Conversational Technologies for In-home Learning: Using Co-Design to Understand Children's and Parents' Perspectives

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ABSTRACT
Today, Conversational Agents (CA) are deeply integrated into the daily lives of millions of families, which has led children to extensively interact with such devices. Studies have suggested that the social nature of CA makes them a good learning companion for children. Therefore, to understand children's preferences for the use of CAs for the purpose of in-home learning, we conducted three participatory design sessions. In order to identify parents' requirements in this regard, we also included them in the third session. We found that children expect such devices to possess a personality and an advanced level of intelligence, and support multiple content domains and learning modes and human-like conversations. Parents desire such devices to include them in their children's learning activities, foster social engagement, and to allow them to monitor their children's use. This understanding will inform the design of future CAs for the purpose of in-home learning.

Author Keywords
conversational agents; participatory design; children; parents; home; learning; learning companion; co-design; learning technology; cooperative inquiry.

CCS Concepts
•Human-centered computing → Human computer interaction (HCI);

INTRODUCTION
Conversational Agents (CA) such as Google Assistant and Amazon Alexa have in recent years become deeply interwoven into families' daily lives through devices such as smart phones and smart speakers. This has led children increasingly to interact with CAs for various purposes, such as information seeking, functional reasons, and entertainment purposes [39]. Furthermore, dialogic reading, which CAs can facilitate, has the potential to scaffold children's learning and foster their interest in long-term learning [62]. Therefore, prior work (e.g., [8, 25, 31, 3, 59]) has sought to leverage CAs to develop virtual learning companions for children. Researchers (e.g., [3, 59]) have even found that children learn more and report more satisfaction using learning programs that incorporate virtual conversational tutors. However, despite the potential of these programs to simulate a social companion that can engage children in conversations for learning purposes [9, 52, 62], less is known about the needs, preferences, and perceptions of children using these these this technology for their in-home learning efforts. Furthermore, parental involvement has been found to influence children's use and perception of technology [30, 41, 48, 56, 53] and their learning performance [21]. However, there is limited research regarding parents' preferences and requirements for the design of technology that can help with the in-home learning needs of children. Therefore, with this work, we aim to answer the following research questions:

RQ1: How do children think about in-home conversational technology that can be used to fulfill their learning needs?

RQ2: What are the requirements of parents for conversational technology that can be used to fulfill their children's learning needs?

Developing a deep understanding of children's preferences regarding intelligent learning technology would be difficult with traditional modes of qualitative data collection (e.g., interviews, observations, surveys) [60], not only because of the complex nature of conversational learning companions (e.g., learning modes and levels, and human characteristics such as voice), but also because children can become exhausted in an interview setting, or have difficulty understanding interview questions or accurately expressing their mental models [37, 61]. Researchers have demonstrated that Cooperative Inquiry (CI) enables a researcher to collect rich data from children, as it enables children to concretely articulate their abstract ideas, especially compared to conventional methods [16, 17, 27, 58]. Therefore, for this study, we adopted the Collaborative Participatory Design (CPD) method of CI. In CI, adults and children design technologies for children, with children [17, 18, 26, 65]. To answer our research questions, we conducted three co-design sessions with an inter-generational group consisting of 12 children aged 7-12 and their parents (who participated in the third session with their children).

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After transcribing the audio and video recordings of the design sessions, we analyzed them using affinity diagram [29]. We found that children expect such devices to possess a high level of intelligence in terms of human-like conversation, adaptability, and emotional intelligence. Children also expected these devices to take on the role of learning companion, teacher, and friend. Parents desired such devices to include them in their children's learning activities and to allow them to control and monitor their children's use.

We contribute in two ways to the discussion and design of future CAs that could become in-home learning technologies for children: First, we provide empirical of children's preferences for in-home learning technologies and arrive at a set of recommendations for designers. Second, we provide parental recommendations for managing learning technologies in the home, in terms of design features that could help them participate in learning activities and/or control children's use when needed.

RELATED WORK

To orient readers to our work, this section describes two streams of related research: Children's use of conversational technology for learning at home and the role of parents in children's learning and in-home technology use.

Children's Interactions with Conversational Technology for Learning

The use of conversational agents at home is widespread, both among the adults and children [52]. Traditionally, children have been known to use technology at home not only to entertain themselves, but also to learn [22, 33]. Lovato et al. [38, 39] has showed that children primarily use CAs to seek information, which is considered a skill children require to succeed in school, as they are asked to complete homework and in-class assignments that hinge on search ability [22]. However, researchers [23, 52, 39] have also found that instead of helping children to understand concepts, CAs can currently only provide direct answers to children's questions. Therefore, unsurprisingly, researchers (e.g., [8, 25, 31, 40, 62]) have sought to improve CAs so that they can become virtual learning companions for children. For example, Mack et al. [40] conducted a participatory design study with elementary and middle school children, with the intent to inform the interface design of a social studies educational application. They concluded that including conversational dialogues in such applications, such as while communicating with virtual historical figures, improves children's perception of the technology. Xu and Warschauer [62], in designing a storytelling CA, concluded that children enjoyed interacting with the device for activities such as reading books.

