PopBots

Designing an Artificial Intelligence Curriculum for Early Childhood Education

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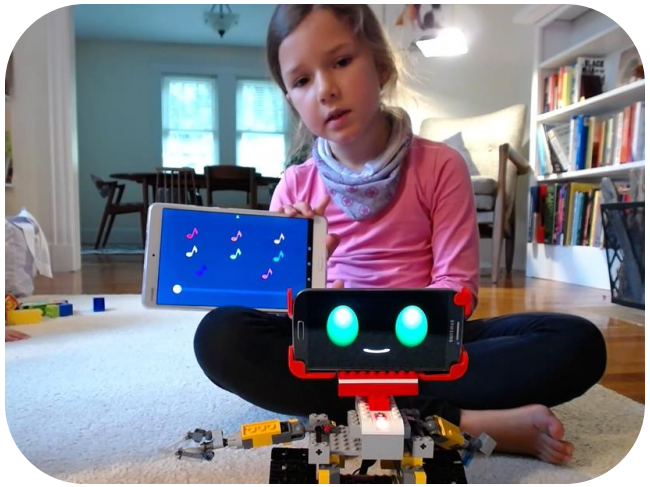
INTRODUCTION

AI EDUCATION IN PRESCHOOL

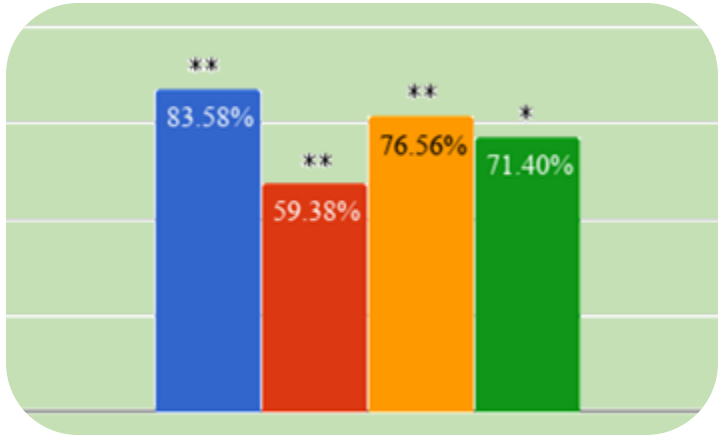
The components of PopBots are a social robot toolkit with AI activities and assessments located on a tablet. We used these tools in an evaluative study in preschool (ages 4-6) classrooms.

Programmable, Social Robot Learning Companion



AI Activities & Assessments

System Interaction Analysis



MOTIVATION

CHILDREN IN THE ERA OF SMART TOYS

Children are growing up with AI-enabled systems that exhibit lifelike intelligence and social agency.

MOTIVATION

However, children do not have the tools to leverage this technology in the best way possible

“Alexa, what do sloths eat?”

“I'm sorry. I don't know how to help you with that.”

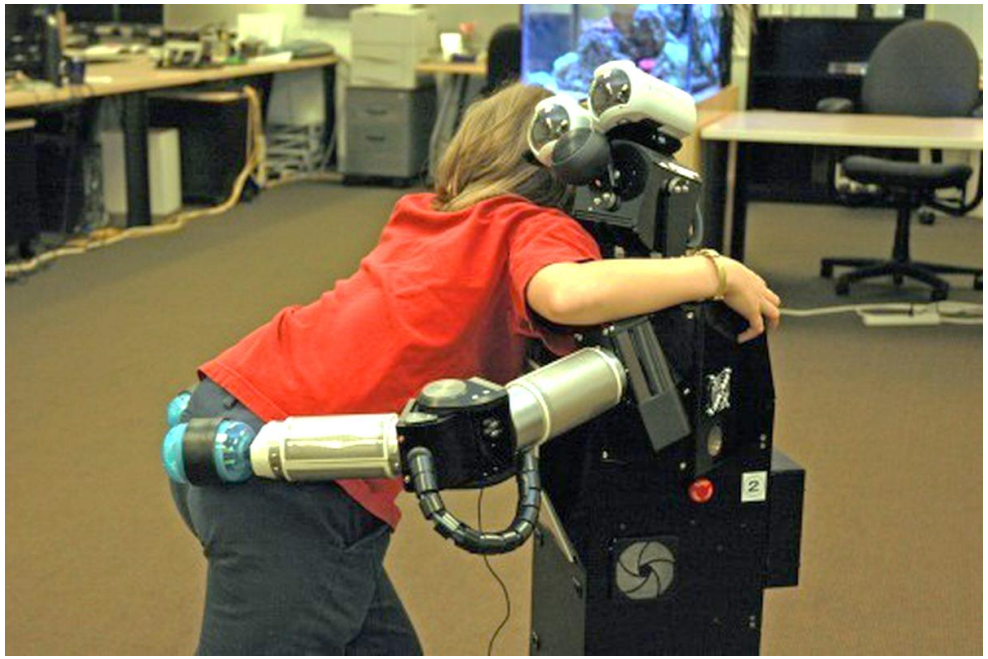
“That's okay,” she exclaimed.

