"If a Robot was Teaching, Then Everybody Would Definitely Like School Better": An Analysis of Grade 3-5 Children's Perceptions of Learning STEM Vocabulary with an Educational Social Robot

Wing-Yue Geoffrey Louie*[1], *IEEE Member*, Tanya Christ*[2],
Amanda Wowra[2], Danielle Alexander[2], Iman Bakhoda[2], Pourya Shahverdi[1]

Abstract— **This qualitative study explored 20 grade 3-5 children's perceptions of learning STEM vocabulary with an educational social robot. A semi-structured interview protocol was used to elicit children's perceptions. Interviews were recorded and transcribed into a database reflecting one talk-turn per row (911 talk-turns total). Two coders used emergent coding and constant comparative method to identify talk-turns that reflected children's perceptions of the assets and drawbacks of learning STEM vocabulary with the robot. Findings identified new assets and drawbacks about the robot's instruction, and new drawbacks about the robot's speech, which were not explored in previous research. Findings suggest design implications, including designing robots with the capacity for more individualization of instruction and adjustable movement and speech features based on learners' preferences.**

I. INTRODUCTION

As robots are burgeoning in children's education, we need to understand children's perceptions about their interactions with robots in order to best inform improvement of their design and effectiveness. Most research focuses on the effectiveness of educational social robots for teaching children [1]. We have only found six studies that explore children's perceptions of educational social robots [2]–[7]. Most of these studies only cited children's perceptions of assets related to working with educational social robots [2]–[5], [7]. Only one previous study cited children's articulation of a drawback related to working with an educational social robot [6]. A better understanding of children's perceptions of educational social robots will guide design decisions for future robots to increase children's engagement with and learning from them.

Given the limited research available on this topic, as part of a broader research project on grade 3-5 children's learning of STEM vocabulary from a robot, we explored how children perceived the educational social robot's assets and drawbacks. Our research question is as follows: What are the assets and drawbacks of a Pepper robot that teaches grade 3-5 children STEM vocabulary?

II. LITERATURE REVIEW

Our analysis of the small body of existing research on students' perceptions about social educational robots yielded four key aspects of robots to which children attended: engagement, movement, speech, and learning from a robot.

Children's perceptions about their **engagement with robots** was reported in four studies [3]–[5], [7]. Kory-Westlund and Breazeal [4] examined early elementary-aged children's perceptions and acceptance of conversations and story-telling sessions with a robot. During interviews and on surveys, children expressed being socially and relationally engaged by the robot, and their acceptance of them increased as they spent more time with them. Using a questionnaire, Lin and colleagues [5] looked into children's perceptions of adding intelligent educational service robots into classroom settings. These 167 fifth-grade students in Northern Taiwan perceived robots as a source of engagement, especially when they had what children determined to be "good appearances" (i.e., smaller in size, cartoon- or animal-like). In a study by Søraa and colleagues [7] involving Norwegian school children aged 6 to 13, surveys and interviews were used to understand their perceptions of different robots. They found the robots entertaining and "cute". Finally, Hwang and Wu [3] conducted a study with 48 sixth-grade students in Taiwan, assessing their perceptions of robots in collaborative learning settings. Through interviews or surveys, children expressed that the robots were engaging and playful.

Regarding children's perceptions of **robots' movements**, 81 children ages 5 to 8 were interviewed after participating in a collaborative task with a tabletop robot [2]. They perceived the robot to be more supportive, friendly, and helpful when it was more expressive (i.e., the robot displayed emotions and behaviors through non-verbal cues such as facial expressions and gestures).

Related to children's perceptions of **robots' speech**, children felt more supported and closer to the robot when it used social verbal content and had variance in its speed and pitch, versus when the robot used only polite sentences with slower and more monotone speech [2].