Prior work has also suggested utilizing parasocial relationships (i.e., one sided emotional bonds that children develop with familiar media figures) to develop intelligent "characters" that children can use as learning tools or companions [5, 7, 25, 42]. Based on the experiences gathered from Sesame Workshop, Gray et al. [25] emphasized the use of personification and social realism in developing intelligent characters to foster learning in children. Along similar lines, due to the human-like characteristics of robots, researchers (e.g., [28, 51]) have found them to be superior to other educational media and technology in promoting and improving children's concentration, interest in learning, and academic achievement. Purington et al. [49] have provided evidence of adults and children who already attribute human-like attributes to CAs and perceive them as their companions. Researchers (e.g., [25, 7]), however, have also argued that the development of these relationships is influenced by parental approval or disapproval – similar to how parent's opinions influence children's relationships with other people – as parents might selectively encourage or limit screen time (we go into detail on this in the next section).

Another stream of research (e.g., [47, 35]) has investigated efficient ways of integrating such CAs into instructional and educational settings. There has been work around investigating the potential uses of conversational pedagogical Aritifical Intelligence (AI) in classrooms, including intelligent tutoring systems and chatbots [34, 54] and exploring how conversational agents can support inclusive education [44]. Lester et al. [36] pointed out that due to 'persona effect' children learned more and reported more satisfaction using learning programs that incorporated virtual conversational tutors.

Instead of developing instructional materials, our study aims to inform the design of intelligent conversational technology for children that can help them in their learning endeavors at home. Specifically, this work can inform the design of intelligent in-home learning technologies that cater to children's preferences and expectations.

The Role of Parents in Children's Learning and Technology Use

Children's use and perceptions of a technology are often mediated by their parents. Prior work has identified several categories of parental mediation: in *restrictive mediation*, parents set limits on permissible activities; in *active mediation*, parents and children discuss appropriate content and use; and in *co-engagement*, parents and children consume content together [30, 41, 48, 56, 53]. Researchers have shown that parents employ restrictive mediation the most and that they establish context- and activity-specific rules for children's media use [30]. However, the ability to implement parental control is not straightforward – parental preferences for restricting children's technology use are contextual [41], and if a child's access, such as to the Internet, is over-restricted, it may even compromise his or her ability to use the device to learn, such as the ability to complete homework [19].

Parents contribute significantly to their children's in-home learning by participating in "family learnings", which generally refers to the involvement of parents in their children's numeracy and literacy activities, reading with children at home, and encouraging homework [14]. Garg and Sengupta [23] found that while parents in general restrict children's use of technology, they encourage children to use devices such as smart phones and smart speakers as part of "family learning" activities. Joint media engagement or co-engagement with technology by parents and children for the purpose of learning has been found to have a positive effect on children's grades [21] and academic achievement [32].

In reference to conversational technology, recent work by Beneteau et al. [4] and Cheng et al. [11] have examined children's interaction with voice-based devices in the home. Their findings noted that children and parents spend a lot of time, at least in first few weeks of use, mitigating the breakdown of children's communication through repair. However, the current scholarship offers little on parents' preferences and requirements for these technologies that become in-home learning companions of their children (e.g., desired functionalities, such as the ability to control children's use, monitor children's progress, and jointly engage in learning activities). Therefore, we aimed to fill this gap by involving parents in our study to elicit their preferences in regard to the design of intelligent in-home learning technologies for children.

METHOD

Prior HCI scholarship with children that utilized CI in the context of complex topics such as intelligent user interfaces, voice interfaces for the visually impaired, the nature of creepiness and technology, and privacy and online safety [43, 44, 61, 65] has not only shown the importance of including children as design companions, but has also produced rich data for improving design of future technology. Therefore, to answer our research questions, we conducted three CPD sessions involving partnerships between children and adults (i.e., design researchers and, in the third session, parents as well). We used the techniques of *Stickies* [17, 58], *Bags of Stuff* [17, 58], *Big Props* [58], and *Layered Elaboration* [57].

We structured our design sessions to begin broadly. We explored what children thought about using conversational agents for learning activities by having them use different speech agents that are currently available in the market. Later, we asked them to design technologies that they thought would help them in their in-home learning activities. In the last session, we included parents as design companions so that parent-child pairs could collaboratively adapt children's design(s) to include the preferences of parents as well.

Participants

An intergenerational co-design group, consisting of both child and adult participants, participated in the design sessions along with adult design researchers. The first two design sessions involved the children and researchers; for the third session, one parent of each child was asked to join as a design partner.

The child participants were recruited through their parents, who volunteered to participate by responding to recruitment flyers on Craigslist and in local community centers and libraries. When recruiting, we aimed for diversity in gender, age, and ethnicity to elicit multiple perspectives. Our study included 12 children between 7 and 12 years of age (see Table 1). The adult participants consisted of one undergraduate student, one graduate student, and one professor [mean age = 27.6, SD = 4.02]. Between the recruitment of children and the three design sessions that the paper includes, the research team (first author and one undergraduate student) had also conducted twelve other 90-minute co-design sessions over a period of 6 months (one every two weeks) where children and researchers engaged in exploratory design practices to build equal and equitable partnership.

Our protocol for the study was approved by the review board of the institution. Upon arrival, the children and parents were informed of the purpose of the research and their role in the design sessions. We also informed them that we would be audio- and video-recording our conversations with them, and that the recordings in their raw form would be used solely by the research team for analytical purposes and would not be shared online or with any other audience. We also informed the participants that we would be collecting any design artifacts. If they agreed to these conditions, we obtained parental consent (for their own and their children's participation) and child assent (for their own participation).

