Robot-Based Learning Design for Young Children

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ABSTRACT

There is a worldwide need for tools to assist young children who learn English as a second language (ESL). The authors have been implementing two approaches to designing robot/child interaction activities for ESL children: one-on-one learning in play and small-group learning in play. In the former approach, a child interacted with an embodied robot individually to develop vocabulary and early literacy skills. Based on our study of theories of learning and child development, we sought to create engaging robot-based learning, where the child played with the robot to practice the skills. Through our experience, it was clear that pedagogically solid design and iterative refinement led to sustainable robot/child interaction. The latter approach is currently being explored in our on-going research. Acknowledging that language learning and cultural understanding are inseparable, we examine the role of a robot as a cultural broker that mediates collaborative learning and play among children from different cultural and linguistic backgrounds. During the workshop, we will discuss our motivation toward this approach and pedagogical grounding for the approach, and the progress that has been made in the design of robot-mediated collaborative activities.

Keywords

Social robotics, Robot-assisted language learning, Cultural brokering, Computer supported collaborative learning, educational robots, Diversity, Inclusive design.

1. INTRODUCTION

As we consider designing robots to play educational roles, it is essential to study how we can incorporate robot technology in ways that support and encourage human development both cognitively and socially. The authors have explored the design of robot-based educational activities that are focused on developing young children's language, literacy, and collaborative skills. The unique, human-like affordance of humanoid robots enables the creation of learning activities that simulate peer play and stimulate imagination beyond the cultural and linguistic boundaries in the real world. The two cases introduced in this paper began as responses to educational problems and progressed to design child-robot interaction activities as pathway to solutions. The paper offers several snapshots of the decision making process.

2. BACKGROUND

2.1 Needs and Opportunities

There is a continuous need for tools to improve language learning worldwide. Not only is migration increasingly common, but a growing number of child refugees demands socially responsible action in schools across Europe, North America, Australia and other areas across the globe. Language acquisition is an important part of every young child's development, but it can be particularly challenging for young second language learners. In the United States, language minority children – children whose home language is one other than English – often enter their first year of school already behind in English proficiency, and this can have long term affects on their success. In fact, longitudinal studies show that the amount of vocabulary a child has acquired by the age of five will affect the income and educational success they attain by the time they reach the age of thirty [1]. Given the effects of language skills on a child's future and the need for language skills across all subjects, early intervention is essential, and technology can play an important role. Similar to early language instruction, research shows that the effect of early technology use in young learners is higher than in older students [2]. Furthermore, in a recent report from the National Literacy Trust in the United Kingdom, technology was linked with higher literacy gains for all children and was especially effective for disadvantaged children and young boys [3].

2.2 Child Development and Digital Toys

Young children learn in a social context while they play with others [4]. Their play is like scientific experimentation [5]; their psychological and behavioral changes often occur through vicarious experiences. Though some digital toys are designed primarily for individual learning, research suggests that educational apps can encourage high quality peer interaction when they are open ended and encourage children to solve problem together [6]. Also, to young children, the boundary between real and virtual is blurred [7]. They socially interact with digital technologies much like they do with humans. In fact, many children develop social and emotional attachments to digital toys, and compared to ordinary computer and mobile technologies, humanoid robots seem to demonstrate stronger social and affective benefits [8]. Additionally, children seem to develop social and affective relationships with a humanoid robot regardless of their cultural and linguistic backgrounds [9], interact with the robot enthusiastically, and voluntarily giving sustained attention to learning tasks mediated by the robot.

2.3 Pedagogical Design Strategies

The great potential of embodied robots can only be realized through careful design of interactions and activities that are grounded in theories of learning and child development. A thorough review of these theories has led us to produce six guiding strategies [10].

2.3.1 Multiple Channels for Interaction

Young children like to be active. As they move around their world, they develop fine and gross motor skills and cognitive skills. In particular, some cultures encourage children's behavioral engagement (i.e., being behaviorally active) in learning tasks, which might be viewed as disruptive in the traditional classroom. Many children thrive in learning environments where they can engage in haptic and kinetic activities.

2.3.2 Autonomy Support
Children are behaviorally and emotionally engaged when programs support the children's interest and preferences, or in other words, support a child's autonomy. Autonomy allows children to engage in self-directed discovery and decision making, which is one key determinant of engagement. To be effective, applications should support what children choose, allow them to direct their own activity, and have a sense of agency in their interactions.

