Inclusive AI literacy for kids around the world*

†

Stefania Druga
MIT Media Lab
Cambridge, MA
sdruga@mit.edu

Sarah T.Vu
MIT
Cambridge, MA
sarahvu@mit.edu

Eesh Likhith
MIT
Cambridge, MA
likhith@mit.edu

Tammy Qiu
Boston University
Boston, MA
tqiu@bu.edu

ABSTRACT

We observed how 102 children (7-12 years old), from four different countries (U.S.A, Germany, Denmark, and Sweden), imagine smart devices and toys of the future and how they perceive current AI technologies. Children outside of U.S.A were overall more critical of these technologies and less exposed to them. The way children collaborated and communicated while describing their AI perception and expectations were influenced both by their social-economical and cultural background. Children in low and medium SES schools and centers were better are collaborating compared to high SES children, but had a harder time advancing because they had less experience with coding and interacting with these technologies. Children in high SES schools and centers had troubles collaborating initially but displayed a stronger understanding of AI concepts. Based on our initial findings we propose a series of guidelines for designing future hands-on learning activities with smart toys and AI devices for K8 students.

CCS CONCEPTS

• Social and professional topics → Computer science education; **• Computing methodologies → Intelligent agents**; **• Applied computing → Interactive learning environments**; **• Human-centered computing →** *User studies.*

KEYWORDS

AI literacy, Child-Agent Interaction, Inclusive education

ACM Reference Format:
Stefania Druga, Sarah T.Vu, Eesh Likhith, and Tammy Qiu. 2019. Inclusive AI literacy for kids around the world: . In *Proceedings of ACM Fablearn conference (Fablearn'19).* ACM, New York, NY, USA, Article 4, 8 pages. https://doi.org/10.475/123_4

*Produces the permission block, and copyright information
†The full version of the author's guide is available as `acmart.pdf` document

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the owner/author(s).
Fablearn'19, March 2019, New York City, NY USA
© 2019 Copyright held by the owner/author(s).
ACM ISBN 123-4567-24-567/08/06.
DOI: 10.1145/3311890.3311904

1 INTRODUCTION

Today, more than 47.5 million households in the U.S.A are using a smart home assistant, and an entire generation of children are growing up with AI. However, these technologies have not yet been widely adopted in other parts of the world and by families with lower social-economical status(SES). In this context, we aim to advance research on children's conceptualization and interaction with smart toys [2, 8, 23] in various social,economical and cultural settings. We pose the following research questions:

- How do children from different countries perceive and interact with AI?
- How is children's SES impacting their AI literacy?
- How can we design inclusive learning activities for K8 AI literacy?

Our research builds on prior studies of children interaction with smart toys, and the theory of constructionism [1]. We discuss developmental differences among ages and conclude with a series of recommendations for curriculum and smart toys designers.

2 RELATED WORK

In the following, we explore through ontological, psychological and developmental lenses children's mental models of intelligence and cybernetic intuitions of animacy, agency, and causality for smart toys. We contextualize these prior psychological findings in children's relationship to AI technology in different cultural and socio-economical contexts.

2.1 "Playthings that do things" as objects to think with

Previous research about children's interaction with computers explored the social role of intelligent toys in shaping and influencing the way young people learn. In her book "Second Self", Sherry Turkle describes these devices as relational artifacts that allow children to explore "matter, life, and mind"[23]. Similar to computers, current emerging autonomous technologies are inviting children to "think about thinking" [16]. Later on, Edith Ackermann also explored children's cybernetic intuitions when interacting with computational objects, which she described as "playthings that do things" [3, 23].

This prior work has shown that children do not distinguish between causation and agency in the same ways most adults do.

Instead, children, older than 5 years old, place these entities along an animate-inanimate spectrum due to their varying anthropomorphic characteristics [13, 21]. Their sense-making transitions from an initial observation of physical characteristics of a device to an understanding based on definitions. Their understanding based on observed characteristics, e.g., a robot, as an object "with wheels and sensors", is typically subjective, where the understanding based on definitions, e.g., the description of a robot as a programmable object, has a more universally applicable character [11, 20].

Similar to the smart toys and games (Speak-and-Spell, Merlin Chess, Lil Ducky Doo, etc) used by Turkle and Ackermann in their studies, the embodied intelligent agents of today like Alexa smart speaker, or Cozmo and Jibo social robots, represent marginal objects. They are placed between an object and a psychological entity, which incites children to form new theories about their nature, and wonder how the distinctions were drawn in the the first place. Today, these new devices are widely present in children's homes, and have many more complex features. This calls for new research to explore not only how children interact with these devices and perceive them, but also how they can develop a meaningful relationship with them over time. Together with my colleagues, we started to explore these new child-agent interactions and we observed that children do not always have the means to probe these computational objects through play [8, 9].

