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Evaluating Technology-Enhanced, STEAM-Based Remote Teaching With Parental Support in Luxembourgish Early Childhood Education

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During COVID-19 confinement, we observed numerous challenges in using educational technology in early childhood Science–Technology–Engineering–Arts–Mathematics (STEAM) education in Luxembourg. Thus, we designed a conceptual framework on parent-assisted remote teaching with active uses of educational technology supported by cycles of design-based research. After a previous study utilizing computer-aided design (CAD) software and three-dimensional (3D) printing in primary education, we used our initial findings to work with 12 early childhood students (ages 4–6), together with their teachers and parents in the second remote teaching period in Luxembourg. We created a STEAM modeling task with CAD software on robots and collected data through chat responses, messageboards, and online communication channels during a 3-week period. Here, we observed new roles in the parent–child relationship while learning STEAM in remote teaching with technology, and new opportunities in using educational technology overall in early childhood education. In this article, we have described findings that are likely to influence students' learning and parent-assisted teaching, in particular parents and students' perceptions and motivations, together with the way in which parents provide technical knowledge and support in remote early childhood STEAM education.

Keywords: early childhood, STEAM, remote teaching, educational technology, parents

INTRODUCTION

Remote teaching due to COVID-19 restrictions in Luxembourg (Kreis et al., 2020) was relatively short compared to the worldwide average, only 15 weeks from 2020 to 2021 according to the United Nations Educational, Scientific and Cultural Organization (UNESCO) (UNESCO, 2021). In Luxembourg, elementary school pupils from ages 4 to 12 received during this time access to various online learning resources. Among these were the automated tutoring system in mathematics education, "MathemaTIC" (Haas et al., 2020) and an online platform with documents, videos, and challenges on different languages and Science–Technology–Engineering–Arts–Mathematics (STEAM) disciplines.[1] These educational resources, used over the past years (e.g., MathemaTIC from 2016 on) by most school classes (ages 7–12), and thus known by pupils and teachers, were quickly integrated into the "schooling at home" teachings in primary education. However, these resources were not designed for early childhood education students, where teaching with educational technology is not usual in Luxembourgish schools, similar to international trends reported by the Organization for Economic Co-operation and Development (OECD) in "Using Digital Technologies for Early Education during COVID-19" (OECD, 2021). The imposed physical and social distancing, where both teachers and pupils were not acquainted with working with technology-supported lessons in early childhood education in Luxembourg, reduced in various classes the learning to a less student-centered approach, and facilitated less active but rather repetitive tasks in learning (e.g., filling out paper and pencil exercises). Throughout previous observations on the use of educational technology and remote teaching in schools in Luxemburg and results from a survey among parents by the Ministry of Education, Children, and Youth (Ministère de l'Éducation Nationale, de l'Enfance et de la Jeunesse—MENJE) (MENJE, 2020a), we observed a high level of frustration including many confrontations between parents and children, and difficulties in understanding tasks or connecting to teachers or pupils vice versa for parents, pupils, and teachers (Haas, 2021). Hence, new educational needs became perceptible during remote teachings, such as understanding the possibilities of using educational technology, connecting through social media platforms, and supporting parents in the teaching process at home. Parents of pupils in early childhood education request more support (MENJE, 2020a), such as how to engage with the teachers' tasks, regulate stimuli, motivation, or monitor media choices, and media consumption (Hirschland, 2008; Neumann, 2018).

Over the past years, several researchers experimented with digital modeling of shapes, forms, or mathematical functions with computer-aided design (CAD) software and augmented reality (AR) technologies in elementary schools to demonstrate motivational factors, new learning opportunities, and a different learning approach (Steen et al., 2006; Liu et al., 2019; Ng and Chan, 2019). These technologies reported higher motivation among children (Bacca Acosta et al., 2019). Moreover, these technologies were recently used among pupils with mathematical learning disabilities (MLDs) to increase visual-spatial memory in cycle 2 to cycle 4 (Haas et al., 2021a).

However, most studies did not directly test these technologies in remote teaching in early childhood education, especially in Luxembourg, without immediate physical or digital teacher assistance and with parents' assistance. A first attempt to use these technologies at home was made in 2020 during the first distance learning in Luxembourg. We conducted a remote teaching study (e.g., egg cup creation) with CAD software and three-dimensional (3D) printing to experiment with their use in remote teaching and to identify the parent's role in the teaching process. In this first study (Haas et al., Under Review) of design-based research (Wang and Hannafin, 2005), we established a framework for learning at home with parent–assisted teaching. In this framework, which is presented in "Methodology and Methods" section, we identified four elements (perception of STEAM and teaching, motivation of students, technology-knowledge of parents, and parent-assisted teaching and scaffolding) influencing students' remote learning experience.