Name	Age	Gender	Ethnicity	Participant Parent
Milly	7	Female	Asian	Mother
Lily	7	Female	White	Father
Sam	8	Male	Asian	Mother
Marianne	8	Female	Asian	Father
Chris	8	Male	While	Mother
Marc	9	Male	African American	Father
Juliet	9	Female	White	Mother
Susanne	10	Female	Hispanic	Mother
Yuling	10	Female	Asian	Father
Lauren	11	Female	Asian	Mother
John	12	Male	White	Father
Daniel	12	Male	African American	Father

Table 1: Demographic Details of Our Participants. (Note: The names listed here are pseudonyms.)

Design Sessions

Our study comprised three 90-minute sessions, which were conducted over two weeks, with the last two design sessions organized on the same day of the second week. Each day began with a snack time (15 minutes), which is known to form bonds with children that lead to trust and teamwork. This was followed up with circle time (15 minutes), when we asked the "Question of the Day" to help the participants (i.e., the parents and children) begin to focus on the day's design activities (cf. Table 2). After that, the participants broke into smaller inter-generational groups for the design session (45 minutes). Finally, there was discussion time (15 minutes), during which every small group presented their designs, and all the participants then reflected together and discussed common ideas across different designs. To document the design sessions, an audio recorder was placed near each small group, and a volunteer with a video camera moved throughout the room to capture interactions in different groups.

Design Session 1 (DS 1)

On the first day, we elicited information regarding how children think about and use different speech agents for the purpose of learning. To introduce the topic of the day, we asked the children to share how and for which learning goals they use technology at home. All our participants had prior experience using several forms of technology (e.g., tablets, smart speakers, computers) for the purpose of completing homework or learning in general. During the design session, we used four different speech agents – Google Home Assistant, Microsoft Cortana, Apple Siri, and Amazon Alexa – for a learning activity. We did not provide children with examples of learning activities we were interested in, but we explicitly told them we wanted to understand what activities they would like to use the devices for. The design groups evaluated the agents in a rotating manner, using the Stickies CPD technique [17, 58]. Following this approach, we gave our participants sticky notes and asked them to write their likes, dislikes, and design ideas for improving/changing the agents in light of the learning activity they tried to use the agent for. We did not in any way control or constrain the responses given by the agents.

Figure 1: Children thinking about their designs during the Session 2 co-design activity.

Design Session 2 (DS 2)

The first co-design activity on day 2 utilized the Bags of Stuff [17] and Big Props [58] techniques. For the first activity, the children were asked to design technology (e.g., construct or depict features of technology) that they would like to use for learning the using technique of Bags of Stuff [17] (see Figure 1). For this technique, we provided large bags that were filled with arts and craft supplies, such as glue, colored paper, markers, styrofoam shapes, pom-pom balls, and scissors. The children and adults were then supposed to act out a scenario of using the learning technology they had designed, using the Big Props technique. The role play began with the children acting as the system and adults playing the part of a potential user. After about 15 minutes, they switched roles. In addition to the material provided in the Bags of Stuff, we gave the children easel pads to act out a scenario. We did not ask them to design learning technology that could fulfill a certain social role, such as learning companion or a teacher, as we did not want to prime their mental models. Furthermore, we did not restrict children to speech as the only input/output modality in their designs, in order to elicit their preferred input/output modalities.

Design Session 3 (DS 3)

After an hour break, we reconvened on day 2 for the third co-design session, which included parents as design companions. At this session, we used the technique of *Layered Elaboration* [57], according to which the design teams iteratively generated ideas by extending existing concepts, while leaving prior ideas intact. The parents were first presented with the ideas that the children had developed. Our co-designers – parents and children – were then asked for ideas about how to make the existing designs better by adding new features or by modifying existing ones. We encouraged the parents and children to work collaboratively when suggesting design ideas.

Design Session	Question of the Day
DS 1	How and for which learning goals or tasks do you use a technology, such as a computer or tablet for in your home?
DS 2	How do you want technology to be better designed for the purpose of in-home learning?
DS 3	Illustrate an instance when your technology use was influenced by your parent(s).

Table 2: Question of the Day for the Design Sessions

Data Analysis

The audio and video recordings (totaling 162 minutes of data – duplicate portions of the recordings were transcribed only once and snack time was excluded) were transcribed for the purpose of analysis. The transcribed data was analyzed using affinity diagramming, an inductive method commonly used to refine and organize statements into larger themes [29]. The data were analyzed using grounded, inductive, and qualitative methods [10, 13]. The authors of this paper collaboratively constructed the affinity diagram using *Miro*, formerly referred to as *Realtimeboard* [45]. The analysis began by identifying individual child and parent utterances. Each statement was then represented as a digital note on the board. Both authors participated in several rounds of discussions to identify the theme associated with each utterance. At the end of this process, all the notes were categorized into 25 themes. We also identified various relationships among these themes that led us to combine them into four major themes: *System Output Modalities and Behavior, User Input Modalities and Behavior, System Intelligence,* and *Privacy Concerns*. We provide further details about the themes in the sections that follow.

RESULTS

Our analysis of the data revealed children's and parents' perceptions and needs in reference to in-home technology that can be used for learning. We discuss below in detail the major themes and sub-themes that emerged from our analysis, with corresponding examples from the co-design sessions.