2.2 From programmable to teachable machines

The idea of a feedback loop is the core concept being introduced when children are interacting with embodied intelligent agents. Instead of just sending a series of commands to the agent, the youngsters also start to reflect on how the agent might represent the world, perceive the information it receives and thus modifies its behavior. Programming in this context calls for a scaffolded way for children to probe, and gradually understand the emergent machine's behavior.

Mioduser et al. explored how children could understand emergent machines by gradually modifying their environment [15]. They discovered that children are capable of developing an emergent schema when they can physically test and debug their assumptions, by modifying the environment where robots perform a task. They also showed that the number of rules and new behaviours should be gradually introduced in the coding activity.

The democratization of current AI technologies allows children to communicate with machines not only via code but also via natural language and computer vision technologies. This makes it easier for a child to control and even "program" an agent via voice, but it makes it harder for a child to debug when the machine doesn't behave the way he expects. A core challenge becomes then to make the agent reasoning more transparent, and allow the child to understand how the machine perceives and models the world [10]. In this context, we see an opportunity to design more physical tinkering and learning activities that use the smart toys and agents that are becoming embedded in children's homes. Such activities would enable children to develop an AI literacy so much needed as they are growing up with these technologies.

Location	Participants	SES	Nationality
Redi School Berlin Germany	10 participants 5 girls, 5 boys 1 younger 9 older	Low & Medium	German Italian Sirian
International school Billund Denmark	21 participants 7 girls, 14 boys 19 younger 2 older	Medium & High	Danish British Mexico India
STEAM center Skelleftea Sweden	15 participants 2 girls, 13 boys 8 younger 7 older	Medium & High	Swedish Korean Romanian
East Somerville School USA	27 participants 9 girls, 14 boys 16 younger 11 older	Low & Medium	Latino American Indian
EPH Center Cambridge USA	15 participants 5 girls, 10 boys 9 younger 6 older	Low	African - American Indian Rusian
Shady Hill School Cambridge USA	16 participants 6 girls, 10 boys 10 younger 6 older	High	American

Table 1: Summary of demographics for the study participants in the different locations (younger = 7-9 years old, older = 10-12 years old)

3 STUDY METHODS

The workshops in all the study locations consisted of one session which lasted 1.5h - 2h. During the session, children were asked to draw and imagine the future of AI agents. After, they were introduced to different AI agents (Alexa home assistant, Jibo and Cozmo robots). First, they would play and talk to the agents, and after they would also get to program them with their dedicated commercial coding applications. At the end of the session, we would ask them questions about how smart, friendly, truthful they thought the agents are.

The study workshops took place in the following locations: Redi School, an NGO based in Berlin, Germany; Billund International School, an affluent private school, based in Billund, Denmark; STEAM Center Skelleftea, a public community science center, Sweden; East Somerville Community School(ECSC), a Spanish-English bilingual a public school with mostly children of modest immigrant families, U.S.A; Elisabeth Peabody House Center(EPH), a non-profit community the center housed in a former church Massachusetts, U.S.A; Shady Hill School, a private school for children from higher SES families, U.S.A.

3.1 Selection and Participation of Children

We recruited 102 participants through announcements to local parent groups, mailing lists, and social media posts. Children ranged from 7-12 years old. We grouped participants per age as following:

younger for 7 to 9 years old, older for 10-12 years old). Further information about the gender and age of participants are detailed in the table above. Before beginning the study, parents and participants over the age of 7 signed assent forms. The quoted names of the study participants have been modified.

3.2 Agents used in the study

During the workshop, we introduced children to three different embodied intelligent agents: Jibo robot, Anki's Cozmo robot and Amazon's Alexa, home assistant. We placed each agent on a separate table, and encouraged participants to form groups and take turns in interacting with each agent. First, we demonstrated the vocal commands for activating each agent and some of its capabilities (e.g., "Hey Jibo" or "Alexa"). We then allowed children to explore on their own, using both voice and existing interactive applications. When the participants were stuck, we would demonstrate new features or ask questions to help them debug.

After the initial play and interaction, we encouraged kids to program the agents using their dedicated coding apps. All the coding apps deployed in the study used a visual block programming language based on Scratch Open Source Blocks and were comparable in terms of design and complexity.

Figure 1: Agents used in the study: Jibo robot, Anki's Cozmo robot and Amazon's Alexa Echo spot

3.3 AI perception questionnaire

After interacting with the agents, participants completed a ten question survey about their experience in the form of a monster game (see Figure 2).