Three studies revealed children's perceptions in regard to their ability to **learn from a robot** (i.e., children's outcomes after the robot's instruction). As for learning assets, the study by Kory-Westlund and Breazeal [4] showed that robots supported their learning, particularly through the ability to retell stories that they were told from the robot. Similarly, the study conducted by Hwang and Wu [3] also displayed assets when it came to children learning from robots in educational settings (e.g., some youth participants shared

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[1]Intelligent Robotics Laboratory, Oakland University, Michigan, USA (e-mail: louie@oakland.edu)

[2] Department of Teaching and Learning, Oakland University, Michigan, USA

* Co-first authors that contributed equally to this work

their learning interest was enhanced whereas others expressed learning problem-solving skills from robots). Finally, Oranç and Küntay's [6] study utilized photos and questions to explore children's views of social robots as information sources to support learning. The study found that children's willingness to learn from robots varied based on the subject matter as well as their perception of the robot's animacy. For example, children indicated that they preferred robots as a better source of information for questions about machines. However, in contrast, Oranç and Küntay [6] found that children were less inclined to consult with robots for human-related subjects like biology and psychology, indicating a nuanced understanding of robots' limitations as knowledge sources, and posing a potential drawback to using robots to promote learning in these areas.

III. Methodology

This Institutional Review Board approved qualitative study explored the assets and drawbacks of using an educational social robot to teach elementary aged children STEM vocabulary words, as part of a broader study. All children were taught three advanced STEM vocabulary words by a social robot in a one-to-one setting. Afterward, we interviewed each child to learn about their perceptions of the robot's assets and drawbacks related to its teaching and their learning of the words. We used emergent coding and constant comparative methods [8] to identify codes that described these assets and drawbacks.

A. Participants and Setting

Twenty English-language dominant children across grades 3-5 participated in our STEM vocabulary instruction intervention, and the subsequent interview that is the focus of this paper. All children were recruited from a university-based STEM summer camp, and provided assent to participate. Their parents also provided permission. This study took place in a quiet lab, decorated like an elementary classroom.

B. Social Robot and STEM Vocabulary Instruction

The social robot taught each child three STEM target words, one at each level of difficulty (easy, medium, hard). Difficulty of words were determined using the Corpus of Contemporary Contemporary American English (COCA; https://www.english-corpora.org/coca/) Every word had two morphemes, or meaning parts (e.g., "hydro" and "power").

The social robot used a predetermined instructional flow, based on the child's in-the-moment responses (i.e., formative assessment data). The instructional flow always began with presenting the target word on the computer in large colored salient text [9]. The social robot said the following:

> *I'm going to ask you the meaning of a hard word. So, if you don't know its meaning, you can click on the "I don't know button at the bottom". But, if you do know the word's meaning, you can click on the picture that shows the word's meaning. The word is [target word].*

The screen showed four images and an "I don't know" option. The images aligned with three possible levels of student vocabulary knowledge [10]:

- Accurate (this is the correct response),
- Partial (this reflects understanding one of the two morphemes), and
- None (this is an inaccurate or "I don't know" response).

Based on the student's initial response, a contingent support was provided by the robot [11], as follows:

- Accurate - no mediation was provided and the robot continued to the next target word,
- Partial - partial support was provided by the robot verbally explaining the definition for the unfamiliar morpheme and the full word meaning [12], [13]
- None - full support entailed having the robot ask the student to say the word, and write the word, explain the meaning verbally and via illustration for each morpheme, and verbally define the full word meaning [12], [13].

After this mediation for students who had partial or no vocabulary knowledge, the student was asked to identify the correct picture that represented the word meaning again to assess learning. Based on the child's response, a contingent support was provided by the robot:

- Accurate - (see above)
- Partial - (see above)
- None - extended support was provided that included illustrations of examples and non-examples of the vocabulary meaning, verbal explanations related to these examples, and a verbal definition of the full word meaning [14].

After this second mediation for students who had partial or no vocabulary knowledge, the student was asked to identify the correct picture that represented the word meaning again to assess learning. Based on the child's response, a contingent support was provided by the robot:

- Accurate - (see above)
- Partial - (see above)
- None - extended support was provided that included the robot presenting a video that explained the word meaning and a definition of the word meaning [15].