Based on this framework, we designed a second study of remote early childhood STEAM education with CAD software and 3D printing, which we is reported in this article. We proposed these tasks to 12 pupils aged 4–6 years studying with parental support. Tasks were integrated in a thematic school week on robots and consisted of designing, showing in AR, and printing an own-designed robot with geometric shapes. Since this happened in remote teaching and due to the young age of the children, parents were highly involved. We sought to answer the following research questions to confirm and question our framework from the first study:

- How do parents and children perceive STEAM education and teaching with technology in remote early childhood education?
- How do students' motivation evolve while using technology in remote early childhood STEAM education?
- How do the parents' technological knowledge influence students' learning while using technology in remote early childhood STEAM education?
- How do parents assist their children and what scaffoldings do they use in remote early childhood STEAM education?

To investigate these questions, we collected data from 12 pupils and each parent, from a heterogeneous socioeconomic background per child over 3 weeks. This article presents theoretical references, task design, the used qualitative methods, and the discussion of our findings. In particular, the opportunity offered by the COVID-imposed restrictions provided a unique opportunity to analyze parents' and children's perceptions and motivation, together with the way in which parents provide technical knowledge and support in remote early childhood STEAM education.

LITERATURE REVIEW

In the following literature review, we outlined the importance of a STEAM transdisciplinary approach, the use of technology (especially CAD and AR) for 3D modeling in class, and the 3D printing of the designed model. Furthermore, parents' role in "schooling at home" and their view on technology use at home are examined. In each subsection, we identified gaps in previous practices or research that to be covered in the present research.

[1] https://www.schouldoheem.lu

STEAM Transdisciplinary Approach

Although STEAM disciplines are still taught separately, the current curriculum in early childhood education in Luxembourg (MENJE, 2020b) requires teachers and educators to work in class with a transdisciplinary approach (Rausch et al., 2021) for STEAM disciplines (Liao, 2016), where arts are integrated in STEM (Lavicza et al., 2018). The integrated approach of STEAM disciplines (Kelley and Knowles, 2016; Haas et al., 2021b) has been shown to support students in applying discipline skills and understanding content more easily than taught separately (Burnard et al., 2018; Lavicza et al., 2020; El Bedewy et al., 2022). Moreover, this approach offers more creativity to the tasks and, thus, is likely to positively affect problem-solving skills of learning (Dana-Picard et al., 2021).

In early childhood education, this is mostly done in Luxembourg through thematic project weeks (e.g., colors in nature or, in our case, robots) where daily activities are interconnected to a specific theme or project (MENJE, 2018). The positive effects of such an approach, close to project-based learning (PBL) (Cesarone, 2007), are in socializing students and connecting content and process skills to real-world situations. Such an approach is further recommended for integrated science teaching (Haatainen and Aksela, 2021) and, thus, enabling STEAM-integrated teaching in early childhood education. Nevertheless, this practice can be conceived as a multi- or interdisciplinary approach, whereas our research will focus especially on transdisciplinarity.

Use of Technology for 3D Modeling in Class

In recent years, technology-enhanced learning (e.g., tablets in class, cameras, or digital measuring tools) has featured within STEAM in primary education and early childhood (Chaudron et al., 2015; Jablonski and Ludwig, 2020; Guntur and Setyaningrum, 2021). Although tutoring systems (Steenbergen-Hu and Cooper, 2013) prevailed in classes in primary education in past years, other technologies, which connected directly to the environment of students (e.g., CAD software, AR, or 3D printing), became more frequent in teaching. Thus, mixed-realities, such as the use of AR, where digital information is applied to the real-world information, were used to support students in visualizing mathematical concepts or explaining cultural or architectural phenomena (Ng, 2017; Liu et al., 2019; Lavicza et al., 2020). A representation of a shape in three dimensions in a real-world environment instead of a 2D representation gives the students a better understanding. Furthermore, the use of AR in an educational context was found to increase students' motivation (Bacca Acosta et al., 2019; Sarkar et al., 2020). In addition to AR, CAD software allows students to modulate polygons, shapes, lines, or other geometry concepts in three dimensions (Stone et al., 2020). As a result, students can reproduce objects from the real world or conceptualize mathematical objects. According to Ng and Chan (2019), 3D modeling with CAD software is likely to support students in learning informally and less in a procedural and formulae-driven learning setting. This further connects STEAM disciplines to real-world objects or situations (Haas, 2021). However, most of the time technology was used in class and not in distance learning.

3D Printing of Designed Model

In extension to AR and CAD software, 3D printing showed in several research stances to further support students in transferring learned STEAM skills to real-world problems or objects (Ng et al., 2020; Pearson and Dubé, 2021). The 3D printing process is an additive manufacturing process based on a designed CAD model, where a digital object is printed as a physical, real-world object. According to Lieban (2019), 3D printing engages and motivates students in a creative process where they can modulate and combine digital and physical objects to understand mathematical concepts better.