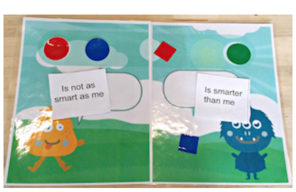

Figure 2: AI Perception Monster Game

The monster game was adapted from the work of Park to more effectively engage younger children in the questionnaire [17]. The two monsters each represented a belief about the agent. The children were asked to place a sticker closer to the monster with which they most agreed. Before asking the questions, we gave an example of how to respond. The usability of this method and the clarity of the questions was vetted by pre-testing it. Responses to each question were recorded as orange, blue, or neutral. The questions queried how children felt about the agent in terms of trust, intelligence, identity attribution, personality, and engagement. We adapted the questions from the work of Bartneck based on the agents' attributes we wanted the participants to explore [6]. We discuss in detail the results for the perception-related questions in the quantitative section of this paper.

4 FINDINGS

How do children imagine AI in the future, how is their cultural and social-economical context influencing their perception of smart technologies, what role do parents and technology access play? In the following section we analyze how children interacted with the AI agents in the different locations discussing their arguments and answers to the perception questionnaire. All the children's names quoted in this study have been modified for protecting their identity.

5 INTERACTION WITH AGENTS AND INTERNATIONAL AI PERCEPTION

Figure 3: Children interacting with the agents during the study in Denmark, Sweden

5.1 Redi School Berlin

The participants in Berlin school were of mixed ages, ethnicities and had varied prior experience with coding. They were good at collaborating, both for sharing the equipment and for helping each other with programming. They had heard about Alexa before, but never interacted with one. They never heard about Jibo and Cozmo and were excited to play with them. Overall, children were much more skeptical of the AI technologies, but enjoyed interacting with the devices and described them as friendly.

When asked if the agents have feelings, students answered with a categorical "no" for Alexa. They said the robots have feelings, but explained:"Cozmo has feelings because the people that made Cozmo programmed a lot of emotions", said Yael, 8 years old. Saveeta, an 11 years old girl added: "Cozmo has feelings because of animations that reflect each feeling".

When explaining how the agents understood them, participants always referred to coding. If a device would not run their program as they expect it, they would say it didn't understand them: "Jibo doesn't understand because I coded a program for Jibo to repeat 5 times, but the program didn't repeat properly", said Saveeta.

The older children said Alexa was smarter than they are, but not the robots. They also thought Alexa didn't understand them. Many of them changed their opinion when they saw the device can speak German.

Selma (8 years old) argued that people are smarter, because they are independent and have brains: "So we might say smarter means you concentrate more on your brain, so they don't have any brains so we might be smarter". She later added that in the future people will make robots with brains but they will be "laser brains".

5.2 Billund International School

The participants in the Billund International School were 7 and 8 years old. They were fluent with coding and new technologies, but they had never used the agents before. In general, they would dispute a lot when having to take turns interacting with the agents, and didn't like to share the study equipment (tablets, robots etc).

During the interaction with the agents, children were good at making logic associations when trying to figure out what questions the devices might know how to answer:

- "Hey Jibo what is the color of the stars?", asked Bella, 8 years old (the robot didn't know how to answer)
- "I think I know how to ask it.. Hey Jibo who is Louis Armstrong?", asked another 7 years old boy while trying to figure out what space related people Jibo might know.

They described the devices as friendly and caring, but when a 7 years old girl, Cami, said the devices "don't know us that well", the rest of the children in her group changed their minds about the caring part.

Children explained that devices that listen to them, such as Alexa and Jibo, understand them and these agents can "kind of remember them" because they took pictures of them. They were vehement when it came to the feelings question and said: "a robot can't really have feelings, he can only act like it" (they called Alexa a robot also).

When it came to the intelligence attribution question, students said Cozmo is not smart because it "cannot talk or do math". Jibo was in the middle as "he knows a little more because he is bigger" said Cami, 7 years old.

When some of the girls discovered Cozmo had a camera, which is small and not apparent at first, they changed their opinion about the robot nature:

- "It's a great spy cam. People think he's so innocent, but he's actually evil", said Bella, 8 years old
- "Cozmo is innocent, but in real life he's evil", added another 7 years old girl nearly screaming

Not all the participants got to program Alexa, but the ones who did said "she likes and cares about us more now".

5.3 STEAM Center Skelleftea

Just like in Berlin, the children at the STEAM center in Sweden were of mixed ages, ethnicities, and had varied prior experience with coding. Overall, the children were good at collaborating and sharing the equipment. The older children were quite advanced with programming, and managed to build more complex programs for the agents. All the participants and would pair well when using the computers. None of them had encountered or used the agents before, but some of them had heard of Alexa. The younger participants would only speak little English, but the local mentors and older children would help them translate.