System Output Modalities and Behavior

In the three design sessions, we identified several themes where children and parents conceptualized the devices' internal logic or functioning and their output modalities. Several themes that emerged included: *Content Domains and Learning Modes, Output Modalities, Persona, Fostering Social Engagement,* and *Parental Involvement and Control.*

Content Domains and Learning Modes

During the design sessions, it became apparent that children expected the devices to offer learning activities corresponding to any subject the user chose. For example, while talking about his design Marc, during DS 2, stated, *So you can learn whatever you want with it. You can seek general knowledge, learn subjects they teach you in school like Math and English, and learn about your favourite sport.*

In DS 3, parents and children also included in their designs the capability to play games and engage in other fun activities (e.g., sketching or listening to music). For example, Lauren's mother said, *"I do not think children will continue to use it for long if there is no fun associated with using the device. So it should have activities that attract children to interact with it."*

Children also included various modes of learning in their designs, which users could select from. Some of the modes frequently included in children's designs were these:

1. Instead of simply providing direct answers to users' questions as children learn a new or revise a previously learned topic, one of the modes used scaffolding to help users work out the answers to the queries themselves. This was mostly done by providing hints in response to users' questions. For example, in DS 2, while acting as a system, Daniel responded to the user's question in the following way:

   Adult: *"Where is the Eiffel Tower located ?"*
   Daniel [speaking as the system]: *"That city is also the capital of France."*
   Adult: *"Is it Paris?"*
   Daniel [speaking as the system]: *"Yes, Good job!"*

2. Children also included "storytelling" as one of the learning modes in the designs. In this mode, devices helped users to learn through engaging stories. The children designed the device to tell stories through voice, images, or videos on the screen. Prior work has argued that engaging stories can support the learner's intellectual and emotional needs [25], which in turn can facilitate the development of parasocial relationships. For instance, during DS 2, Sam noted, *"When children are tired but have a pending homework to complete, this option will let them learn through stories that is always fun."*

3. During DS 2, the children included practice drills and formative and summative assessments in the form of quizzes and competitive games (to be played with other users, who might be in the same room or in a remote location, or the device itself), as one of the learning modes in their designs. The possibility of competing with the device echoes the findings of Woodyard et al. [61], who found that children like to challenge and compete with the intelligence of intelligent devices.

   During DS 3, parents added the functionality of generating weekly or monthly progress reports on the assessments that the children participated in. For example, during DS 3 Juliet's mother said,

   "If my daughter is preparing for some specific test we can generate reports to track her progress. But, when she is using it [the device] for day-to-day learning we can disable this feature. We do not want to watch her progress like a hawk all the time."

Output Modalities

Children considered a wide range of output modalities for the systems they designed, with voice, text, images, videos, sound, facial expressions (in cases where the device was designed to include a face), and physical output being the most common. While the fact that we asked the children to evaluate different speech agents in DS 1 might have influenced the inclusion of voice in all of their designs, it was more important to understand their reasoning for including multiple output modalities. Frequently cited reasons were to scaffold users' interactions (e.g., if a user is deaf, he or she can view the response in the form of text), to express emotion (e.g., facial expressions or gestures were used to convey emotions), and to reward the user.

For example, in DS 3, the parents and children, while discussing the need for devices to reward children's progress, included physical output in form of merit badges (made from colored paper in various shapes, such as stars and trophies) and "candies" (pom-pom balls representing candies). In DS 3, Lauren's mother observed: *"To applaud progress, the device can reward the child in the form of stars, something very similar to how it happens in a school setting."*

Persona

In DS 1, we observed that, before starting to interact for the purpose of information seeking or learning, children tried to attribute identity to the devices, by asking questions such as *"How old are you?" "Where do you live?"* and *"Can you understand if I speak in Chinese?"* Often, when the children found the responses to such questions to be unsatisfactory, they lost interest in learning from the devices. Christine noted, *"If he [device] does not know what his age is, how should I believe he will tell me true facts about my favourite historical figure?"*

In subsequent design sessions, the children conceptualized intelligent technology for learning with a personality and a backstory. In terms of personality, they assigned the devices physical human features, such as voices and human anatomy (e.g., faces, hands), and the ability to move; intellectual features, such as decision making ability and knowledge; emotional states, which could change based on those of its user, and human behavior, reflected in its various functionalities. The backstory of the technology was often based on that of children's favorite media character (e.g., the character's demographics, expertise, and so forth).

Depending on the assigned personality, children also conceptualized these devices to play several roles, with companion, teacher, and friend being the ones that were most mentioned during the design sessions. For instance, Lily designed a device that looked like Robo Baby [55] and expected it to act as a life-long companion, one who grows old with the user and helps with learning. She said, *"It looks like Robo Baby from Rescue Bot. It will be same age as that of the user and it keeps growing too. Just like a companion would. They grow together and learn together."*

Fostering Social Engagement

In DS 3, parents expressed concern about the children's conceptualization of devices as potential companions or friends. As a solution, parents built on the children's designs by adding the ability to foster social interaction and engagement, which would serve as a *"reality check"* (Milly's mother, DS3) for children. For example, Lauren's mother, during DS 3, explained, *"I have added the feature of social games, which children can play with their siblings or friends, but also collaboratively learn in the process. This way they kind of know a technology is only a technology after all."*

This shows that parents required the technology to facilitate children's social interactions with other people in the household, as otherwise it might negatively influence the children's social awareness.