C. Educational Social Robot: Pepper

The Softbank Pepper robot, shown in Figure 1, has been used in a variety of contexts such as education, healthcare, and daily companionship. With a body similar to a human's upper body, this robot stands 120 cm tall and can move with its omnidirectional wheels. To make Pepper communicate effectively through speech and body language, we first divided the script into smaller actions. These actions were then programmed into Choregraphe[1], a block-based programming language. Engineers carefully designed the tone of voice, intonation, and movements. A teacher with 23 years of experience in teaching young children reviewed these actions to ensure they resembled natural human behaviors and were

[1] https://www.aldebaran.com/fr/support/pepper-naoqi-2-9/downloads-softwares

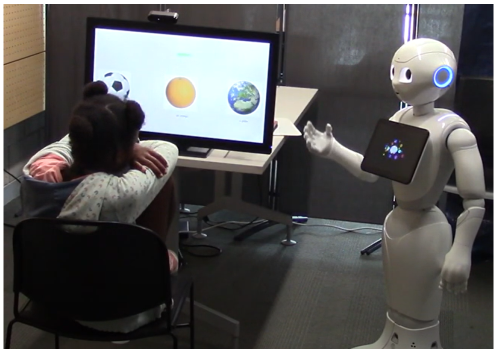

Fig. 1. A participant interacting with Pepper during vocabulary instruction

easy to understand. Two main body language cues were identified: pointing to relevant parts of the screen and turning Pepper's body towards the screen when discussing its contents. These behaviors were linked to touchscreen interactions in a custom application. This allowed Pepper to guide children seamlessly through the educational interaction, synchronizing its actions with the children's selections.

D. Data Collection and Preparation

A semi-structured interview [16] was conducted by a trained research assistant with each child, after being taught the STEM words by the robot. The **interview protocol** included the following questions: (1) What did you think about learning with the robot?, (2) Was there anything that the robot did that helped you learn? (3) Was there anything that you liked about working with the robot? (4) We want to make the robot a better teacher–what do you think would make him a better teacher? When the research assistant was unsure what the child meant, or needed more information, she provided the broad prompt, "Tell me more about that."

All interviews were video-recorded and transcribed for analysis. Transcriptions included gestures and other non-verbal information related to children's responses and were organized into talk-turns denoted by when one speaker's turn ended, and the next began. The dataset included 911 transcribed talk-turns across all interviews. An example of talk-turns is presented in Table I.

TABLE I

A SAMPLE OF TALK-TURNS BETWEEN TEACHER AND CHILD

Teacher	Was there anything that you liked about working with the robot?
Child 101	Yeah.
Teacher	What?
Child 101	[Child moves arms like the robot.]
Teacher	You liked his movements?

E. Data Coding and Analysis

Given that we were trying to identify possible new assets and drawbacks related to students' STEM vocabulary learning, we used open coding and constant comparative methods to allow for systematic, yet flexible, analysis deeply grounded in our data [8].

First, two coders tagged each line of the transcripts that they thought denoted a child's articulation or gesturing related to an asset or drawback of learning with the social robot. For example, Child 101's response would have been tagged as an "asset".

Second, both coders used emergent coding and constant comparative methods [8] to identify codes that described assets and drawbacks. They also used themes from the literature review, when relevant, to help identify codes (see Table II, column 4). About 30% of the dataset was used for code development. Codes are presented in Table II, column 2.

Third, both coders separately coded all of the dataset using the codes in Table II. When a child expressed the same idea across multiple lines of talk, the code was only used once to represent the idea. Thus, codes each represented a discrete idea expressed by a child. There were 110 discrete ideas expressed by children about the robot's assets or drawbacks across the dataset.

Inter-coder agreement was 81%, which is considered acceptable in qualitative research [17]. Coding disagreements were discussed to achieve consensus, and then final codes that reflected consensus were used to calculate summary statistics for each code within each category (i.e., assets or drawbacks).