Picking up a second Amazon Echo,
"I'll see if the other Alexa knows.”

Paraphrased from “Hey Google, Is It OK If I Eat You?” Druga et al. 2017

BACKGROUND

Children treat AI devices like people and don't understand privacy and safety concerns

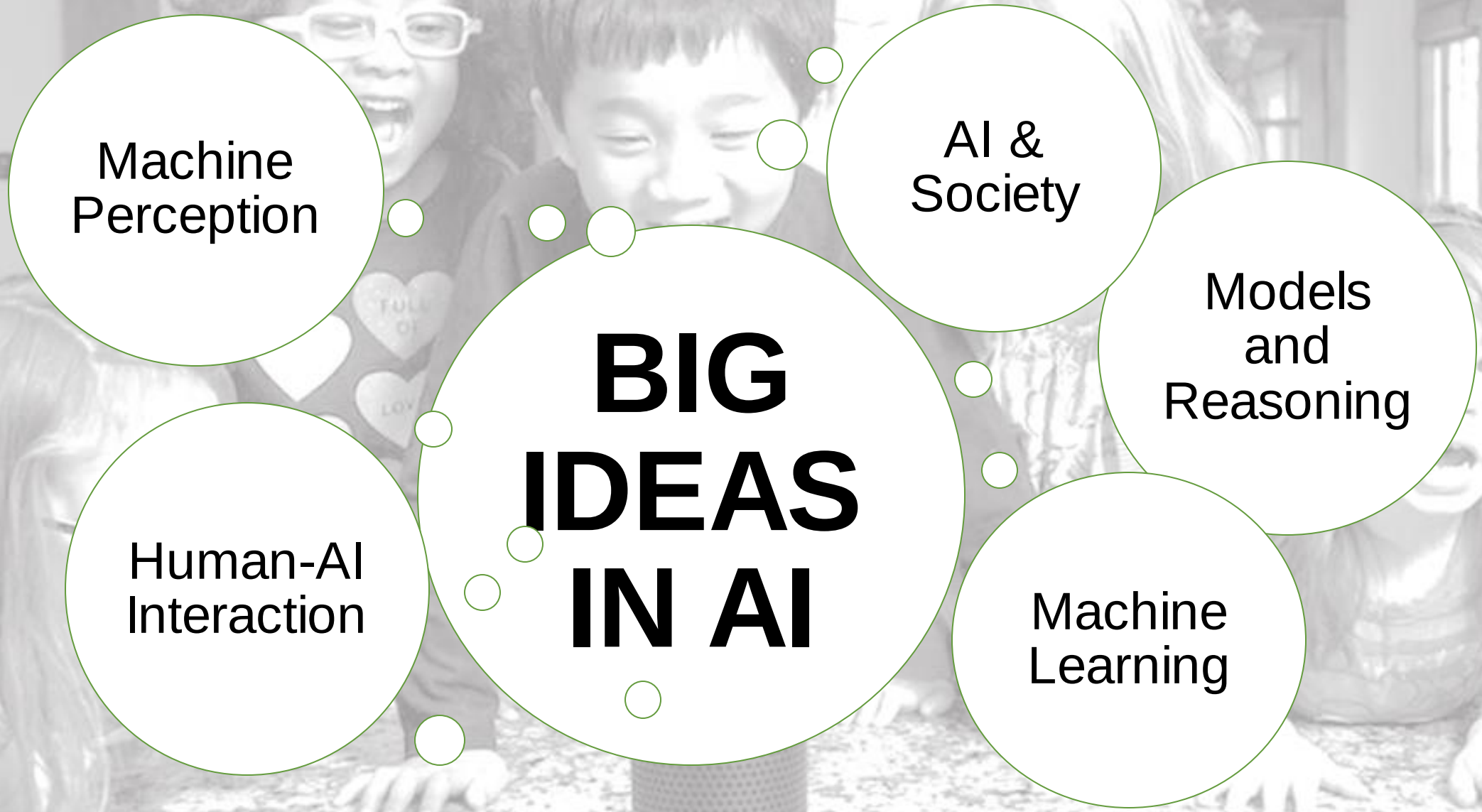


Children better understand AI devices as they:

- Get older
- Develop socioemotional skills
- Learn programming

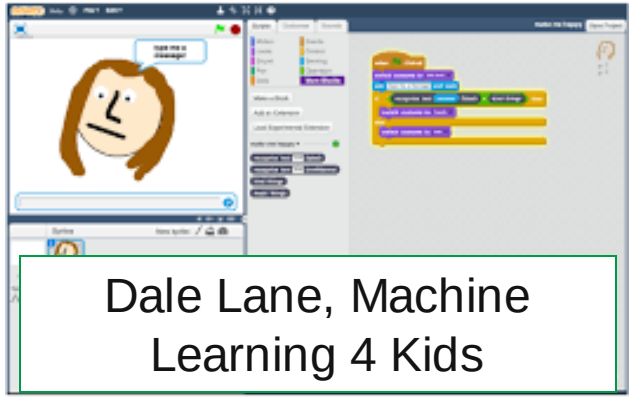
Williams, R. et al. My doll says it's OK. 2018
Druga, S. et al. Hey Google is it OK if I eat you?. 2017
McReynolds et al. Toys that listen. 2017
Kahn, P. et al. Robovie you'll have to go into the closet now. 2012

BACKGROUND

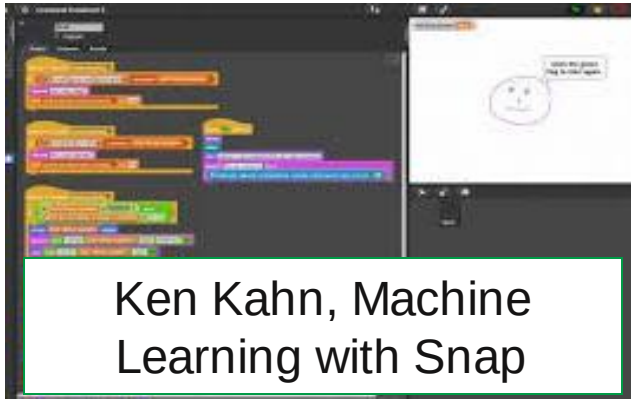


Touretzky, D. et al., Envisioning AI for K-12: What should every child know about AI?. 2019

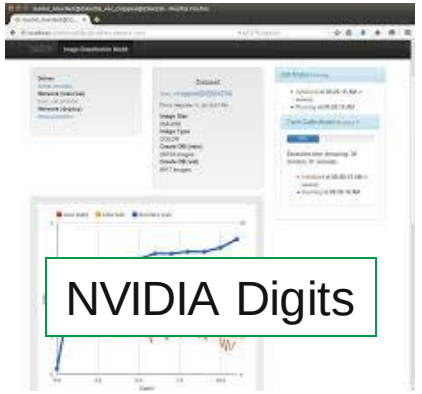
BACKGROUND



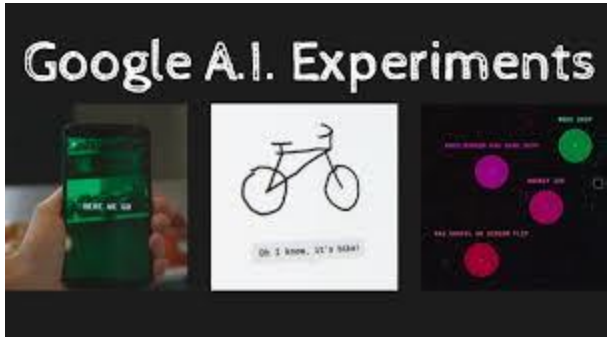
Dale Lane, Machine Learning 4 Kids

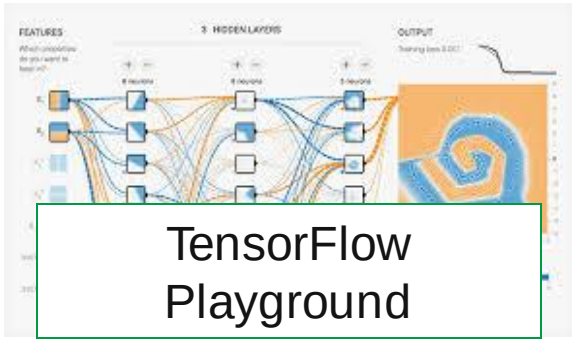


Ken Kahn, Machine Learning with Snap

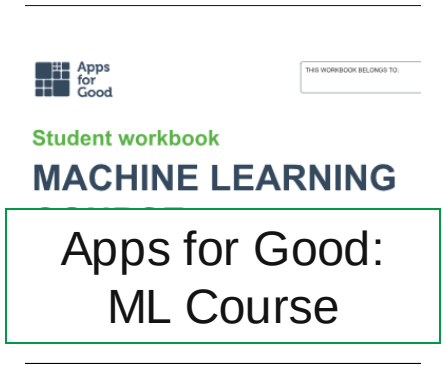


NVIDIA Digits





TensorFlow Playground



Apps for Good: ML Course

ReadyAI

TOOLKIT

KEY DESIGN PRINCIPLES

PopBots is a developmentally appropriate, powerful way for young, non-programming children to understand AI