Parental Involvement and Control

Prior work has found that parents to influence children's use of technology [23, 30, 48]. Therefore, we included parents as design partners in the third co-design sessions. In this session, parents refined the children's designs to reflect their perspectives on parental involvement in children's use of learning technology, on controlling and monitoring children's technology use, and on privacy concerns. The following section provides details in reference to these themes.

Parents desired to be able to participate in children's learning activities. Considering their current involvement in children's learning and educational endeavors, the parents assumed several roles – co-learner, motivator, overseer – in children's use of learning technology. For many parents, this was driven by their fear that their children's continual interactions with connected educational devices would exacerbate their dependence on technology, which in turn could displace parenting relationships by excluding tasks that would otherwise be considered primarily a parent's responsibility. For example, Marc's father noted in DS 3,

> *"I am scared to think, that slowly but surely, technology can take over all the tasks parents are responsible for. I can see my child perceives this technology to behave like a living being. So, I do not want to be excluded. I want to be able to monitor what my kid is learning and participate in the activities."*

Parents also considered improving children's social behavior and interactions to be an important learning activity. Therefore, in DS 2, while examining children's designs, parents refined the devices' intelligence by giving them the ability to monitor a user for the use of inappropriate words and tone in their interactions with the device. Parents designed features that could inform them when children communicated in an unacceptable manner and could automatically restrict children from further use. For example, Yuling's father, during DS 3, noted:

> *"Current technology does not check and restrict children from using swear words or a rude tone. For example, while learning math, the device should motivate the use of polite tone and kind words and also restrict the use if it happens repeatedly."*

Parents who were not technologically savvy shared their fear of falling behind the technology. Sussane's mother felt that in order to participate and be able to monitor what her kids were actually learning through the device, it is important for such devices to provide interfaces that explain their functioning and use in a user- friendly manner. She said, *"It is impossible to monitor or participate if you do not understand how it works. Children know much more these days and I want to be in control their use."*

Parents also included the option to set daily learning goals and/or routines for their children and monitor their progress. Sam's mother said, *"My son has a very fixed routine. I think that is true for most children. So this option will enable us to specify her daily routine in terms of learning goals."*

User Input Modalities and Behavior

The analysis of the design session data revealed several themes about the possible ways children desired to use the devices, and their *input modalities.* Children also included in their designs the possibility of *customizing* a device's behavior.

Input Modalities

As with the output modalities of the systems, the children included an array of input modalities for interacting with their devices. Speech and touch were the most common, probably because we asked the children to interact with voice-based agents in DS 1. Other modalities they included in their designs were gestures (e.g., nodding or shaking the head to indicate approval or disapproval), facial expressions (e.g., to show emotion), wireless hardware (e.g., pens, wearable technology, CD-ROMs), or physical buttons on the device. Also, all the children's designs supported more than one input modality. For example, Juliet, while explaining her device in DS 2, said, *"I can speak to the device, but I can also write on its screen."*

Many children also included the ability to remotely access the device through other devices, specifically when they would not be at home. The children stated that portable devices like tablets, phones, and wearables should be able to connect to the main device, which they envisioned to be always present in the user's home. They acknowledged that this might mean some functionalities or characteristics of the device would not be available remotely. For example, Marianne noted in DS 2,

If I am out to a friend's place, my phone can be linked to the main device that is in my house. So if I quickly need to recall a fact or learn something while being there, I could use that. It's okay if I cannot use a storytelling mode from [my] phone, but this will allow me to quickly ask a question.

Customization and Selection

In their designs, all the children enabled the user to change and control any functionality or configuration. As seen before, the children included multiple personas and learning and input modes in their designs, and the user could choose and customize any of these. Furthermore, while the devices had the ability to change their emotions and personalize learning modules based on the user's current mood and characteristics (as elaborated in the section "System Intelligence"), the users were also able to control and reconfigure a device's adaptive behavior based on their preferences. For example, during DS 2, Chris showed a button to one of the adults that would enable the user to change the device's personalization:

> Adult: *"You selected a module that is too difficult for me."*
> Chris [speaking as the system]: *"Okay. If you want to change it, click on this button."*

System Intelligence

In DS 1, all the children tested and challenged the intelligence of the technology by asking questions they already knew answers to, or thought would be difficult to answer. This echoes the findings of other studies [39, 61] For instance, when talking to Google Home in DS 1, Marc said, *"Do you even know how far the Sun is?"*

In subsequent design sessions, as the children were designing technology for learning, it became apparent that the children expected a high level of intelligence in such technology. These expectations of were manifested in the participants' designs as a system's ability to sense users' emotions and respond appropriately, to evaluate user characteristics such as learning needs and demographic background, and to maintain a natural conversation. Therefore, this theme comprised the sub-themes of: *Human-like Conversation, Adaptability Based on the User's Characteristics, Motivating or Initiating Use,* and *Emotional Intelligence.*

Human-Like Conversation

One common theme that emerged in the designs of all the children was the ability of intelligent technology to hold human-like conversation. In their designs, the devices tailor their communication to the user by developing an understanding of the user's context and characteristics (e.g., mood, intention, likes or dislikes, level of expertise) from information gathered from prior interactions (e.g., learning history), or by sensing current situations (e.g., other people in the immediate surroundings). Children also designed interactions with the device to be more social, rather than just being transactional (e.g., asking for clarification, developing a mutual and common understanding). The following exchange took place during DS 2, where "the system" (a child) posed a question in response to a statement from the user (an adult), in order to understand the user's characteristics and clarifications:

> Adult: *"Math is my favourite subject."*
> Milly [speaking as a system]: *"Which topic do like the most?"*
> Adult: *"Multiplication"*
> Milly [speaking as the system]: *"Did you say multiplication?"*
> Adult: *"Yes."*

Adaptability and Personalization Based on the User's Characteristics

The children consistently expected learning technology to adapt itself based on the users' characteristics (e.g., demographics, level of expertise in different subject areas). For example, in DS 2, Lilly explained that the device should be cognizant of a user's current expertise in a particular subject area, to not only better understand the user, but also motivate them to practice and improve in other subject areas. She further said,

> *"A three- or four-year-old might have difficulties in properly talking to the device. So the device can help the child by asking clarifying questions that one could respond in a yes or a no, or even write the response down."*

During the design activity of DS 2, the children also talked about the learning profile of the user. The children expected these devices to remember and adapt based on users' past learning activity on the device. For example, Sam explained,

> *"If you keep on using the device, it will give you more difficult questions with each subsequent use. If you want to revise something, you can always ask for revisions, but it will always give you a new module if you successfully completed the one before it."*

The parents' desire to facilitate holistic learning led them to include in their designs the ability to nudge children to practice a subject (e.g., a school subject), which a child might not have done by him/herself. In DS 3, Marc's father designed a device that *"could motivate or tell the kid to ... [work on a] subject that he or she ignores. I know at least for my kid this is needed, as otherwise he will just do his math and no other subject."*

Motivating or Initiating Use

In their designs, the children and parents gave devices the ability to activate automatically and motivate a user to participate in a learning activity. While parents did this to ensure that some part of a child's daily or weekly schedule would be dedicated to in-home learning activities, the children thought it could help them when they were supposed to practice or revise a topic but forgot, or were not motivated, to do so. For example, in DS 3, the following discussion took place between John and his father:

> John: *"If a user clicks on this button, it will start to track if there is any pending homework or task that needs to be completed. This way if somebody forgets or is too lazy, the device can understand it and help the user. "*

> Father: *"Actually, it should just get activated at certain time of the day by itself. That way it ensures the child is doing his lessons regularly."*

Emotional Intelligence

In their designs, the children frequently included the capability to sense the emotional states of its users (e.g., irritation, fatigue, sadness). This enabled the systems to adapt their responses and the learning activities offered to the users. Prior work has even found this to assist in developing parasocial relationships [7, 25]. In DS 2, Chris designed a device that looked like Elmo (a Muppet character on the television show *Sesame Street* [20]) and could change its emotion based on that of its user: *"So this Elmo look-alike device is more like a learning partner who can change its emotion and adapt the learning module to help the person who is using it to learn. For example, if someone is demotivated, he can begin the learning session by teaching the person his favorite topic. This might help in uplifting his morale."*

Privacy Concerns

While parents acknowledged that digital technologies can offer highly personalized and adaptable behavior due to the vast amount of data they can collect and analyze (e.g., expertise levels, learning interests, frequency of use, learning progress, and children's emotions or moods), they also had privacy concerns, since the data being collected were primarily related to children. For example, the parents asked questions like: What kind of data will be collected from the child user to support personalization? Besides creating a child's profile, for what other purposes will the data collected about a child's learning history and preferences be used? How and where will be the data be stored to prevent its use for malicious reasons?

Half of the parents also expressed concern that because their children are young, they might not even understand the potential harm that such a technology could cause. While no child or parent offered a privacy-conserving mechanisms, many parents desired to be informed about the details of data collection, and expected the devices to enable users to turn off any sort of data collection and processing, provided this did not compromise the device's functionality. For example, Daniel's father noted, *"When a device collects so much data, it should declare the data it is collecting, not in the hidden policy documents, but directly on the screen. The most ideal case will be if the user is also allowed to approve the data collection and the reasons for which it is used, without losing the possibility of using the device for a particular functionality."*

DISCUSSION

In this study, we conducted three co-design sessions to better understand children's perceptions about in-home conversational technology that can be used to fulfill their learning needs. To elicit parental preferences and needs, we included parents as design partners in the third co-design session. Our analysis of the audio recordings of the sessions and the design artifacts generated by the participants revealed four major themes. Based on these themes we developed a model (cf. Figure 2) that depicts the major themes along with the sub-themes and the interrelations among the themes. While many of the major themes (e.g., system output, modalities, user input, system behavior, system intelligence) confirm the findings of Woodward et al.'s [61] model of error detection and correction for intelligence user interfaces., several details vary for the context of conversational technologies for in-home learning. The following section discusses this model and offers recommendations to support designers in their efforts to design new technologies that can be used for the in-home learning activities of children.

User Input Modalities and Behavior

The participants incorporated multiple input modalities in their designs to convey their intentions to learn and interact with the devices. While all the designs included speech as the mode of input, various other modalities (e.g., gestures, connections to external hardware) were included as well.

How users were to behave and interact with the system was based on the system's intelligence and behavior, but users could also configure and adjust a system's intelligence and behavior to suit their preferences. For example, based on users' emotions, children expected a device to adapt its own emotions to scaffold learning. This is consistent with the conceptual model identified by Woodyard et al. [61] in reference to children's understanding of intelligent interfaces and the errors they might encounter.