The younger children would mainly ask the devices to play music or open games, and they enjoyed teleoperating Cozmo and programming it. These children would also program together multiple Cozmo robots, and make them build a structure together by using their cubes.

When asked if Alexa is smarter than she is, one of the older girls replied: "I don't hope so" and another older boy added "She is not smart because she didn't know the capital of Sweden, she is only American, not Swedish". Most of the older children concluded Alexa is only smarter than they are in some situations, "50/50" smarter as one child described it. They also wanted to teach Alexa their names and program it. Older participants described Cozmo as intelligent, because he can "react to things", but said it is not smarter than they are.

5.4 East Somerville Community School

Many of the students here were fascinated by Cozmo's expressions and moves, they were also drawn by the natural voice interface of Alexa and Jibo. Once they figured out how to talk to them (e.g. using the wake-up word) they would group around the devices and talk on top of each other trying to get the devices to play specific songs (the most common request), answer math questions, beat-box or speak other languages. Often they would also ask the devices questions about the companies that created them or about the other agents (e.g. "Alexa what do you think of Google Voice?"). To the children, the most fun feature for Alexa was to beat-box, play music and take pictures, and for Jibo, play games ("Circuit saver" game) and take pictures.

The kids were reassured by the fact that some devices could not move as they were quite intimidated by the amount of information they believe the devices hold.

Most of the children who participated in the study, both younger and older ones, had heard about AI and smart robots before, either from popular culture(movies) or from the news (many children knew about Alexa and Sophia the robot from the news). Some of the study participants said they had friends who have an Alexa at home but none of them have experienced interacting with these devices first-hand before.

Overall, they were excited to discover how these "smart" devices work, what they can do, how they can be controlled. Interacting with the devices in groups was helpful for their learning as the children would scaffold and build on each others' questions or actions. They would also debate and discuss more how an agent might respond or behave in a specific way. It is worth noting that learning through peer-interaction was particularly important as most of these students were initially fairly apprehensive of outsiders, especially if the outsiders were perceived as belonging to a different SES group. They also described the agents as technologies for "rich people" and most of the younger participants were extremely disappointed that they could not take the robots home.

5.5 Shady Hill Private School

Most of the participants had seen the agents before or had some of them at home. They were fluent in the interaction and wanted to jump into programming in the first session. In the beginning, children didn't want to collaborate as much and were especially debated over who should control the robots.

When interacting with Alexa, children often built on each other's questions and spent a long time showing each other tips and tricks in interacting with the device (e.g., making it beatbox, sing a song, tell jokes or riddles).

Some of the children tried to get Jibo to answer the same questions and were comparing the answers. They also asked the agents about other agents and try to be mischievous in the interaction. Chad, 10 years old asked: "Alexa, do you have a crush on Google?" After he saw the answer was not amusing enough, he decided to program Alexa with the Cognimates extension: "I'm trying to figure out how to make it say 'I am potato', or, or, I want to say 'Are you a potato?' then it will say 'yes'".

During the perception questions, all the children described the agents as friendly and said that the agents like and care about them. They expressed mixed opinions on whether each agent is smarter than them, or if they will tell the truth. The robots were described as more truthful overall, and children justified that choice by saying "robots are supposed to be programmed to tell the truth".

The children asked Alexa and Jibo complicated Math questions to test their smarts. The participants who said the agents are not smarter than them justified it by saying that the agent cannot move and still needs a person to help it move (in the case of Alexa and Jibo): "Not smarter, not smarter. He can't even move an inch without a human helping", Nick, 8 years old. One 7 year old girl said that the agents are as smart as the people who programmed them: " I think it's smarter, but a person created it – so it's as smart as the person but programmed to be smarter".

Children often reference their use of the agents at home (especially in the case of Alexa) when describing how they feel about it, why they think the device understands them (or not), or if it will remember them (or not). All of the children who saw that Cozmo and Jibo can take pictures of them said that the robots will remember them. The majority of children said Alexa, in return, will not remember them. Jibo and Cozmo were described both as animals or something in between a pet and a person. All children described Alexa as a person because it can talk "like humans do".

5.6 Elisabeth Peabody Community Center

In the beginning, the children in this center were playful with their questions posed to the agents ("Alexa is the tooth fairy real? Alexa is the Easter bunny real?"). When being asked if Alexa was smarter than they were, one younger boy responded "no" because "Alexa doesn't know everything, she doesn't know how I am feeling". He then proceeded to ask Alexa how he was feeling and confirmed the fact that Alexa did not know the answer. The rest of the children said Alexa was smart because of her having access to so much information. The younger children said the robotic agents might be smarter than they are, while the older children thought the opposite. Overall, the children described Cozmo as the agent that understood them the most, but also admitted that he doesn't always understand them either:"hmm I don't know... sometimes he does and sometimes he doesn't," said the 8-year-old Shanise.