Hands-On Learning

End-to-End Learning

Transparency and Tinkerability

Creative Exploration

Flannery et al., ScratchJr. 2013
Gordon et al., The Social Robot Toolkit. 2015
Sullivan et al., KIBO Robot. 2015

TOOLKIT

A. PHONE

Learning companion guides children through activities

Social other allows children to comprehend algorithms through social reasoning

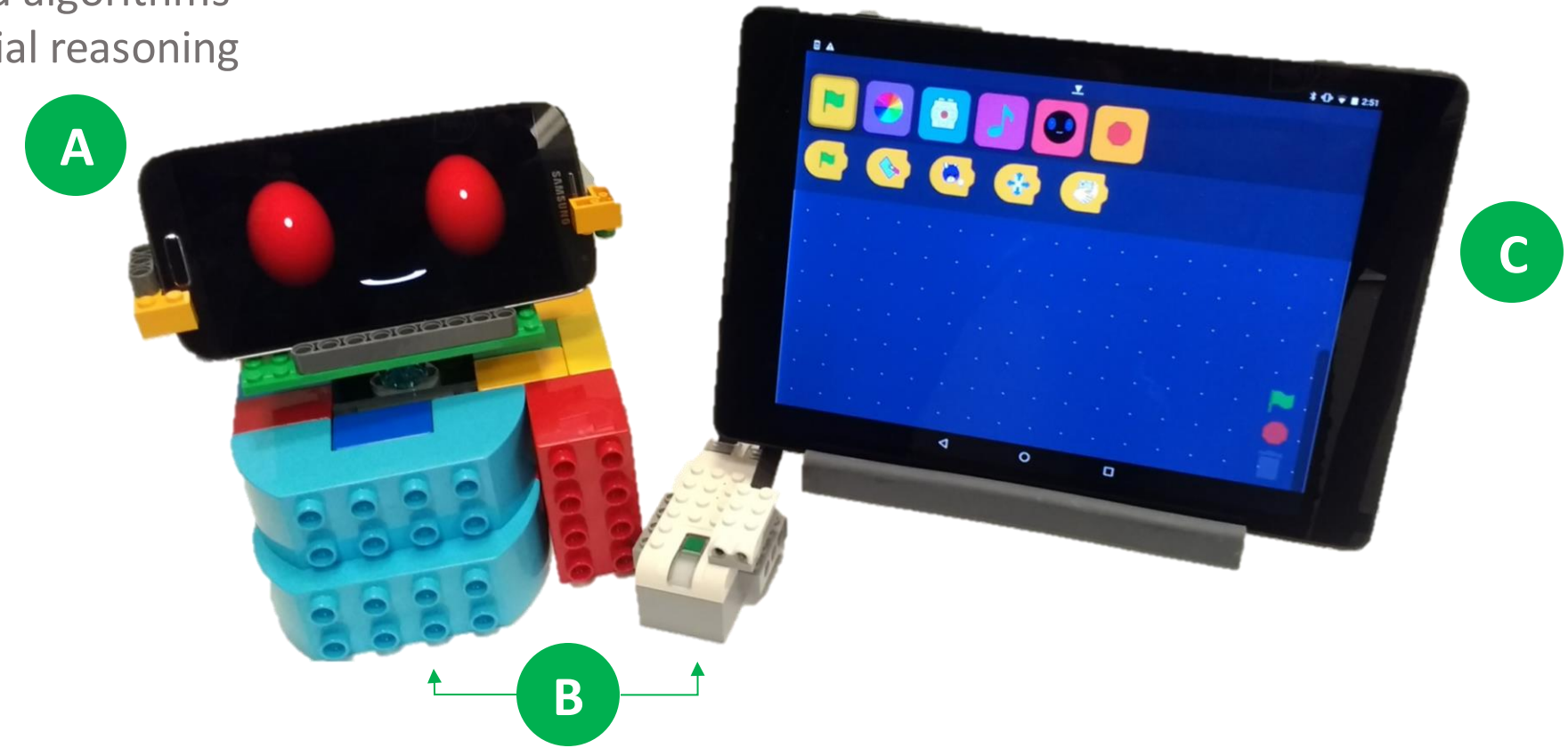
B. LEGO BODY

Hands-on robot allows children to work and learn together

C. TABLET

Icon-based programming for non-readers

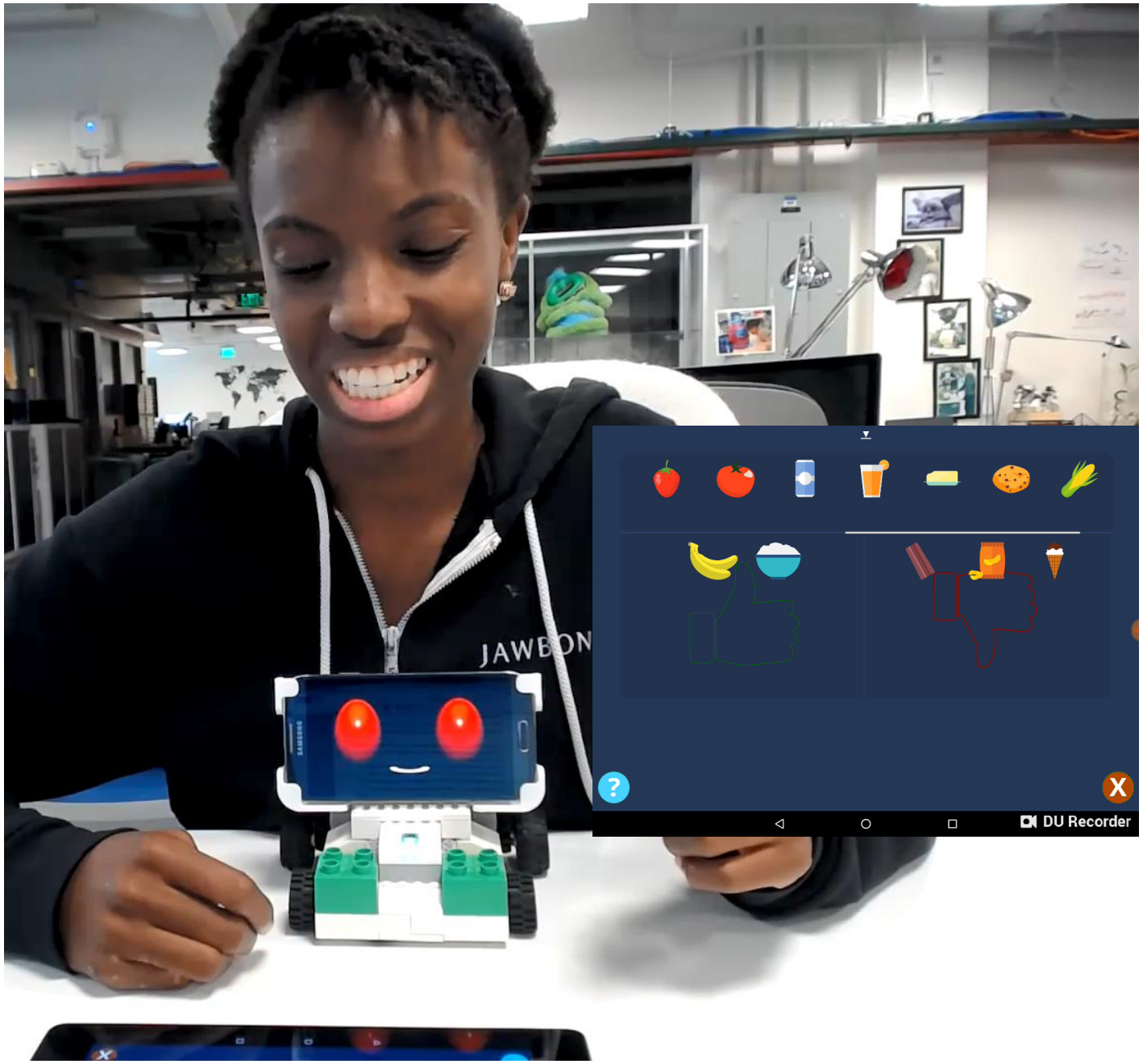
AI activities and assessments



TOOLKIT

POPBOTS ACTIVITY DEMO

The robot plays an active role in the curriculum guiding children through activities and explaining its reasoning.