System Output Modalities and Behavior

As with the input modalities, the participants incorporated multiple output modalities in their designs, all of which included speech. They also included multiple learning modes, such as storytelling, and formative and summative assessments, and instead of providing direct answers to a question, the device could scaffold users' learning by providing hints or prompts, so that they would be able to arrive at the answer by themselves. The children in our study desired technology that could support learning activities in their homes and would have a personality similar to that of their favorite media character, taking on several roles, such as teacher, friend, and companion. Prior work has also argued that when a technology is perceived to have a personality and is associated with a social role, it can promote learning in children [7, 25].

Design Implication 1 - Supporting Different Learning Modes, Roles, and Personas

The children expected the technology to offer multiple learning modes, roles, and personas, so that the modes can be selected and adjusted automatically based on the user's characteristics, or controlled manually by the users themselves. Therefore, to enable adaptability in learning technology, we suggest that designers design technologies that offer different learning modes and possess different personas. However, while designing a technology that has a persona (e.g., a human-like personality, a backstory, and a range of emotions and interests) and can be associated with a social role, designers will have to critically examine the impact this will have on the different learning modes that it offers (e.g., engaging in a competitive game as a friend versus offering a formative quiz as a teacher). Furthermore, designers should also consider the fact that children can be fearful of technology that pretends to take on certain roles, such as that of a parent, or mimic people from their trusted networks [65] or people they are attached to.

System Intelligence

The children in our study expected to see a high level of intelligence in this technology, in the form of the ability to converse

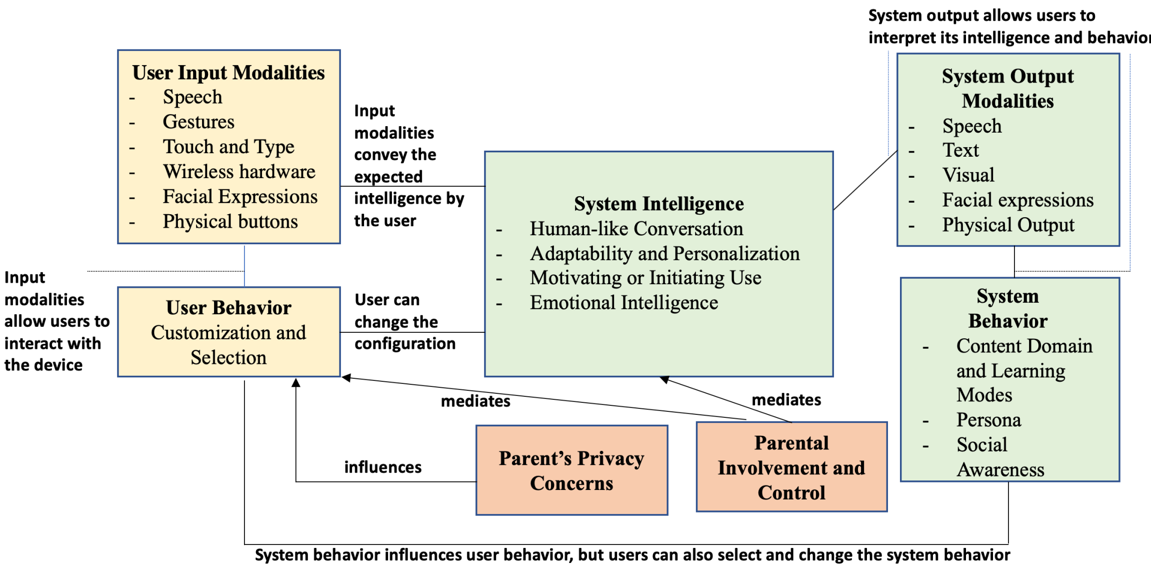

Figure 2: Model depicting the interrelations among the major themes in the children's and parents' expectations regarding in-home learning technologies.

and to adapt its interactions, emotions, learning content, and mode based on the users' characteristics (e.g., demographics, expertise in a particular area, emotions), which are capabilities that are considered to be typical of humans.

As was the case in children's conceptualization of intelligent user interfaces [61], our participants interpreted a system's intelligence through its output. For example, all the designs supported learning not only by answering questions or asking the user to solve problems, but also by adapting their interactions to the user's characteristics.

The current state-of-the art technology does not fulfill the intelligence preferences of children that our study revealed. For example, interactions with current conversational agents (e.g., Google Home Assistant, Amazon Alexa) are sequential, constrained, and task-oriented [12, 50]. In other words, the devices are unable to understand the context of interactions, express emotions, or engage in social talk, which are essential elements for engaging in a human-like conversation [15, 24, 12] (one of the abilities that the children associated with intelligent technology). Prior work, however, has found that when a child trusts a media character and perceives it to be knowledgeable, when a character is able to converse and express emotions, or when personalized experience is offered by a character or a technology based on the user's context and characteristics, the strength of the parasocial relationship, and as a result learning, increases [7, 25].

Design Implication 2 - Including Human-Like Characteristics

Based on our findings, we recommend that designers include in future devices human-like characteristics such as adaptability based on the context, the ability to sense and express emotions, and the ability to converse like a human as much as possible, in order to foster a parasocial relationship between the device and the child, which in turn can promote learning [5, 7].