Moreover, 3D printing in the process itself (e.g., adjusting temperature or preparing the print) makes students experience an engineering task while applying different STEAM skills. In combination, the three mentioned technologies (AR, CAD, and 3D printing) offer the possibility to combine STEAM disciplines, apply skills transdisciplinary (Takeuchi et al., 2020), and modulate digital and physical objects. This task is quite complex and cannot be left to young children alone. Preparations can be done remotely, but the printing task requires physical presence at 3D printers.

Parents' Role in "Schooling at Home"

Since technologies are not necessarily constrained to physical presence courses, a pedagogical use in remote teaching is possible (Chilton and Mccracken, 2017). According to Kreis et al. (2020), there are different remote learning forms. The situation in Luxembourg during the COVID-19 lockdown could be best described as "schooling at home," where parents received tasks, documents, and instructions from teachers. Parents took the role of an assistant-teacher and instructed their children. Like teachers in class, parents are likely to use different forms of support (e.g., affective) in teaching (Wood et al., 2016; Neumann, 2018) and use their own school experiences and educational knowledge (Livingstone et al., 2015; Elliott and Bachman, 2018). The first framework on parents' "schooling at home" was developed in our first study on an eggcup creation (Haas et al., Under Review). In this study, we obtained valuable data on parent-assisted STEAM remote learning and with the presented second study in this article, we were able to confirm some of the data from the first experience and add new insights and findings.

Parents' View on Technology Use at Home

Our experiment is designed to explore technology-enhanced remote teaching with parental support in Luxembourgish early childhood education. Thus, the parents' view on technology use at home is crucial to our research. Touchscreen devices have been used by children for a number of years even before the age of 2 (Burns and Gottschalk, 2019; Dardanou et al., 2020; Rizk and Hillier, 2020). In contrast, parents' knowledge about the quality of apps is rather limited, and they are mostly concerned about the use of technology could harm their children (Chaudron et al., 2015; Papadakis et al., 2019, 2022). In our research, we aimed to address how the technological knowledge of parents influence their children in remote learning.

TASK DESIGN AND EXPERIENCE IN EARLY CHILDHOOD EDUCATION

The remote teaching in STEAM education in early childhood education with AR, CAD software, and 3D printing was planned with a pedagogical team of three class teachers in Luxembourg. For the thematic project weeks on "Robots and Geometry," the team agreed to propose a remote teaching activity to pupils aged 4–6 years. During the experience, schools were closed, and all the teaching happened remotely. The duration of the experience was limited to 3 weeks, the length of the project weeks. Furthermore, participation was opened to parents who were willing to join and participate actively. The 3D printing happened after 2 weeks remotely, in the presence of the pupils and teachers. We used the following project timeline (**Figure 1**).

Parents who enrolled with their children received two sessions of introduction to the modeling task, a design of a robot, and the basic explanation of the used CAD software and the AR function, with worked examples (Sweller et al., 2011). During these sessions, parents and their children asked questions and received details on the software's manipulations. In our first experience with remote teaching and technologies like CAD or AR, we observed the importance of such tutorial sessions before beginning the modeling task. After the tutorial week, parents worked with their children for 2 weeks on the modeling task (see **Figure 2**). The tasks were designed according to the four principles of Dienes (Dienes, 1960; Lieban, 2019): Construction, Multiple embodiments, Dynamic, and Perceptual variability. These principles supported different requirements to manage the heterogeneous group of students for the modeling process (e.g., dynamic principle with reproducing, constructivity principle with free design). Therefore, we offered children and their parents' several entries and goal levels. The assignments ranged from reproducing a robot with given shapes to designing a completely new robot with a free choice of elements of constructions. Parents exchanged through online chats, video conference tools, e-mails, and messageboards in the modeling task process with the researchers and teachers. Furthermore, they exchanged as peers on the messageboard.

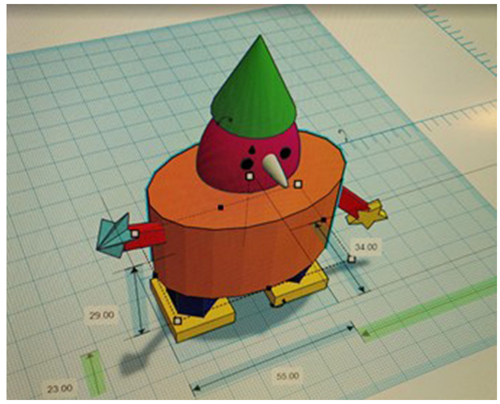

FIGURE 2 | A designed robot with the CAD software.

At the end of the modeling task, teachers, and researchers performed the 3D printing process of the robots in class with the pupils since it seemed important to show pupils the engineering part of the 3D printing in real time (e.g., functions of the printer, time to print, heat, and transformation of the filament).

METHODOLOGY AND METHODS

The iterative design-based process started with the first study in primary education, focusing on the parent's perspective within the learning process while designing a cultural artifact (Haas et al., Under Review). That study was design-based research on technology-enhanced environments (Wang and Hannafin, 2005) in remote teaching using AR, CAD, and 3D printing technologies. The second study with early childhood students, presented in this article, chose a qualitative approach (similar to the grounded theory approach) in a quasi-experimental design with participant's selections and no control group (Campbell and Stanley, 1963).