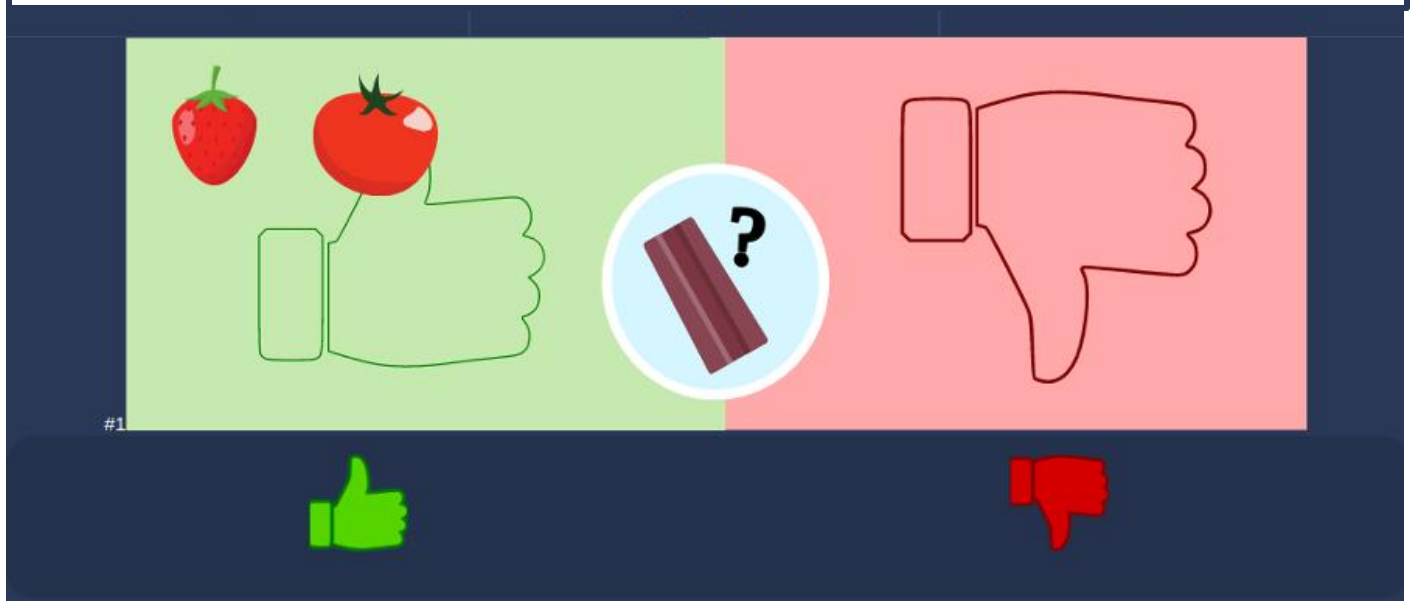


TOOLKIT

POPBOTS ASSESSMENTS

Assessments were completed individually and covered basic functionality and edge cases for each concept.

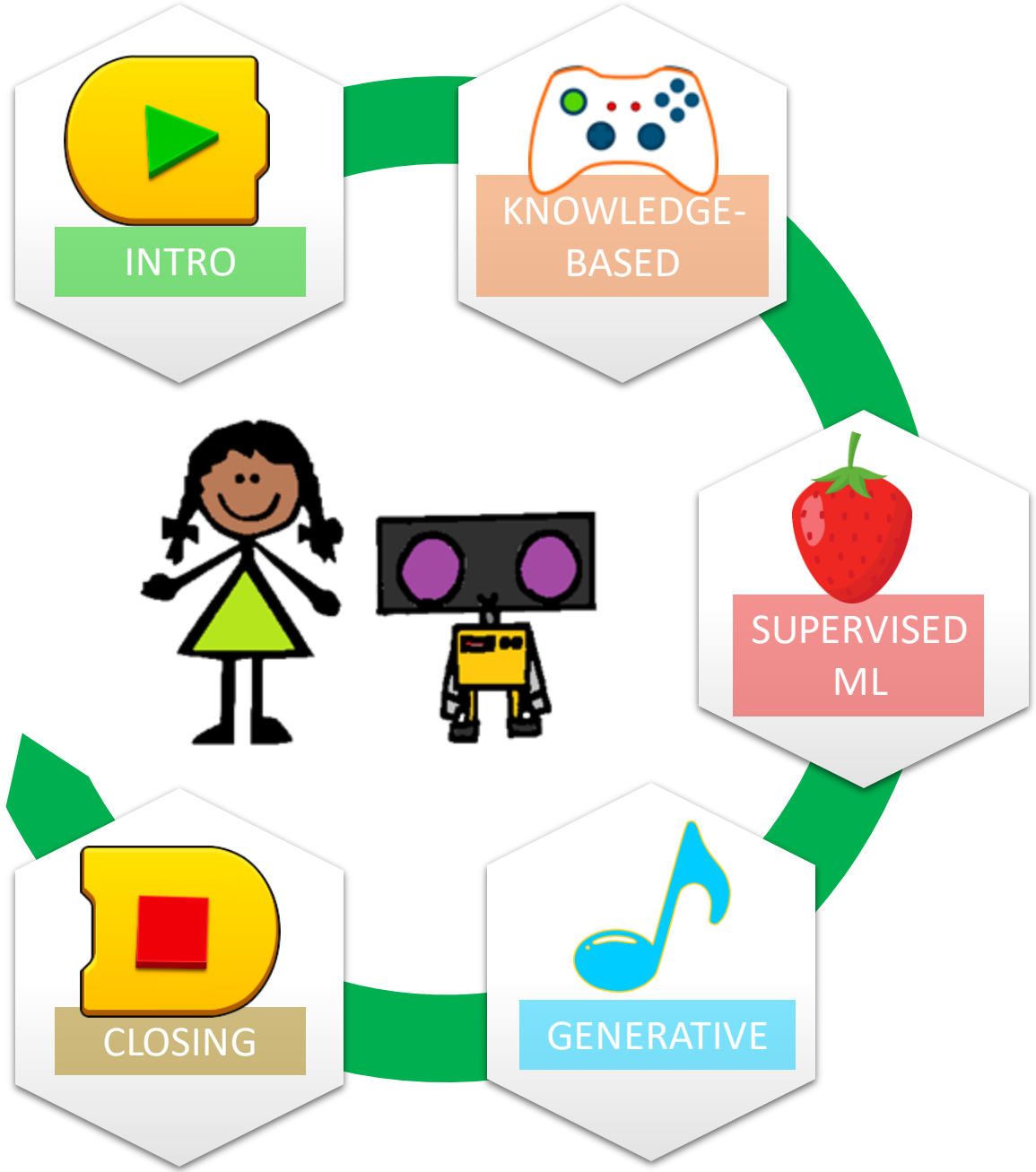
You tell the robot that strawberries and tomatoes go in the good group. Then you ask the robot where to put chocolate. What will the robot think?