Sometimes certain children would defend the agents in front of other children:

- "She does not have feelings", Alex, 7 years old (talking about Alexa)
- "What? How can you think she doesn't have feelings. If you say that to her she would probably say 'oh my god how could you think that'", Shanise, 8 years old.

In the post perception survey, the children still described the agents as smarter than they are, but justified their answers differently: "she is smart because she was programmed to be smart," according to the 11-year-old Jordan; while another younger girl (Sarah, 8 years old) said "not too smart because they are programmed but they can be programmed to be smarter than me." Some of them started saying that the Cozmo is smarter because it knows "division and times" (something they discovered while programming it). Many would probe the agents with math questions before deciding how smart the agents are.

Those who discovered that the agents could take pictures of them or say their name said the agents will remember them: "that's easy because you just put your name into him and he remembers you," according to the 9-year-old Andres.

The older children described the robots to be more like animals, while the younger ones saw the robots as somewhere in the middle, between an animal and a person: "Animal and person I think. I like both. I think both because he knows what you're saying", said Hannah, 7 years old, while talking about Cozmo.

6 QUANTITATIVE ANALYSIS OF AI PERCEPTION DIFFERENCES

To compare the perception questionnaire answers between the different locations, we compared the proportions for each of the answers, using the "N-1" Chi-squared test as recommended by Campbell and Richardson [7, 19]. The confidence interval was calculated according to the recommended method given by Altman et al [5].

6.1 Intelligence attribution

When answering if the agents are smarter than they are, children in Berlin were the most skeptical. They had significantly less "yes" answers than children in Sweden ($p = 0.0437$), Denmark ($p = 0.03816$) and EPH Center in U.S.A. ($p = 0.015$). The "yes" answers for the intelligence attribution were comparable between Berlin, Shady Hill Private school, and ECSC Public school. Berlin recorded the highest number of "maybe" answers to the same question, significantly different than the children in Sweden ($p = 0.0139$)(see Fig.4).

6.2 Truthfulness attribution

Swedish children were the most skeptical when answering if the agents are truthful, with less than 1% answering "yes". The "yes" answers for the truthfulness question, were significantly different between the Swedish and the U.S.A children($p = 0.0007$ - Shady Hills school, $p = 0.0003$ - EPH center). The answers in Sweden were also significantly different when compared with the school in Berlin ($p = 0.0028$). When analyzing the "maybe" answers to the same question significant differences were recorded between

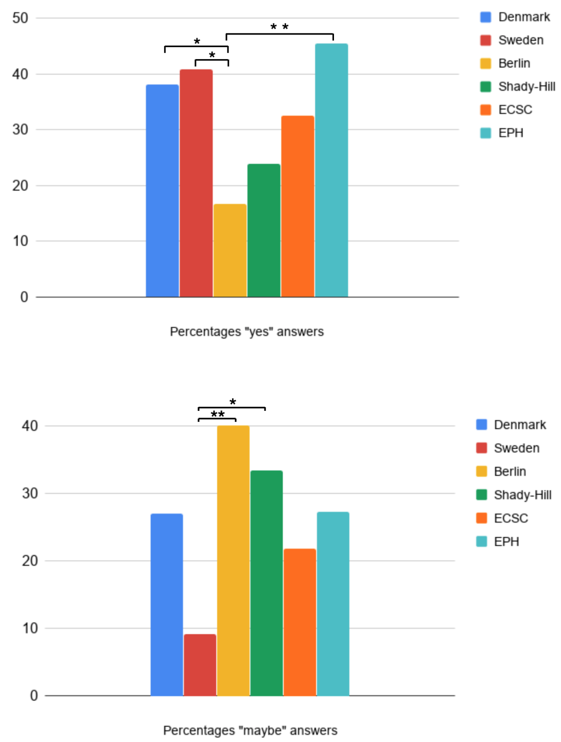

Figure 4: Comparison of "yes" and "maybe" answers to intelligence attribution question across all the locations, * p<0.05, ** p<0.01