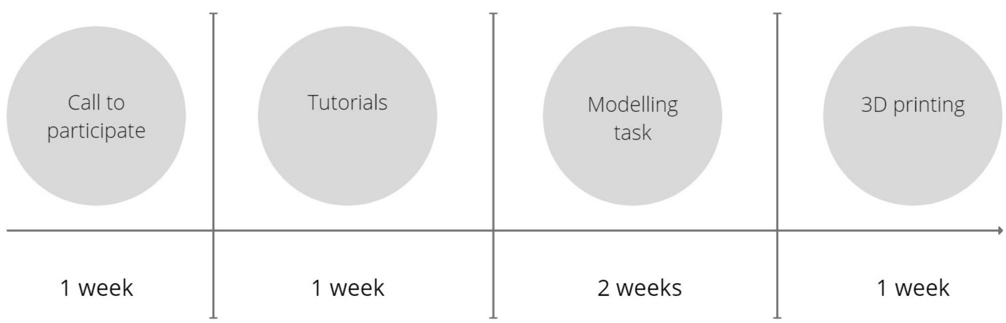

FIGURE 1 | Experience timeline in remote STEAM teaching in early childhood education.

TABLE 1 | Communication channels and their uses.

Communication channel	No. of parents using it
Online chats	$n = 8$
Online video conference tools	$n = 6$
Online email	$n = 5$
Online messageboard	$n = 12$

Participants

The participants of this study volunteered from a class of 36 pupils aged 4–6 in an early education class in Luxembourg. Parents were encouraged to enroll their children in the class communication channel. Of the 36 possible participants, 12 pupils with one parent each chose to join the experiment. Conditions to participate were to assist children in solving the tasks with technical and pedagogical support, responding to questions, and collecting data. Every participant finished the study and participated in the data collection. The group of participants was from a heterogeneous socioeconomic background. Since access to the Internet and remote learning content was assured by the school community in procuring hardware and software to families, there was no accessibility restriction observable.

Data Collection

We offered the parents with different communication opportunities: online chats, video conference tools, email, and messageboard. Parents chose to use different channels, and we collected all communication from each channel. As indicated in **Table 1**, parents used the communication channels differently. Some parents used only one channel, others multiple channels. During the study, we collected overall 129 messages from parents *via* the different communication channels, with a clear dominance from the messageboard. Communication from emails and videoconferences was used mainly in the week on tutorials and less often than other communication sources.

Data Analysis

The collected quotes were coded using a grounded theory approach (Glaser and Strauss, 2005; Corbin and Strauss, 2014) involving the application of inductive reasoning. Details of the coding are explained in the last paragraph of this subsection. Grounded theory differs from traditional scientific models of research that follows the order (1) theoretical framework, (2) hypothesis, and (3) data collection (to assess the validity of the hypothesis). When using a grounded theory approach, hypotheses and theories emerge from the analysis of the collected data. Thus, this methodology starts with a wide range of data collection and then subsequent detailed analysis.

In this second study on remote teaching with technology in early childhood education, we compared the coded wordings to our developed framework (**Figure 3**) in remote teaching with CAD and 3D printing (Haas et al., Under Review). This framework identified four major elements influencing remote teaching with parent assistance and digital modeling tasks. First, the perception of STEAM courses and teaching and students' motivation influence the learning in remote teaching and technical knowledge of parents, and scaffolding of parent-assisted teaching influences the teaching by parents. Based on these four elements and focusing on our mentioned research questions in early childhood education, we coded the collected data.

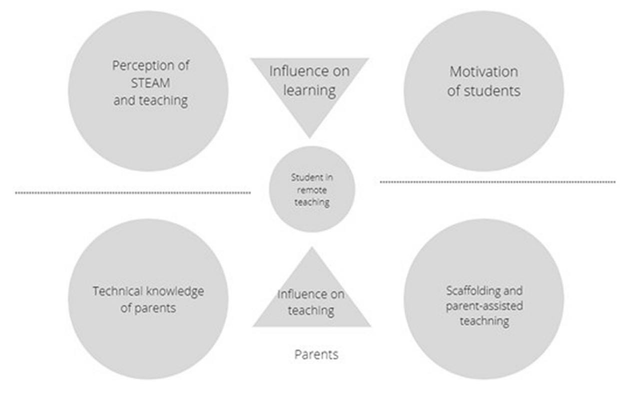

FIGURE 3 | Framework on learning in remote teaching with parent-assisted teaching.

Quotes from parents using different communication channels (e.g., video conference tool, email/messageboard, and online chats) were thus coded and connected to the elements in **Figure 3**. Our iterative coding process identified findings for every element we analyzed, described, and discussed in more detail in this section, with a clear focus on early childhood education. Different codes were compared to the first study in remote teaching from the design-based research and discussed.