IV. RESULTS

Across the dataset, we coded 110 discrete ideas expressed by students that were related to the robot's assets or drawbacks. Of these, 79 (or 72%) focused on the robot's assets. We identified six categories of assets that students mentioned: engagement, movement, instruction, speech, novelty, and learning. Additionally, there were 31 discrete ideas expressed by students (or 28%) related to the robot's drawbacks. We identified four categories of drawbacks that the students' expressed: engagement, movement, instruction, and speech.

Among children's responses, 20% of all coded assets were related to their **engagement** with the robot. Children expressed how the robot engaged them in different ways. For example, one child shared that "it always paid attention to me." Another child shared that they "liked how friendly the robot was." Several children mentioned that the robot was "fun." For example, one child said, "Learning with the robot was really fun." Other children thought the robot was "funny." A couple of children thought the robot was "interesting." For example, one child compared the robot to a human teacher, stating that "the robot is much more interesting to me." Finally, a child concluded that "if a robot was teaching, then everybody would definitely like school better." Engagement was the third most frequent asset category that children mentioned.

Additionally, about one in four (22.5%) of the children's coded drawbacks were related to their engagement with the robot. A few students shared that the robot was "scary," "creepy," or "weird." For example, one child stated, "The robot was a little creepy." Another child shared the following:

TABLE II
CODES DERIVED FROM THE DATA ANALYSIS

Category	Codes	Example Quotes	Research with Related Codes
Assets	**Engagement**	”funny”, ”fun”, ”likes robots”, ”kind of nice”	Hwang and Wu, 2014; Kory-Westlund and Breazeal, 2019; Lin et al., 2009; Søraa et al., 2021
	Learning	”learned the meaning of the words”	Escobar-Planas, 2022; Kory-Westlund & Breazeal, 2019
	Novelty	”extraordinary”, ”I’ve never seen a robot before”	none
	Movement	”participated”, ”danced along”, ”paid attention”, ”gestured with hands”	Escobar-Planas, 2022;
	Instruction	”shows video”, ”tells definition”, ”pointed to things”, ”explains things”	none
	Speech	”the way it talked”, ”like talking to a normal person”, ”talking slowly”	Escobar-Planas, 2022;
Drawbacks	**Movement**	”kept on looking on me”	none
	Speech	”voice too high”	none
	Engagement/ Comfort	”creepy”, ”scared me”	none
	Instruction	”could give me paper”	none

> *”I’ve never been that close to a robot, so it’s a little scary, but not that scary like this much. [Child put fingers about an inch apart to show how scared they were]. Just tell the robot I’m not trying to hurt its feelings.”*

In addition, another child shared, “It felt a little weird learning from a robot.” Lastly, a child shared that “the robot was kind of unsettling.” Engagement was the second lowest frequency of drawbacks that children expressed.

Of the coded assets that the children shared, 24% were related to **movement**. A few of the students shared about the robot’s body movements. For example, one student said, “I also liked how it swayed its hands like this [student got up from the seat and demonstrated the hand motion] when it was not moving, it was just swayed its hands.” Another student shared, “It could like move. Like it’s, not only its hands, but it could like turn.” Another child said, “It could go sideways and it could also move its fingers. That was really cool.” Other movement-related responses were specific to the robot looking at the children. One student shared, “It was cool how it always looked at me and always paid attention to me.” Lastly, a few students commented on the robot’s ability to listen and gesture. One example was, “It listens like yes or no. Like and like, uh, it would like point and like just like kind of gestures. Like hand gestures. You know?” When another student was asked about what they liked about the robot, they responded, “...[the] hand gesture. It looks at me. It listens for my answer and stuff.” Movement was the second most frequent category of asset that children mentioned.

However, notably, the majority (39%) of the drawbacks identified by the children were related to the robot’s movement. Children noted the lack of fluid movement, For example, one student said, ”Maybe it should be like more like the human like more like [student moves his arms to show a fluid movement]...instead of being like one arm movement another arm movement.” Further, there were a few responses related to the robot’s movement being slow, facing the incorrect direction, and the fact that it repeated certain moves. For example, a student stated, “like if she’s going to like point at the screen like two times. Like maybe not like just like point at the screen and then turn back and then do it again.” Lastly, a student shared their confusion “It’s just that I didn’t know how come it was facing Miss [camp counselor’s name]. I was just confused about that.” Other drawback-related responses were about the robot looking at them and how that made them feel. For example, a student shared, ”So like when when we were like when I was like stretching and when I was done when the quiz came up and then the robot came, it was just not cool because then it kept facing me when I was trying to think which one it is”. A few other students noted that “it was kind of freaky because it kept on looking at me” or that an improvement in the robot would be “If it didn’t keep on looking at me.” Of all the drawbacks that children shared, movement was the most frequently mentioned.

