and without using loops (see Fig. 5). This again include combining more blocks of code and use what was learned in task 1 and 2.

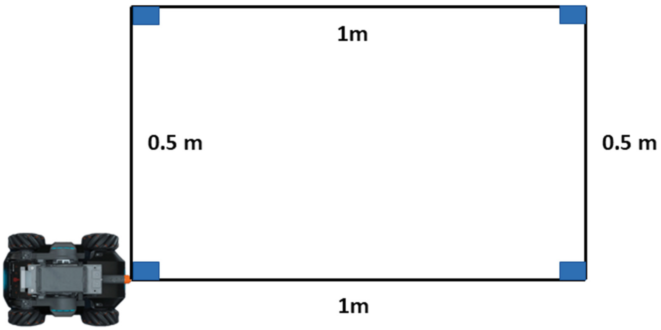

Fig. 5. Example from the booklet from task 3. The robot has to be programmed to move in a rectangle using a loop.

Task 4

In this task different sensors and events are introduced e.g., changing the color of the LEDs when the robot drives into a wall, when it registers the sound of a clap or when the camera detects a person.

Task 5

Task 5 involves using the gimbal cannon. First part of the task is to manually control the robot to shoot down practice targets with water pearls (Fig. 6). In the second part of the task the robot must be programmed to shoot down the practice targets using yaw and pitch degrees to turn the gimbal cannon (Fig. 7).

Task 6

In this task a slalom track must be built using cones. In the first part of the task the robot has to be manually controlled to complete the track and afterwards programmed to automatically complete the track. The same was repeated with another track, this time built using tape. The next step is to add practice targets and make the robot shoot them as it moves through the track. In the process different coding concepts are introduced such as conditions.

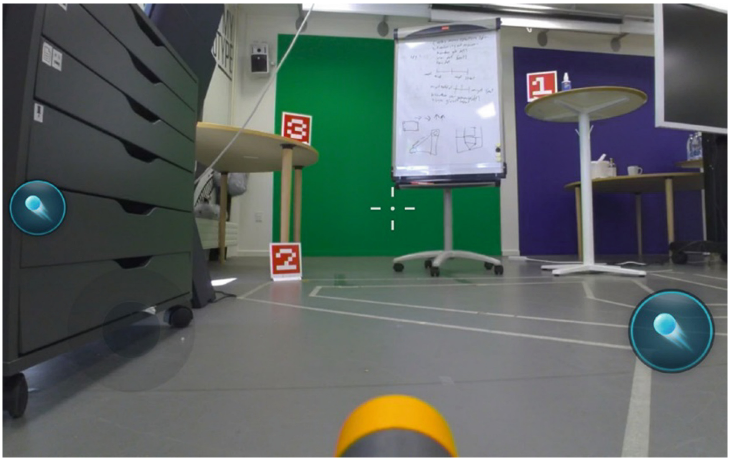

Fig. 6. Example from task 5 taken with the build-in camera.

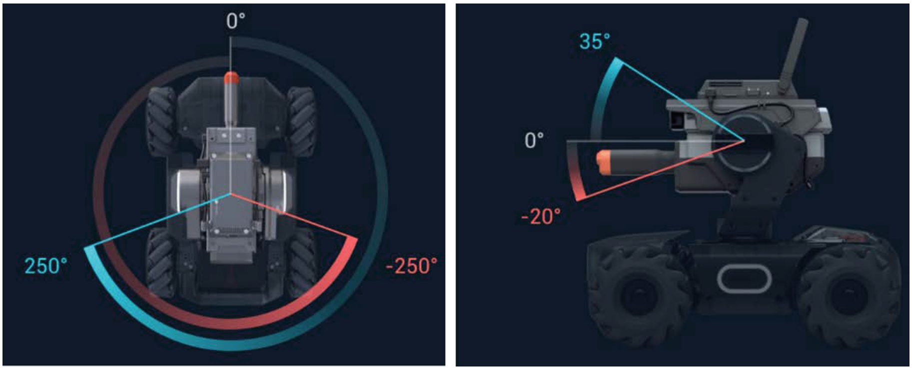

Fig. 7. Illustration from the booklet showing how the gimbal cannon can rotate in pitch and yaw axis.