We coded the messages in three rounds, starting with open coding (Glaser and Strauss, 2005). In the second round, we tried to connect the coded message to the framework, established from our first study, into those influencing the learning of pupils and those influencing teaching of children by parents. In the last coding, we coded the messages to the four categories on the perception of STEAM course and teaching, motivation of students, parents' technical knowledge, and parent-assisted teaching and scaffolding. Six quotes were not possible to categorize, as they were not relevant for the topic (e.g., messages on other teaching activities, school openings, and private appointments).

In **Table 2**, we regrouped recurrent message examples and coded categories. This section highlighted our Data Analysis, and in the following "Discussion" section, we explained in more detail the collected and categorized data.

RESULTS AND DISCUSSION

In this study, we observed if these tasks were likely to positively affect the STEAM learning behavior of pupils and how the parents were involved in their learning. Recalling our research questions relating to parent and student perception, students' motivation changes, parents' technological knowledge, and parental assistance, we presented two elements of perception

TABLE 2 | Examples of parents' messages and codes.

Categories	Examples of parents' messages
Perception on STEAM course and teaching	X used Geometry to build the robot What are the names of the objects you can move? I asked him the names of the shapes Will the robot stand on these cubic feet? Is the weight in the robot balanced? I showed X how to transform a shape into another
Students' motivation	This is better than doing it on paper X is happy to print her own robot We can't wait to see if the robot could be printed It is easier to do this than to complete the worksheets My son and I spent a good time trying out the different shapes on the robot
Technical knowledge of parents	How do you change the view? I can't find all the shapes Are there videos or explanations on how to drill into a shape? I find it hard to work on the Ipad, it is rotating too fast Will it save automatically?
Scaffolding and parent-assisted teaching	I ask questions like yes or no to see if he understands X has done so well, I am telling her all the time Should we share the great work of students? X if you show your son first how to do it, he can do it himself

STEAM, Science–Technology–Engineering–Arts–Mathematics.

of STEAM courses and teaching and motivation of students' learning behavior. Then, with the elements of technical knowledge of parents and scaffolding and parent-assisted teaching, we described the parents' perception in a similar role as a teacher. Overall, we can observe the high participation of the 12 parents and children, a positive acceptance of such tasks and strong interconnectivity between parents during the remote teaching. Furthermore, the acceptance of such tasks by the teachers evolved during the experience was subject to integration into the upcoming regular courses.

Parent and Child Perception of STEAM Course and Teaching

Parents and children from the study perceived the teaching of STEAM skills in early childhood in general interconnected but mentioned at the beginning of the modeling tasks with the CAD software, the importance of learning mathematics more in-depth separately. This might be related to the fact that currently only mathematics and no STEAM education is included in the curriculum (MENJE, 2018). According to early childhood research in mathematics education, parents' behavior toward learning (Elliott and Bachman, 2018) and the parents' socioeconomic backgrounds (DeFlorio and Beliakoff, 2015) impacts the learning behavior and perception of the students. Hence, the more parents invest in playful and continuous support, the more likely the pupils succeed in early childhood education (Cheung and Kwan, 2021).

Nonetheless, according to Vandermaas-Peeler et al. (2009) parents with low socioeconomic backgrounds tend to use less specific knowledge and vocabulary in supporting their children. Thus, beliefs and perceptions in education play a crucial role for early childhood students in learning STEAM skills. As mentioned earlier, parents supported strong interdisciplinarity with physical, face-to-face teaching in early childhood. However, parents did not know that the remote modeling tasks supported their children in STEAM skills (e.g., recognition and modulation of shapes). Beliefs and perceptions were similar to our previous research findings (Haas, 2021) from the first remote teaching experience on eggcup creation, where we observed a change of perception of STEAM courses and teaching among children and their parents. In addition, during the modeling tasks in early childhood, we observed a change in perception by all participating parents (Haas et al., Under Review). Moreover, with this second experience in early childhood, we confirmed a similar perception change as for the first experience.

Parents reported, mainly in the messageboard, that their children used "geometry," had to "think about the names of the shapes," or "combined cubes and transform shapes to obtain a robot." Thus, pupils used math words to describe their creations in the CAD software and observed the diversity of a given shape. Compared to non-technology-enhanced tasks, such as building a robot with wooden construction blocks, shapes can be transformed and combined with CAD software. The manipulation with the software supported parents and children to use math vocabulary to construct the robot together.

Furthermore, parents reported on the added value by modeling shapes in every direction, size, and color. The usefulness of such tasks for parents was reported several times during the online chats, and both parents and children appreciated the playful approach. In addition to mathematical vocabulary, parents reported on physical rules they discussed with their children. A question like "Will the robot stand on these cubic feet? Is the weight in the robot balanced?" Critics on technology use in early childhood were often criticized for not connecting educational tasks to a real-life situation, which was reported essential in the early childhood development (Rushton, 2011). Regarding the parents' report, they perceived the modeling task, once engaged, as a learning activity that playfully connects to real life.