TOOLKIT

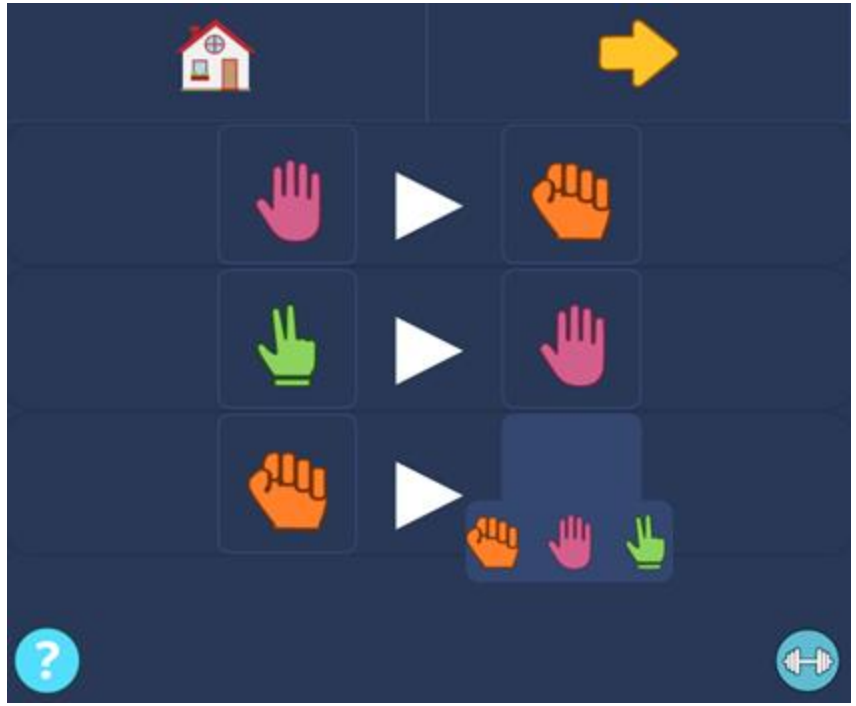
POPBOTS ACTIVITES AND ASSESSMENTS

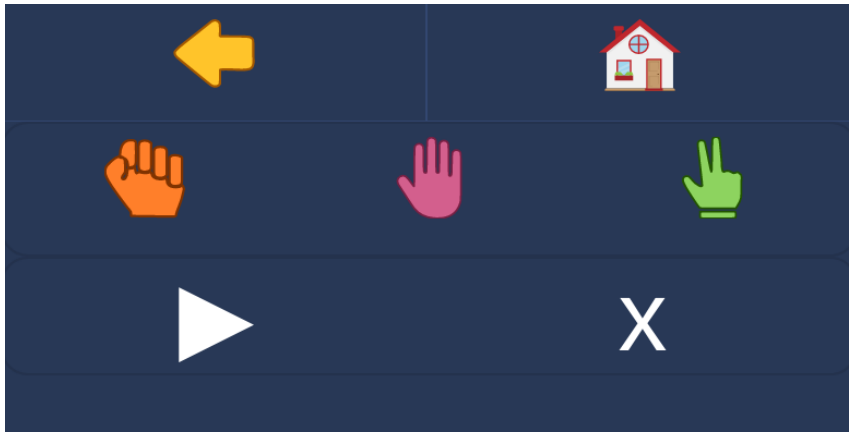
In each session children spent 10-15 minutes completing hands-on activities about AI then completed an assessment



KNOWLEDGE-BASED SYSTEMS

1. Children create a knowledge base with rules
2. Robot remembers past moves and over time gets better at predicting next moves
3. Robot uses knowledge base to choose a move
4. Children connect this to video games and talking toys