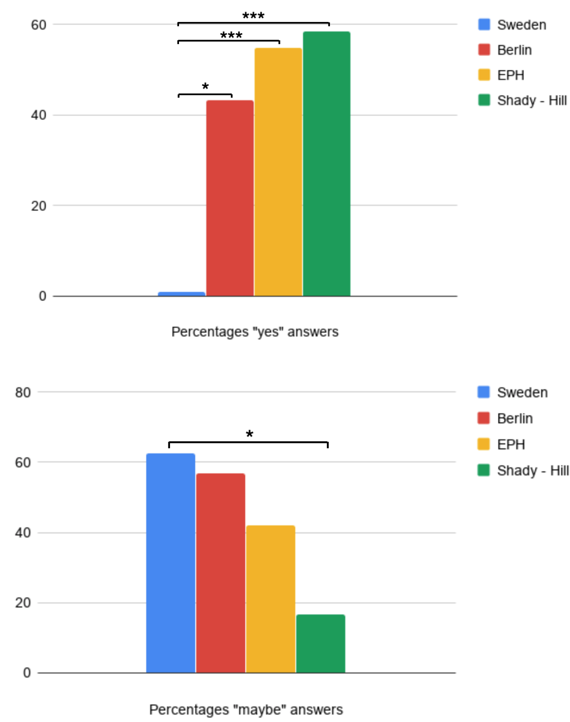

Figure 5: Comparison of "yes" and "maybe" answers to truthfulness attribution question across all the locations, * p<0.05, ** p<0.01, *** p<0.001

Sweden and Shady-Hill school, with more "maybe" answers in the Swedish school ($p = 0.0172$). See Fig.5.

6.3 Perceived understanding

Children in Sweden were the ones that reported the agents understand them the most(68% "yes" answers) and EPH center children were the ones that said they were understood the least (40% "yes" answers). Shady-Hill students had the highest number of "maybe" answers. Their answers were significantly higher, when compared to Swedish children($p = 0.0151$).See Fig.6.

7 DISCUSSION

It has been clearly recognized in children development research that learning doesn't happen in the void. Besides the immediate intrinsic and extrinsic factors that influence the way children learn, there is also a socio-cultural dimension that is important. Cognitive and human development, according to Vygotsky, is a result of a "dynamic" interaction between the individual and the society. This dynamic relationship denotes a relationship of mutuality between the two. Just as society has an impact on the individual, the individual also has an impact on society. In this context the social and cultural settings where the children's activities take place require social interaction and communication. Children learn best through social interactions, and these interactions are defined by the culture and the social-economical environment they grow up in [12, 14]. This approach to situated learning motivated us to explore and compare how children interact, and perceive computational objects in different geographies and SES communities.

Our findings show that children in Europe were overall more skeptical of the agent's smarts and truthfulness. When it came to describe how much the agent understands them their answers would be similar but the justifications were diverse, with children in Europe associating understanding more with coding and kids in U.S.A referring more to the voice conversations. I believe this difference in their explanations is due mainly to a more limited representation of voice technologies in the international countries.

The international children would be more skeptical of the agent's intelligence and truthfulness at first, because they didn't know what the devices can do, or because they heard critical conversations about AI technology at home or in the news. However, when they got to interact with the agents, some of them would get enchanted, but they would maintained their stance that these technologies should be kept at a safe distance(not program them to make people happy) even if they are fun to engage with.

The younger children in all locations would not dissociate programmability from the agent ability to have it's own identity and agency. For example, the 7 years old students in Denmark, thought Alexa cares more about them because they are programming it. Meanwhile, the younger children at ECSC school, assumed Cozmo

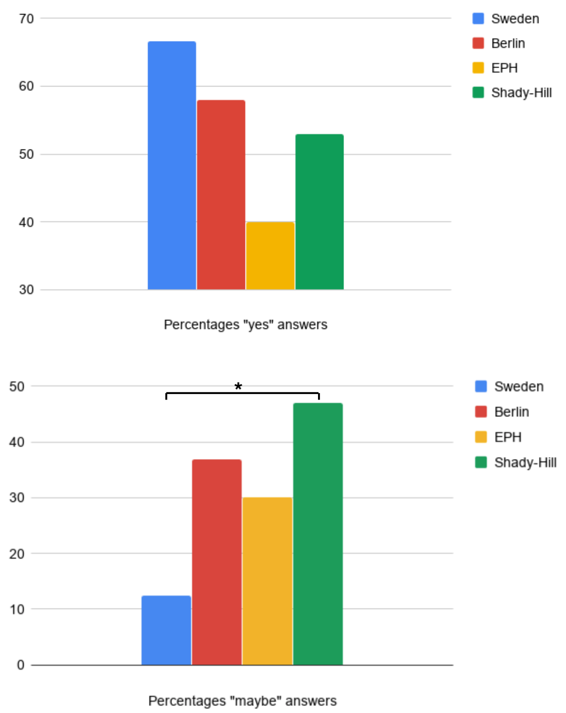

Figure 6: Comparison of "yes" and "maybe" answers to understanding attribution question across all the locations, * p<0.05

might get upset because they are programming it, and thus controlling it.

The non-us participants were often disappointed when the agents didn't know more about their country, or couldn't speak their language. Overall, all the participants were excited to program the agents and teach them things about their culture.