Task 7

This task is inspired by the game battleship (Fig. 8). First, a coordinate system must be built on the floor using tape and each player picked a square (without telling the other player). Each turn the player has to program the robot to move from one square to another. The player who first move the robot to the other players square wins the game. In this task variables and coordinate systems are introduced.

Task 8

The last task is an open task where the families must come up with an idea of their own and try to program it. The purpose of this task is to assess what they have learned in the previous tasks and how they use it to program their own program with no guidance.

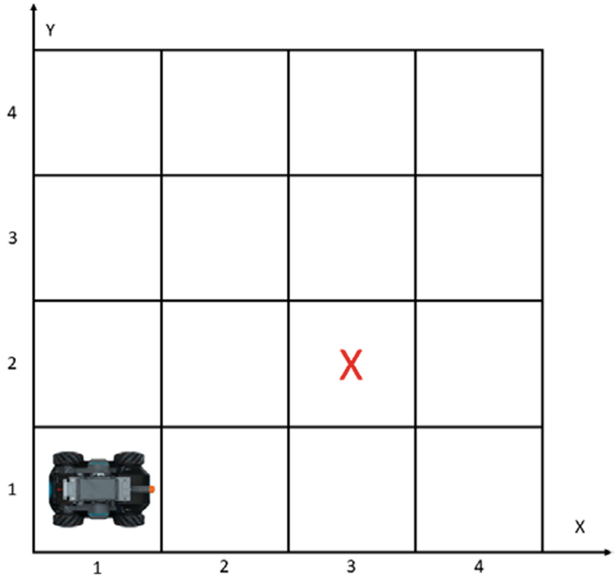

Fig. 8. Overview of the battleship game.

3.4 Data Collection

In this study we report the preliminary results from one family (a mother and her two boys aged 14 and 15) who tested the robot at home for a period of six weeks. In this period, they could complete the tasks in the booklet or explore the robot on their own. We collected preliminary data from the families' work with the robot. After every task, the family answered five questions about their work with Robomaster and how they collaborated. The approach was inspired by a cultural probe approach (Gaver et al. 1999). For each task they completed there was an envelope with questions written on postcard sized cardboards. The cardboards contained both rating- and open questions. They were e.g., asked to review the task and described how it were supposed to work and what challenges they had. In the process they were asked to discuss both mathematic, CT, and robotics-related content and how they collaborated during the tasks.

During each task, the family used a screencast on the iPad that recorded data about how the family programmed Robomaster. We intended for the screencaster to collect sound as well, but the family forgot to push the button.

The robot had a built-in camera that could live-record from the robot's point of view and the family was asked to use the recording function when using the robot.

We also had planned that the family should record their solution to every task on a video camera, however, the boys of the family found it too intimidating.

The authors conducted an individual semi-structured interview with the mother. The interview lasted 45 min. The interview guide was jointly developed by both authors. To structure the interview guide, three general themes were identified: Cultural Probe Approach, family collaboration, CT, and mathematics. A flexible approach was taken to the use of the interview guides. As an example, the order of the questions changed if she had already answered some of the questions or if the follow-up question covered some of the following questions. The interviews were recorded, and significant segments were transcribed.

3.5 Ethical Considerations

Before the start of the study the family received information about the purpose and process of the study, how data was collected, used, and stored. To ensure voluntariness we asked both children and parent to sign a consent form after introducing them to the study. The collection and storage of the data was done in accordance with the existing GDPR legislation.

4 Preliminary Results

The mother stated that she has learned a lot through the project, both in terms of coding and programming and working with the children. The family initially tested the Robomaster through play, trying out the different functions without going through the tasks. When they got to the tasks, it became a bit of a must-do, and working with the robot was not the same joy. The robot testing took place in the evening after the family had been to school and work, as this was the only time the mother had time to participate. The two children had different approaches to the tasks; one was very competitive and wanted to finish quickly, and the other was more interested in constructing and creating something with the robot.

Along the way, the family took on different roles, with one acting as the expert, one programming, and one reading the tasks aloud. Often the mother read aloud and asked them to stop and reflect along the way. Their roles also changed along the way, so everyone had a chance to chime in and be the programmer. Here, the mother felt that the more they worked with the robot, the more she dared to be inspired by the children; she learned a lot by observing them and then trying it herself.