Specifically, designers and system developers can design devices to sense users' emotions by scanning their facial expressions [46] or by wirelessly monitoring their heart and respiration rates [66]. This form of emotional intelligence can enable devices to adapt their interactions with a child based on the child's emotions; if the child is sad and not motivated to practice his or her lessons on a particular day, the device can motivate him or her through stories or humor. However, as already pointed out, it is currently difficult for conversational/speech agents to completely model a human-like conversation. Also, it is challenging for children to assist a device with this process [4, 11, 63], for example, by providing contextual information [63], which is considered to be one of the essential components for successfully modeling human-like conversations [12, 50]. Therefore, an interim solution could be for a device to develop contextual grounding by continually learning from users' prior interactions and asking them to confirm or clarify input or part of it (e.g., identify a pronoun used in an input), or asking for follow-up information if what the user said was unclear or insufficient for the device to understand the context and generate a response.

Parental Concerns and Role

Prior work has found parents influence children's use of technology [30, 41] by monitoring or restricting their use. Furthermore, parents' communications and attitudes towards technology or media characters influence children's access to them and shape their direct participation in the children's activities [5, 25]. The parents in the study, acting as design partners, changed the children's designs by including features that foster *social engagement* in children, allow for *parental involvement and control*, and cater to parents' *privacy concerns*, thereby influencing the system's intelligence and the user's behavior.

The parents were worried about not being able to participate in or contribute to their children's learning activities, monitor their children's progress, or understand the capabilities of the technology at least as much as their children do. The parents expressed concern that their children's complete dependency on technology for the purpose of learning might also displace them by excluding them from tasks that are otherwise considered to be primarily their responsibility in the home.

Sciuto et al. [52] also reported that children are highly influenced by the spoken nature of conversational technology, which can also influence their social behavior. All of the children's designs included speech as the mode of input and output, parents also desired the device to facilitate social interaction, so that the children would converse with other people, rather than only with the conversational technology. For example, to foster social interaction, the parents built into their designs social games that children could play with other people (e.g., siblings or friends).

Design Implication 3 - Fostering Social Interaction and Engagement

Based on our findings, we recommend that designers of future technology for children incorporate features that can include several members of a family or friends-circle in children's interactions with the device. For example, a device could motivate children to learn as they participate in a device-facilitated group activity (e.g., a competitive game) with their siblings or friends, or could include a parent as a co-learner, motivator, or overseer (e.g., by sending a progress report to the parent) as the children use the device for learning.

Design Implication 4 - Providing Control to Parents

Based on our findings, it is imperative for parents to be in control of the technology that their children use. Designers could provide this control by including features that enable parents to set learning goals for children, to monitor (e.g., by informing parents about the daily learning progress of children) and restrict (e.g., by setting time-limits) the children's daily use and progress, and to approve or disapprove of any data collection pertaining to the children's use or behavior.

Ethical Considerations

In this study, we recommend that designers include human-like characteristics such as the ability to converse, express emotions, and display personality in future technologies for in-home learning, as these attributes have been found to establish a parasocial bond between a child user and the technology, which might in turn foster learning. We believe this poses an ethical dilemma – while it will fulfill children's desire for technology to have a persona, exhibit intelligence, and promote learning, it may also lead children to develop asocial behavior, a feeling of eeriness, revulsion, or disturbed [65, 6], an overdependence on technology, or an inaccurate sense of control. For example, a humanoid device designed to support learning can lead children to attribute more intelligence to the device than to adults in the family and agree to what it says, while ignoring others. The parents in our study raised concerns about a possible decrease in the social awareness of children due to increased interactions with intelligent technology. Gray et al. [25] also suggested that a child's "theory of mind" i.e., their attribution of emotions, intent, and knowledge to oneself and others [2] becomes more complex when they have to also theorize about AI-driven characters.

Therefore, we believe it is an ethical and a moral responsibility of the HCI community and parents to critically examine such technologies in terms of their impact on children to gauge implications that can go beyond the technologies' original intended purpose. In other words, while designing and using such technology one has to evaluate: How do interactions with intelligent human-like devices impact children's development of social emotion and social cognition?

LIMITATIONS AND FUTURE WORK

Our co-design session included 12 children and their parents from a single geographic region. While we did not aim to reach statistical generalizability [64], future work should test the validity of our themes more broadly – for example, through large-scale surveys. Prior work has also found that technology use often differs in families from different backgrounds [1]. Therefore, future work could also compare preferences of children and parents from different racial and socioeconomic backgrounds or from different cultures with different rules for social interaction. It will also be critical in the future to examine how the preferences and needs differ for children who struggle with learning disabilities or sensory impairments.

All of our participants' designs were low-fidelity paper prototypes rather than interactive high-fidelity prototypes. Therefore, they might have missed potential challenges presented by their designs or opportunities to improve the designs. Finally, future work could produce specific technologies in light of our findings to prompt designers and parents to critically reflect on the open questions that we pose throughout this study.

CONCLUSION

In this study, researchers collaboratively designed learning technology with twelve children in three participatory design sessions. The third session also included parents as our design partners,. The participatory design sessions enabled us to arrive at a deeper understanding of children's and parents' preferences and needs for in-home conversational technologies that can be used for children's learning endeavors. We found that while children desire a high level of intelligence, human-like characteristics, and support for multiple content domains and learning modes in such technology, parents expect the devices to foster social interaction and engagement, to allow them to participate in their children's activities, and to control and monitor their children's use. Designers can utilize our findings to design future conversational technology that is tailored to children and their parents.

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