Out of all of the children’s responses concerning the robot’s assets, 29% were related to the **robot’s instruction**. The children shared several positives about the robot’s instruction. One child said that they liked how the robot helped them learn by showing videos and asking “Do you need help?” when they were “stuck.” Another child said that they found it helpful when they would get something wrong, and the robot would help them “understand it.” Similar to this, a third child thought it was beneficial that when they did not know the answer, they were able to “press the ‘try again’ button” to see “what it means.” Several children commented that they specifically liked the robot’s explanations. For example, one child said, “It was like he was trying to explain it good, for I could like understand it more, [and] then I got it.” Likewise, another student stated that they liked how it is “a robot that actually teaches you stuff.” A couple children stated that they liked the speed in which the robot instructed. For example, one child shared that they liked how the robot “went slowly with some stuff." Out of all the categories, instruction was the most frequent asset that children mentioned.

Additionally, 16% of the children's responses concerning the robot's drawbacks were related to its instruction. The children shared several ideas on how they think the robot's instruction could improve. A couple of children stated that a drawback to the robot's instruction was how different the robot is compared to a human. One student said, "I thought it was a little, like, weird and different than learning from [a] person because it, like, was only programmed [to] do that stuff, so it didn't really change the words [and] was really direct." The same student expanded, adding that they felt the robot's instruction made it "pretty hard" to learn "cause it wouldn't give you any other details [and] was just straight to the point." Similarly, another child stated that the robot "could [not] give you, like, a paper and tell you to fill it out" like a human teacher could. Of all the drawbacks that children shared, instruction had the lowest frequency.

Five percent of all coded assets encompassed the robot's **speech**. A couple children expressed that they liked that the robot had the capability of talking. For example, when one child was asked about what they thought was "cool" about the robot, they replied, "That it can talk." Another couple of children discussed liking the way the robot talked. One, for example, stated that they liked how the robot was "talking slow enough" for them. Speech was the fifth most frequent category of asset that children mentioned.

Twenty-two and one-half percent of the children's responses concerning the robot's drawbacks were related to the robot's speech. Several children discussed the robot's volume. One child commented that the speech could have been "a little louder" since they did not "hear very properly." However, two other children commented that "the volume was a little high" and to "turn that volume down." A couple others honed in on the robot's cadence. For example, one child mentioned that they heard the robot "skipping some of the sound," suggesting that there should be improvements on "how it speaks" in order to make sure that it "doesn't skip parts of words." Finally, the robot's voice was also described by one child as "a bit scary." Speech was the second lowest frequency of drawbacks that children expressed.

Nineteen percent of all coded assets included children's commentary about the **novelty** of the robot. A couple students discussed that the robot was appealing to them since they have never learned from a robot before. One student said that they use computers every single day at school, but that the robot was "10 times more interesting" because their school does not have them. Similarly, another student remarked that learning with a robot is not something "you do in your everyday life" because students usually only have the opportunity to learn "from [your] teacher, somebody who instructs your after school activities," or "your parents." Several children also said that they liked that the robot was not real. For example, one child positively described their experience with the robot as a "[non]-human's presence." Another child explained that they enjoyed not "talking to like a real person" but rather "talking to like an AI." A third child stated, "Like, it wasn't a person. And more fun right there." One child even commented on the robots' novel looks in comparison to a human, stating that the robot "has eyes and it's like hands are like made of kind of rubber and it has an iPad attached to it". Also, the same student added that the robot has "a bunch of circles, probably reading what you're saying and it's metal and it's not human." Novelty was the fourth most frequent category of asset that children mentioned. Students did not identify any drawbacks related to the robot's novelty.