2.3.3 Simulation of Peer Interaction
The benefits of peer interaction for learning and development are broadly acknowledged. Children develop as they interact with friends. A sense of companionship is crucial for children's motivation. Applications for children should be designed so that a robot serves not only as a tutor but also as a peer/playmate, facilitating the child to mimic target language and intended behaviors.

2.3.4 Stimulation of Imagination
Fantasy can stimulate children' interest and even help students who struggle to learn because of past trauma [11]. Narrative stories help increase interest and curiosity. The inclusion of a narrative around a robot's personality can enable children to imagine the robot as not only a fun toy but also a character in a unique story-world. The combination of robot technology and fantasy engages children in both immediate and extended ways as they play, imagine, and learn.

2.3.5 Repeated Exposure
Children learn language effectively through repeated exposure to the use of language in a social and interactive context. Also, literacy development requires repeated practice in systematic, explicit instruction. Given that limited practice is one major challenge for second language learners, robot technology offers a way to repeatedly expose the children to the use of the target language as well as reinforce what children have already learned.

2.3.6 Synergistic Use of Old and New Technologies
Digital media and print tools each have unique affordances, and using both new and traditional technologies can improve a child's ability to access language effectively through multiple mediums. Not surprisingly, many digital learning technologies use metaphors of familiar materials when presenting content, e.g., songs/rhymes, flash cards, and storybooks. In particular, some parents and teachers show reluctance to use new technologies for children and prefer familiar materials [3]. Robot-based learning is likely to be broadly adopted if it uses familiar materials integrally (books, cards, manipulatives, etc.) and let the synergy of both old and new technology enhance learning at all levels.

3. ONE ON ONE LEARNING IN PLAY
3.1 The Robot and Learning Material
Here we offer a few examples of how we applied the strategies in our designs of robot/child interaction activities. We used a robot combined with a mobile phone that was equipped with three types of sensors (optic, touch, and proximity) and movements and controlled by Android apps via Bluetooth technology. A phone is cradled on the robot's head implying the robot's visible brain.

In our first project, the learning objectives were to build English vocabulary in three areas: identifying basic shapes, colors, and initial consonant sounds. The design was focused on helping children achieve learning outcomes and, at the same time, providing developmentally appropriate and engaging activities for young children. The activities and resources were also chosen to carefully balance the familiar and the new. This balance in the materials was achieved with songs and the accompanying book and cards (familiar), connected to the robot and app (new). The balance of familiar and new in content also came from having familiar items that are easily recognizable (items from home, simple colors and shapes) and imaginative content (spaceships, secret labs, etc.).

The activities build on each other by introducing, reinforcing, and extending. For example, the song portion of the app was designed to introduce children to the target vocabulary through a fun and low-stakes "call and response" activity. For reinforcing, the game portion of the app allows the user to practice all of the target vocabulary introduced in the songs. For extending, the book gives additional context to the vocabulary. As children see the target words used in the text and help the robot to find shapes, colors, and words in the spaceship, they are able to more fully grasp the meaning and proper usage for the vocabulary, which in turn, can help them produce it more fluently. Figure 1 presents the robot and children using the robot in a public school.

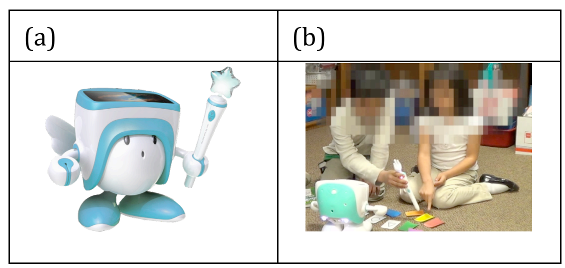

Figure 1. (a) The robot; (b) two seven-year-olds playing together.

3.2 Observation and Discovery
3.2.1 Main Design Questions
As part of our development, we observed eleven English learning children (aged three to seven) one-on-one either in a school or at home. During observations, we were concerned with three major questions: i) Could a child could easily navigate the interface and materials (cards, book, etc.)? ii) Would they demonstrate engagement with the robot and content? and iii) Could they could successfully learn the content? The iterative cycles of our design and observations of children's interactions with the robot led us to adjust the design in ways that would support successful interaction.