Figure 4 shows 4 printed CAD software designs of robots. Each design presented differences in stabilization and positions. Parents worked with their children on shapes and a more general STEAM combined approach. This scientifically supported approach in the parent–child relationship was thus observable throughout the modeling task and supports a positive learning development with explorations as requested by research in learning in early childhood (Hu et al., 2021).

In the upcoming section, we described results related to the motivation of students, based on coded data from parents.

Student Motivation Changes

Several studies researched and discussed motivational factors using technologies like AR or CAD software (Ng, 2017; Bacca Acosta et al., 2019; Haas et al., 2021a). Thus, technology-enhanced tasks with digital modeling are more likely to support students in understanding 3D geometry, support the

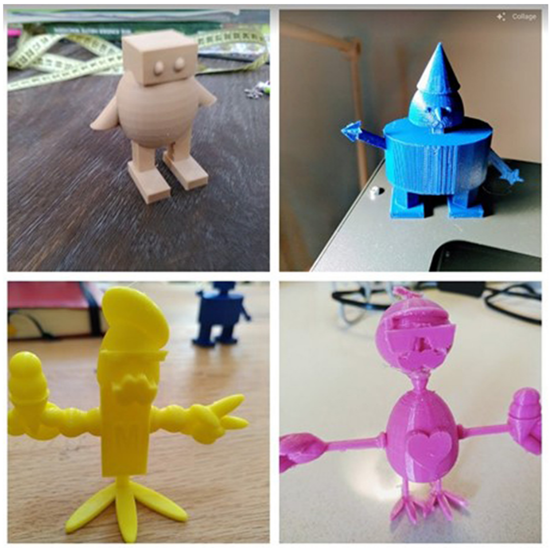

FIGURE 4 | Printed robots of the modeling task.

development of additional solving strategies, and delve into new learning behaviors (e.g., manipulations of geometric objects, experiment with objects, or transform properties). In our experience in early childhood, both parents, and children reported a higher motivation to solve the tasks than the standard tasks received during the confinement (e.g., paper–pencil tasks with a closed setting). Moreover, as for the first experience, they confirmed that working together with such a task was positive. Modeling the robot in the CAD software was perceived as a "playful construction game" with a "really unique result" at the end of the process. Parents reported that their children were motivated to experiment with the software and "see if the robot could be printed" and "how it could vary by adding or changing shapes and objects." Consequently, it appears that the experimental approach in verifying the feasibility of the design (e.g., Can it stand detached? Is it printable?), the modulation of shapes (e.g., What happens if we raise the number of sides of a pyramid? What varies?) or the creative combination of shapes, forms, and given objects, renders the tasks highly motivational in terms of learning. Pupils seemed to be in a flow (Nakamura and Csikszentmihalyi, 2014), similar to our first experience, where the task supports a positive learning motivation.

Moreover, Carlton and Winsler (1998) described tasks that support the free exploration of a student's environment and allowed self-regulation of goals to foster intrinsic motivation in early childhood. In addition, parents reported a positive effect on learning since the modeling task required a standard action between parents and children. This is a general trend in using technology in education with parents, called co-using (Chaudron et al., 2015). According to Dias and Brito (2021), co-using could lead to a negative motivation for children since parents decide on the educational content and manipulation. However, since the teachers gave the tasks, tools, and the criteria for the result, we observed equity of choosing in the designs between parents and children instead. Thus, pupils needed guidance and support from their parents and were motivated to create a design with their parents. Parents reported that pupils were "eager to present a robot" or "my son and I spent a good time trying out the different shapes on the robot." However, what we observed as well was that a high amount of time invested was only possible for parents who did not need to work outside the house (e.g., who were not in the home office or permanently at home). Another vital element within the modeling task was the technical knowledge of parents, which is described in the next section.

Parents Technical Knowledge

Over the last few years, parents have become more comfortable in letting their children in the early childhood age use technology for educational purposes and acknowledge their value-added for learning (Livingstone et al., 2015). In their role as digital mediators, they decide on the validity of educational technology or tasks and if it is suitable for their children. Parents who are more positive about using technology are thus more supportive of using it than parents, not in favor of educational technology (Nikken and Jansz, 2006; Dias and Brito, 2021). In the modeling tasks, parents were better prepared than in our first experience. This could be attributed to the proposed 1-week tutorial support from the teachers' and researchers' side. In worked-examples, messageboards, or videos, parents learned the content and manipulations of the used CAD software. Based on their replies, parents were less intimidated and insecure than in our previous experiences.

Furthermore, parents linked the modeling task to the everyday activities of their children (e.g., building with wooden bricks) and discussed the possibilities the software could offer. On the other hand, we observed a similarity to our first experience, the difference for parents in using the software. Parents working with similar software in their work-life (e.g., interior architect, road planer, or construction site manager) knew about more functions and manipulation strategies than those with more minor technology-enhanced jobs. The simple experience of using the smartphone or tablet for social media, games, or video streaming did not prepare parents, as reported in the online chats, for the manipulations in CAD software. Yet again, there was a high discrepancy between socioeconomic backgrounds. Manipulations with software like CAD are not generalized in public education and are thus reserved for those visiting higher education or specialized educational training (e.g., technology-enhanced works).