Out of all of the coded assets, 3% related to **learning from the robot**. One child said they preferred learning from the robot versus a computer since they "learned better" and "didn't forget so much." Another child mentioned that they were happy to learn "the meaning[s] of all those three words." Learning was the sixth most frequent category of asset that children mentioned. Students did not identify any drawbacks related to learning with the robot.

V. Discussion

Our findings extend previous interview and survey studies [2]–[7] by identifying three new kinds of assets and drawbacks that children mentioned about their interactions with educational social robots, which have design implications.

First, we identified assets and drawbacks about the robot's instruction. In previous research, children's learning had been discussed [3], [4], [6], but assets and drawbacks about the robot's instruction had not been articulated. Understanding children's perspectives about our robot's instruction informs future design principles for educational social robots. For example, based on children's feedback, we should design robots that are able to incorporate the following into their instruction: showing videos, helping when children are stuck, providing multiple opportunities for children to master learning, and providing adaptive instruction (e.g., examples and directions that vary). Further, our nuanced findings about children's preferences for how the robot provided instruction, such as some children enjoying the robot's ability to provide explanations and show videos but others wishing the robot could teach vocabulary words differently, suggest that it may be beneficial to design robots with the capacity for more individualization of instructional based on learners' preferences for content delivery. This should be a focus on future educational social robot design.

Second, we identified drawbacks related to the robot's speech. Although research had identified robots' speech as an asset in one previous study [2], drawbacks related to robots' speech had not been mentioned by children in previous research [3]–[7]. Therefore, our findings extend previous research to reveal how the children perceived our robot's speech. This is useful to inform the future design of educational social robot's speech capacities. For example, our findings suggest that robots' speech should be designed to talk at an adjustable speed and volume, as indicated by the particular child who is interacting with it. Further, the robot's cadence should be improved to make it more like human speech. This latter implication also aligns with the findings of Escobar and colleagues [2].

Third, we identified a new drawback to children's engagement with social robots. Some children in our study mentioned that they found the robot to be "scary," "creepy," or "weird". In contrast, children in previous research did not mention these kinds of responses [2]–[7]. This may be due to the fact that children in our study had only one 20-minute interaction with the robot, compared with children in another study that had multiple interactions with the robot across time [4]. Or, it could be the visual difference between the size and visual characteristics of our Pepper robot as compared with robots in other studies, such as the small desktop size Tega robot with fur and hair, somewhat resembling an exotic pet, used in Kory and colleagues' study [4]. Previously, Lin and colleagues [5] found that small and animal-like robots were considered more engaging by children. Future research might further explore how educational social robot size and visual characteristics impact children's engagement with them.

Additionally, although the categories of movement and learning have been mentioned in previous research [2]–[6], our findings revealed new perspectives about robots' movements and children's learning. For example, previous research included that robots' gestures were helpful in general, but our study extended this by identifying specific aspects of gestures that were helpful or not helpful to learning. General gesticulation, such as non-pointing arm movements while talking, some children found confusing. Thus, future robot design should carefully consider the pedagogical intentions behind the robot's movements, and ensure that they are meaningful and not just for the sake of making the robot move. Further, based on our nuanced findings about the differences in children's preferences for movement, such as some children appreciating the robot's direct gaze and others feeling uncomfortable about it, we suggest designing robots with more adjustable movement features to better align with individual students' interactive preferences.

Finally, our research provided further support for some previous findings, as well. For example, similar to previous research [2], [4], we found that children felt the robot facilitated their learning (e.g., when they would get something wrong, the robot would help them better understand it), was engaging (e.g., they liked how "friendly" and "fun" the robot was), and was comparable to humans (e.g., they liked how, like humans, the robot would make eye contact).

While our study offers new contributions to the assets and drawbacks of an educational social robot teaching students, it is also limited in scope. We had a small sample and focused just on students' learning of STEM vocabulary from a Pepper robot. Future research is needed with broader participant samples and scopes.

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