8 DESIGN GUIDELINES FOR INCLUSIVE AI LITERACY ACTIVITIES

Based on our field observations, we recognize the following sets of challenges and opportunities for people interested in developing future smart devices and inclusive AI learning activities for children:

- Avoid deceiving technologies, assume current state of the technology and involve participants in the process of developing it while making debugging intuitive and fun.
- Design systems where intelligence is associated more with decision making, gestalt, emergent schema and less with human imitation via a nice voice prosody.
- Put the child "in the agent shoes". Make the reasoning behind the machine as transparent as possible and give children opportunities for perspective taking, acknowledgment of different dimensions of mind perception.
- Provide various ways in which children could teach, customize and program the machine.
- Emphasize the importance of learning and provide meaningful feedback to children with each action they take so they see what the machine has learned or not.
- Encourage reflection and collaboration by allowing children to share and modify each other projects and models.

As a results of our initial explorations of child-agent interactions in various socio-cultural settings we propose three initial hands-on learning activities to be furthered tested and developed by educators and parents: lo-fi prototyping of AI agents, mobile agent turtle activity, role playing by embodying the agent.

8.1 Lo-fi Prototyping of AI Agents

We recognize value in creating lo-fi smart toys and AI agents prototypes both in terms of supporting an inclusive understanding of these technologies by allowing children to imagine how they would like these devices to behave, look and feel [4, 18, 22]. Prototypes could take any form from drawings to LEGO creation. In our workshops we found it useful to provide children with an "Imagine AI" activity sheet that would ask for the creation name, three things they would like to teach the AI and three things they would like to it to do for or with them. This activity sheet is available in annex together with the the other study materials (bit.ly/cogni_printouts).

Figure 7: Design your AI activity with paper and LEGO

8.2 Mobile Agent Turtle Activity

During our workshops, when the children didn't know what to make the robot do, we would ask them to make the robot draw various geometric shapes like a square, circle or triangle with its motions. To better visualize what the robot does in contrast to the expected behavior, often we would attach a pen to the robot and put a paper underneath so the children can more easily visualize its movements. Other times we would ask a child to pretend to be a robot while the others would give him or her motion commands to better understand what algorithm they would need for drawing different geometric shapes. This kind of exercise is always a lot of fun for kids and draws on their body sintonicity intuitions as shown in the early work of Seymour Papert on logo and Turtle geometry.

We imagine this kind of activity could be adapted to any kind of mobile smart toy (e.g. LEGO robots, Dash and Dot, Sphero). While these platforms come with their own programming interface adapting the Turtle activity to a mobile agent enables children to visualize the process better and embody the agent actions to better understand them.

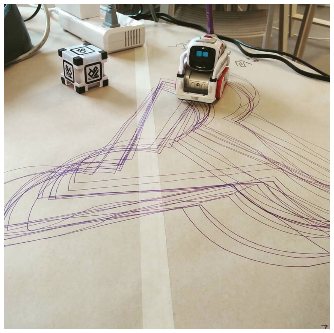

Figure 8: Example of Cozmo Turtle Activity

8.3 Role Playing by Embodying the Agent

Children liked to start playing with Cozmo or Jibo in explorer mode and control it by teleoperation via a phone or a tablet. The robot was able to recognize different objects and people (cube, faces that were taught to him). When the children saw and realized that robot was able to pick up a cube it had just recognized, they became amazed. We prompted them to think about how is the agent capable of recognizing specific objects: is it because of the camera, or does the object send a signal? The children were asked also to think how they might test these hypotheses. Children also loved to spend a long time communicating with their peers by role-playing via the agent's text to speech functionality.

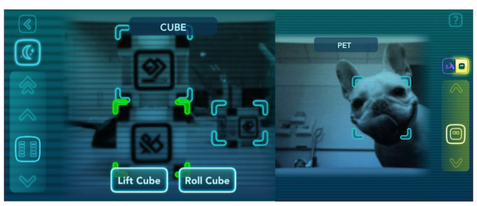

Figure 9: Example of Cozmo's Explorer interface

We imagine many future learning scenarios where are children able to embody and customize any agent that has a camera and/or speaker and pretend they are the agent while engaging with other children. This would allow them not only to experience first hand how these devices perceive the world but also to explore their relational affordances with their peers.

9 CONCLUSION

From Syrian children in Berlin to the children in a church community center in the USA we saw how children could both take the smart devices at an interface level or engage with them in more creative and meaningful ways. Children in low and medium SES schools and centers were better are collaborating but had a harder time advancing because they had less experience with coding and interacting with AI technologies. Meanwhile, students in high SES schools had a harder time collaborating and sharing the study materials but were more fluent in programming. As designers of technologies that support inclusive learning we are at arms race with consumer applications which create and define trends of technology literacy for an entire generation. We hope this paper will inspire other practitioners to democratize access to AI literacy through tinkering and play and we invite also children, parents, and teachers to co-design future learning activities and smart toys hacks.