3.2.2 Spoken Language: Inviting Interaction
One key goal was to encourage the child to produce spoken language during interaction with the robot. A three-year old Somali-American boy was very interested in touching the robot. However, he always needed additional prompting from adults to repeat key vocabulary words. The designer noticed that when she

tried to elicit a response from the child, she would typically repeat the word three times and use different variations in her voice to encourage the child to respond. We implemented this same pattern of repetition and variation to the robot's dialogue. Example 1 presents a child's interactions before and after adding repetition and voice change:

Interaction Example 1:

Without repetition and voice change:

> *Robot: Sings a song about the color red finishing with the line "Oh please tell that color to me."*
> *Child A: Stares at the robot. Chooses another color and listens to another song.*

After adding repetition and voice change:

> *Robot: Sings a song about the color red finishing with the line "Oh please tell that color to me." Then the robot says "Red."*
> *Child A: "Red"*
> *Robot: "Red" (higher tone)*
> *Child A: "Red" (matches higher tone)*
> *Robot: "Red" (says the word in a low voice)*
> *Child A: "Red" (says the word in a low voice)*

This relatively simple addition became a very important part of the curriculum. Repetition of words after the songs made a big difference not only in this child's willingness to respond but also added more fun to the activity as he tried mimicking the playful tones of the robot's speech. This design change also supported what we already knew about the importance of repeated exposure (see Strategy 2.3.5) and helped us to see how our own experiences with authentic social interaction could make the repeated exposure more effective.

3.2.3 Let's Play…But How? Choices in Interaction

Young children seem to know instinctively that exploration is a way to uncover choices, and most children were very interested in moving the robot's arms, picking up the robot, and/or exploring the robot's wand. The simple act of placing the robot on the floor seemed to open up the opportunity for the child to become more involved in how they and the robot would occupy the space and react to one another. However, home testing revealed that we could not assume that children would maintain a certain distance or be in a certain location during play. Three examples introduced here illustrate very different interaction choices.

Interaction Example 2:

Designer places robot on the floor and points to the screen.

> ***Robot:*** *Explains the True/False game where the child must put their hand close to the right to indicate "true" and the left to indicate "false."*
> ***Child A:*** *Stares at robot. Grabs its arm and moves it up and down. Picks up robot and tries pressing his hand directly on the robot's face. The robot begins to respond, but Child A still keeps his hand in place.*
> *Robot: Begins skipping through questions and then suddenly goes to the score screen.*

Interaction Example 3:

(This example is a direct quote from [10], p.11)

Designer places robot on the floor and presses a button for a song.

> *Child B: Does not look at the robot, but begins singing with it as he plays with another toy in another part of the room.*

Designer tries a different song and the boy responds the same way. After a few more tries, the designer starts to pick up the robot and take it away.

> *Child B: (looks up) "No! I continue to play."*

Designer returns and Learner 10 continues to play in distance, singing along and repeating after the robot.

While Child A actively engaged with the robot, Child B seemed to enjoy parallel play with the robot, and rather than interacting face to face, chose to talk and sing with it while playing with another toy nearby. These observations of different choices in interaction helped us realize that we had unintentionally limited our expectations for interaction, perhaps because adults typically interact with technology in one position the entire time. This was obviously not the case with children, and therefore we chose to adjust our design to fit a variety of interactive options (see Strategies 2.3.1 and 2.3.2).

Interaction Example 4:

> *Book pages 1-5: The two children take turns touching the play button with the wand and listen to the robot's story together.*
>
> *Page 6: The robot asks the children to find three shapes, starting with a rectangle. Child C finds a rectangle. Then he hands the wand to Child D. The robot asks for a square. Both children look intently on the page. Child C gets excited and points to one blue square on one part of the page and then a red square in another part. Child D goes for the blue square first, but then changes her mind and selects the red square instead. The robot asks for a square again. Child C then takes the wand and looks around the page. Child D points back to the red square, but Child C shakes his head. Then he finds a grey square at the top of the page and touches it with the wand. The robot nods its head and a treasure box full of shooting stars appears. (This scenario is repeated two more times until the children find all the components- shapes, colors, and letters- needed for the passcode).*

4. BROKERING SMALL-GROUP COLLABORATION

4.1 Design Goals

The second project, launched in January 2017, explores the role of a robot in mediating equitable collaboration among children. The project seeks to address the need of language minority children living in the United States, who start learning English as they begin public schooling and primarily speak a different language at home. Due to the children's developing English, many educators often view the children as deficit in language, social, and cultural skills. This deficit thinking results in marginalizing the children in the classroom community by characterizing them as ESL kids and remedial kids. This marginalization seems connected to their long-term weaker academic performance and higher dropout rates later in schooling, compared to their native English-speaking peers

To address this problematic situation, we are experimenting with using a robot to create a socio-technical triad with a robot, English-speaking children, and English-learning children, where all children feel respected and cared for. In this approach, we view an embodied robot as a neutral agent that can help children co-construct a small learning community that is relatively free from social and cultural biases. Grounded in culturally responsive pedagogy and communication theory, we design the robot to mediate and facilitate collaboration between the two groups of children. The goal of the collaborative activity is supporting equitable friendship building and positive identity construction of the children as they learn and play together in the triad.