The tutorial week, however, aided parents to discover and manipulate the different functions, which helped the children in the manipulation of the task. Some parents reported that for them it seems easier to work on a computer with a mouse and for their children, the tablet (**Figure 5**) was "much easier" to manipulate for the digital design of the robot. Furthermore, the AR function on the application on the tablet allowed the transfer of the digital design into the real-world environment (**Figure 6**).

This was not done by every parent and child, since this manipulation was "too difficult" or "not understandable to

FIGURE 5 | Pupils working on a tablet.

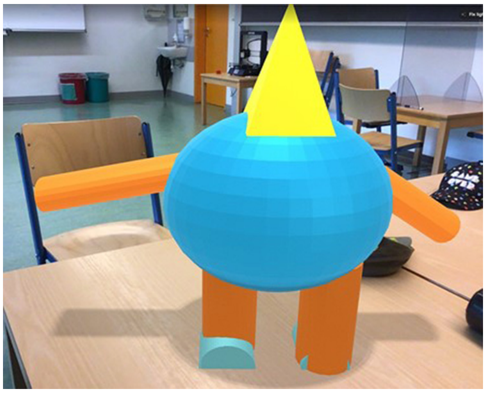

FIGURE 6 | AR visualization of a robot done by a child.

produce" by some of the parents. AR can develop new strategies but need to be used in a well-prepared and proficient-learning setting (Billinghurst and Duenser, 2012). Half of the parents noted that they would need additional training to use AR and to work with their children in this function.

Independently of the technological knowledge, the mediator role or parents' performance in manipulating CAD software, parents offered similar scaffoldings and parent-assisted teaching, which we described in the upcoming section.

Parental Assistance

During the modeling task with the CAD software in early childhood, the interactions between parents and their children were high and similar to interactions teachers would experience in class with their pupils. Similar to the research findings of Aram (2008) and Kucirkova et al. (2013), the digital task can support new, more intense interactions between the learner and the teacher (e.g., parent). Within the experience, parents used different scaffoldings to assist their children, similar to what a teacher would do (e.g., by dichotomous questions, rewards, subtargets in the construction process, or technical help). According to Neumann (2018), and this was similar to our first experience, parents use cognitive, affective, and technical scaffoldings when working with their children on a task. In **Table 3**, we grouped recurrent examples of the scaffoldings parents reported in one of the communication channels.

Based on recurrent messages in the communication channels, it appears that every parent used cognitive, affective, and technical scaffoldings to certain degrees of intensity. Parents who were described by teachers in general as more supportive showed in the data higher-affective support messages and showcased their children's work. We assume that the intensity of support in the modeling tasks with parent-assisted teaching is strongly related to their usual child–parent relationship, which was confirmed by the teachers in later discussions. However, similar to the findings of Wood et al. (2016), all the participating parents intended to positively support their children's STEAM learning experience during the task. The exchange on the messageboard, between parents, revealed moreover a desire to support the whole group of participating children. Thus, we observed how parents assisted each other in finding solutions to function manipulations or on how to best use the software in general. At the end of the tasks, parents acknowledge the importance of having a communication channel with support from teachers and exchange with peers. Peer learning among parents (Shilling et al., 2013), as well highlighted in our previous remote research experience, seems to have a supportive and likely positive effect on the accomplishment of remote tasks with parent-assisted teaching. According to Guldberg (2008), peer learning among adults can support the community of practice, which could lead to an improvement in support for the entire community. Compared to regular school teaching activities, the participation of parents and the exchange on school subjects and pedagogical techniques were much higher in this remote modeling task. A continuation of using exchange platforms during regular STEAM education could eventually improve the overall participation of all parents in the learning process.

At the end of the modeling task, the designs of the pupils were printed with the school 3D printer in their presence and tested on functionality (**Figure 7**). Each child received his/her robot and took it back home. Parents posted the designs and the prints of their children on the messageboard, and pupils received positive feedback from the community of participants. While we initially wanted to observe how parents and children react to the remote teaching with CAD software in STEAM education, we realized at the end of the experience, how important the community of parents and children is in the learning process overall. There are often barriers (Hornby and Blackwell, 2018) for parents to be involved in the educational community (e.g., bad own experience in school, low verbal communication skills, and social fears) and be supportive of their children. This is leading to exclusions, which do have strong effects on students' scholarly and social development (Sime and Sheridan, 2014). The community within the modeling task, however, worked like an enabler for parents' engagement in school activities and gave guidance in supporting their children. It could be a supportive place where parents could work together, similar to a real-world community, but mixed in its socioeconomic factors, backgrounds, and skills. As stated by Ainsworth (2002) that it takes a community (or village) to raise a child and support it, the proposed remote practice with support could eventually reduce the gap between parents' communal possibilities to support their children in STEAM education.