REFERENCES

[1] Edith Ackermann. 2001. Piaget's constructivism, Papert's constructionism: What's the difference. *Future of learning group publication* 5, 3 (2001), 438.
[2] Edith K Ackermann. 2005. Playthings that do things: a young kid's incredibles!. In *Proceedings of the 2005 conference on Interaction design and children*. ACM, 1–8.
[3] Edith K Ackermann. 2007. Experiences of artifacts: People's appropriations/objects'"affordances". In *Keywords in radical constructivism. Edited by Marie Larochelle*. Sense Publishers, 249–259.
[4] Edith K Ackermann. 2012. Programming for the natives: What is it? What's in it for the kids. *Constructionism* (2012).
[5] Douglas Altman, David Machin, Trevor Bryant, and Martin Gardner. 2013. *Statistics with confidence: confidence intervals and statistical guidelines*. John Wiley & Sons.
[6] Christoph Bartneck, Dana Kulić, Elizabeth Croft, and Susana Zoghbi. 2009. Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots. *International journal of social robotics* 1, 1 (2009), 71–81.
[7] Ian Campbell. 2007. Chi-squared and Fisher–Irwin tests of two-by-two tables with small sample recommendations. *Statistics in medicine* 26, 19 (2007), 3661–3675.
[8] Stefania Druga, Randi Williams, Cynthia Breazeal, and Mitchel Resnick. 2017. Hey Google is it OK if I eat you?: Initial Explorations in Child-Agent Interaction. In *Proceedings of the 2017 Conference on Interaction Design and Children*. ACM, 595–600.
[9] Stefania Druga, Randi Williams, Hae Won Park, and Cynthia Breazeal. 2018. How Smart Are the Smart Toys?: Children and Parents' Agent Interaction and Intelligence Attribution. In *Proceedings of the 17th ACM Conference on Interaction Design and Children (IDC '18)*. ACM, New York, NY, USA, 231–240. https://doi.org/10.1145/3202185.3202741
[10] Heather M Gray, Kurt Gray, and Daniel M Wegner. 2007. Dimensions of mind perception. *Science* 315, 5812 (2007), 619–619.
[11] K Inagaki. 1993. Young children's differentiation of plants from nonliving things in terms of growth. In *biennial meeting of Society for Research in Child Development, New Orleans*.
[12] Vera John-Steiner and Holbrook Mahn. 1996. Sociocultural approaches to learning and development: A Vygotskian framework. *Educational psychologist* 31, 3-4 (1996), 191–206.
[13] Frank C Keil. 1986. Conceptual domains and the acquisition of metaphor. *Cognitive Development* 1, 1 (1986), 73–96.
[14] Valerie E Lee and David T Burkam. 2002. *Inequality at the starting gate: Social background differences in achievement as children begin school*. ERIC.
[15] David Mioduser and Sharona T Levy. 2010. Making sense by building sense: Kindergarten children's construction and understanding of adaptive robot behaviors. *International Journal of Computers for Mathematical Learning* 15, 2 (2010), 99–127.
[16] Seymour Papert. 1980. *Mindstorms: Children, computers, and powerful ideas*. Basic Books, Inc.
[17] Hae Won Park, Rinat B Rosenberg-Kima, Maor Rosenberg, Goren Gordon, and Cynthia Breazeal. 2017. Growing Growth Mindset with a Social Robot Peer.. In *HRI*. 137–145.
[18] Marc Rettig. 1994. Prototyping for tiny fingers. *Commun. ACM* 37, 4 (1994), 21–27.
[19] John TE Richardson. 2011. The analysis of 2× 2 contingency tablesâĂŤYet again. *Statistics in medicine* 30, 8 (2011), 890–890.
[20] Astrid M Rosenthal-von der Pütten, Nicole C Krämer, Laura Hoffmann, Sabrina Sobieraj, and Sabrina C Eimler. 2013. An experimental study on emotional reactions towards a robot. *International Journal of Social Robotics* 5, 1 (2013), 17–34.
[21] Michael Scaife and Mike Duuren. 1995. Do computers have brains? What children believe about intelligent artifacts. *British Journal of Developmental Psychology* 13, 4 (1995), 367–377.
[22] Mike Scaife and Yvonne Rogers. 1999. Kids as informants: Telling us what we didn't know or confirming what we knew already. *The design of childrenâĂŹs technology* (1999), 27–50.
[23] Sherry Turkle. 2005. *The second self: Computers and the human spirit*. Mit Press.