The youngest of the boys tended at times to withdraw from the tasks and lie down on the bed, and if the tasks became too difficult, they both gave up. The older brother became preoccupied and persistent in working with the robot, perhaps because the difficulty level was too easy in the first of the tasks. By working with the robot, the family gained a deeper understanding of technology regarding Robomaster as well as other technologies and programming. The mother, in particular, was unsure of the mathematical content and found it challenging. Here she had to be helped by her sons, who had to explain how to do it along the way. There was, therefore, a strong focus on how they could solve the individual tasks together.

In the interview, the mother explained that it worked well with the instructions in the booklet. They were detailed and guided them well through the tasks. It was also a great help to see the correct solution for each task. They got through the first tasks easily, however, the mother reported that it became very difficult around task four which could also be deducted from the rating of the difficulty for the task, and they were also unsure if they had completed the task correctly.

According to the mother it could have been helpful with more tasks that built up their skills and prepared them more before task four. As the difficulty increased, the motivation would also drastically drop especially for the youngest child. This also led to a change in engagement, where the youngest child in the beginning was the most active the roles changed. As the tasks became more difficult, it was the eldest who stuck to the task until it was solved. It was also requested that more open task was implemented to simply play with the robot.

5 Discussion and Conclusion

In this paper, we have presented the method, including tasks where children and their parents work in collaboration with robotic programming with the purpose of learning about STEM and CT. The preliminary results show that both the mother and the children participated actively in the collaboration to solve the tasks and with changing roles. The mother indicated that she struggled with the mathematics content but received help from the children who explained it to her. From her statements, it seems as if she in the beginning took on a role as a facilitator but engaged more in the task when the children started having trouble trying to solve it together.

From the ratings and the statements in the interview, we noticed that it became difficult around tasks 3 and 4. One explanation for the perceived level of difficulty could be that in the first tasks, the family could follow the instructions step by step. Still, for each task they completed the tasks would progressively require that they combined the things they have already learned in new ways. This could indicate that the family may not have a sufficient understanding of the programming concepts to use them in new ways this is what Brennan and Resnick (2012) refers to as the intersection between concepts and practices and can be seen as a literate understanding of the programming concepts. To achieve this, we may need to add more sub-task to better scaffold the understanding. The perceived difficulty could also partly explain why the family went from feeling joy when during the task but later felt it as a must-do as the challenges in the beginning better matched their abilities (Nakamura and Csikszentmihalyi 2014). Other factors could be due to the time of the day and fatigue. The mother felt she had insufficient time and thus started to feel like it was an obligation instead of a fun activity. It was also mentioned how the free-play activities were more fun and that the family would have liked to see more open tasks. We did encourage the family to play around and experiment with the robot but perhaps this should be more explicit in the booklet and incorporated into the tasks.

Despite the difficulties the family managed to complete all the tasks in the booklet except for one task that was not solved correctly. In the process the family have worked with different programming and mathematic concepts and applied these to solve the task. Furthermore, the tasks would require a basic understanding of how the robot works and practical issues regarding the robot such as connecting it to the tablet, understanding how the robot received input from the sensors loading the cannon etc.

While the mother only to a limited extend articulated the learning and use of the STEM and CT competencies, the completion of the tasks indicate that there has been a development.

From the data collection, we gained insights into their experience with working with the robot. The cardboard questions informed us about the instant experience of working with the robot, which could later be elaborated in an interview. The screen recordings helped us understand some of the issues they had while programming the robot. However, while the data collection provided insights into their collaboration and how they interacted with the robot there we also a few issues. One was due to an error where the voice-recording was not activated. Thus, we were able to use the screen-recordings to see the process of programming the robot but unable to hear the ongoing discussion while they did it. Secondly, the family did not use the video-camera due to privacy reasons. We wanted the family to use the camera to document what they did and use it for creating a walk-through video.

In the preliminary results we have presented in this paper, we have only interviewed the mother, but for future studies we want to include the children as well. The interview will be based on the data we collect from the self-assessment and recordings so we can ask concretely about specific episodes and working relationships.

The preliminary results have shown how one family interacts with the robot and have given us insight into how the family has collaborated to complete the tasks. Based on the preliminary results, we only saw limited indications of STEM and CT learning potentials but expect that the future results will help develop our understanding of these collaborative learning outcomes and interactions that can support the development of STEM and CT competences for children and their parents.

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