4.2 Robot Mediation Model

Our model of robot mediation for cultural brokering is built on a theoretical framework of three key concepts: invitation, opportunity, and empathy. These concepts represent core qualities of culturally relevant pedagogy, an approach to education that values and incorporates the lived experiences of children from diverse backgrounds when designing curriculum for the classroom and beyond [12, 13]. Invitation is necessary to welcome children into a learning community where they will be positioned as contributing, integrated members. It is a key idea of both communities of practice [14] and positioning theory [15]. Opportunity is a set of circumstances that is frequently undersupplied in the education of language minority learners. The importance of opportunity is emphasized in theories of second language acquisition [16]. The language minority children often have little opportunity to practice the English they are expected to learn and little opportunity to participate in creative and challenging educational experiences. Empathy requires that children be treated with respect and understanding; it is a concept closely linking with the theories of caring [17] and relationship building that supports social and intellectual growth [18]. The mediation model guides the robot to invite children into a series of collaborative learning opportunities. The robot communicates with the children in an empathetic, supportive register without judgment or correction.

Robot mediation aims at achieving four communication goals that offer optimal conditions for equitable collaboration and fluent intercultural communication [19]. The goals include i) building common ground, ii) developing coordinated meaning, iii) building equitable empathic partnership, and iv) developing a co-cultural schema. The first step for children to be able to work together is building common ground. Children need to feel comfortable with each other and share their thoughts and backgrounds in order to establish a minimum of common experience and trust. Second, meaning is not constant and reliable but is developed through interactions with others. Children come to understand and share meaning of symbols, artifacts, and identities as they participate and interact repeatedly. Equitable partnership emphasizes that respect for the other's autonomy and identity is as important as one's own. This respect is developed through careful listening, openness to new experience, and collaborative interactions. Cultural schemas are sets of knowledge about appropriate behaviors and roles for specific situations in an individual's culture. They are created through repetitive past experience in cultural situations. While children are engaged in imaginative activities in the triad, they co-construct meaning, understanding, and identity in the activities that are shared uniquely among the children. As they do this, they create new cultural schemas of which they are each an integrated part.

The outcome of the project will be the refinement of communicative tactics and the production of a corpus of representative utterances that any robot can use. In order to produce the robot's mediating utterances, we are testing our draft message designs using a pseudo Wizard of Oz method, in which we run a triad with a human mediator and two groups of children. This testing enables us to refine our design. The process of initial design, test, and refinement will occur iteratively throughout the project span.

5. CONCLUSION

The strategies guiding our designs came from a broad study of theories of learning, child development, and communication and research on educational technology. However, the development of the strategies was also influenced by repeated trials where we presented our designs in progress and the robot itself to young children. In fact, many of our most exciting discoveries about the robot's potential as a language tutor and socially supportive playmate came as we observed children making unexpected choices about when and how to engage with the robot. In this vein, the iterative process of design and test was critically important. Each observation provided the design team with new discoveries and insights and led us to revisit our assumptions and further refine our design.

We hope that a similar approach will work in our current research, and given the technical and pedagogical limitations of the current robot technology, we plan to use an adult mediator to fill the gap between the robot's constraints and desired interaction goals. The observation of the group may lead us to identify where we should go next in the design of robot mediation and even inform us of new solutions. In our first design case, the children's spontaneous behavior sometimes provided insights for the design of creative and appropriate solutions. When our design did not work as intended, we often simply took the robot to the children and watched how they solved problems on their own. Based on these observations, we then tried to design a creative and appropriate solution to accommodate to the child's behavior, while explicitly guiding the child to the learning goals. This type of transactional reflection on child behavior and intended goals may be consistently applied to the design of a socio technical interaction group with a robot and humans. We can observe the human mediator's behavior of a learning activity and then design the robot's mediation so that it elicits a similar quality of interaction and in turn, helps us to reach the overall goal of improving children's learning experiences.

In this paper, we shared our approaches to the design of robot/child interaction. We hope that our design cases will stimulate thoughts and discussions on sustainable robot/child interaction design.

6. ACKNOWLEDGMENTS

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