TABLE 3 | Observed scaffoldings done by parents.

Type of scaffolding	Description of the scaffolding	Recurrent examples
Cognitive	As a cognitive scaffolding, we considered supports on conceptual and procedural understanding of the modeling task.	Parents used dichotomous questions to explain differences in shapes or to support students in combining several shapes. Parents showed examples and asked students to recreate shapes or combinations of shapes. Parents used examples to explain the functionalities of a design.
Affective	As an affective scaffolding, we considered supports that were positively encouraged to realize and stay on task within the modeling task.	Parents encouraged students by saying positive words about the work or the designs of the children. Parents complimented their children on their capabilities to design with the software and to create their own robot.
Technical	As a technical scaffolding, we considered supports that procured help with the features and manipulations within the CAD software.	Parents explained and showed functions within the software, as the drag and drop function or to change the view of the design. Parents showcased with examples how to combine shapes, change lengths and heights, place shapes on the platform, or change colors of the designs. Parents showed videos from the Internet to explain functions to their children.

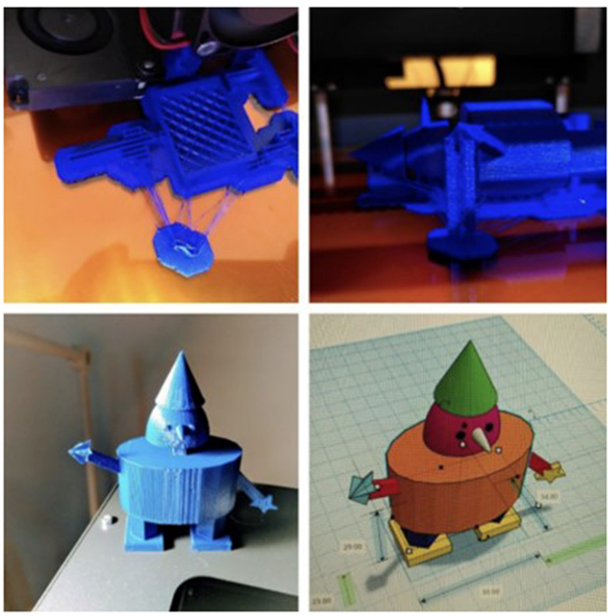

FIGURE 7 | Printing result and process.

CONCLUSION

The present study was designed to evaluate technology-enhanced, STEAM-based remote teaching with parental support in Luxembourgish early childhood education. We formulated four research questions to confirm and supporting the framework from our first study (Haas et al., Under Review). We observed several similarities and thus confirmations on children and parents in remote teaching with CAD software. Our framework with the four elements fitted the collected and coded data during the modeling task. In relation to the research questions we found that (1) STEAM was perceived as interconnected which is characterized by the use of mathematical vocabulary and the testing of physical rules, (2) tasks were highly motivational in terms of learning, (3) manipulations of CAD software were not common and differed based on socioeconomic background, whereas the use of AR was too difficult to use for half of the parents, and (4) interactions between parents and their children were comparable to the ones between teachers and students, and strongly related in intensity of the usual child–parent relationship. An interesting fact is that parents preferred to use computers with a mouse, whereas children preferred touch-based tablets for the modeling tasks.

Accordingly, there were changes in the perception that could have effects beyond the modeling task for parents, pupils, and in the retrospective for the teachers. What started as an experience of new technology used in remote teaching revealed opportunities not only on the content and skill level in STEAM but also, overall, in the educational process. The experience led parents to participate actively with their children, question STEAM contents, experiment with scaffoldings, and connect to each other. We observe scientific approaches and high motivation among early childhood students, who actively designed and created real-world objects with STEAM skills.

Of course, this experience was reduced to 12 participants and one parent each, and findings should again be confirmed and discussed in future research. Questions on community learning for parents and children in remote teaching for STEAM education became clearer and need more data, which should be collected in the next research stances. In particular, socioeconomic backgrounds need detailed consideration. Probably, an eco-learning system, where communication channels, digital technologies, like CAD software, AR, and 3D printing, and professional and peer resources are made available, would provide a promising setting. Finally, we need to consider the long-term effects of remote learning in STEAM education in early childhood. Children and parents benefit from active learning technology and social interactions through proposed communication channels with professional support. Training and workshops in teacher education should prepare schools to propose similar experiences in future.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because the dataset cannot be shared, as agreed with participants' legal representatives. Requests to access the datasets should be directed to BH, ben.haas@outlook.com.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

BH produced the first draft of the manuscript and edited the research design. ZL consulted on the methodology and methods and edited and reviewed the manuscript. TH reviewed and edited the manuscript. YK consulted on the research design, reviewed, edited, and formatted the manuscript. All authors contributed to the article and approved the submitted version.

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