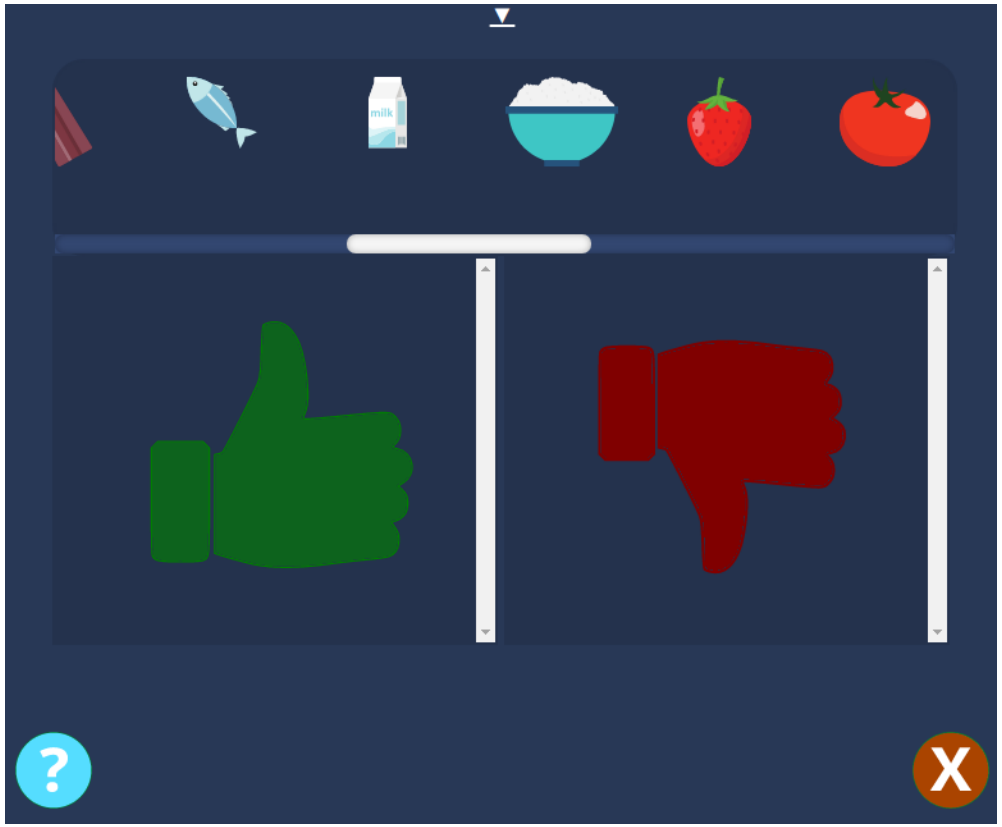


Assessment

Basic Reasoning	Basic Prediction
Advanced Reasoning	Advanced Prediction

SUPERVISED MACHINE LEARNING

1. Children label foods as the training set
2. Children test the unlabeled foods as the test set
3. Robot compares test set foods to the training set
4. Children connect this to YouTube and Netflix



Assessment

Initialization

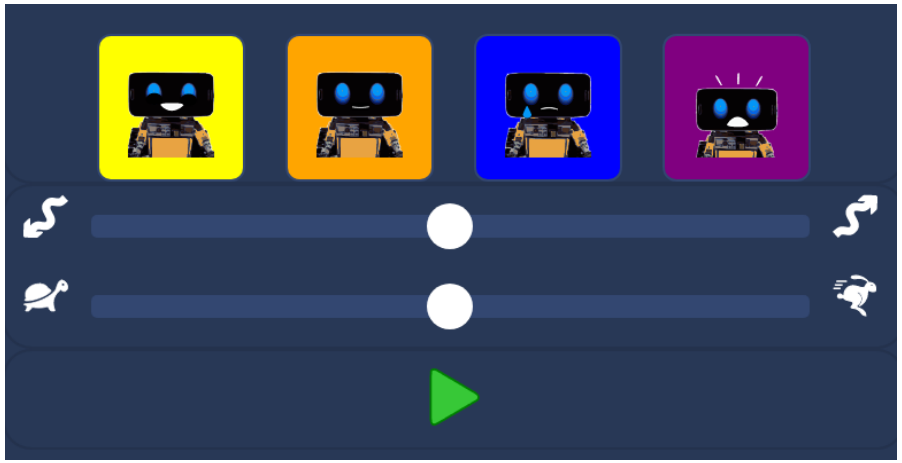
Comparison

Basic Prediction

Robot knows **food group**, **color**, amount of **sugar**, amount of **calories**

GENERATIVE AI

1. Children configure the parameters of robot emotions
2. Children input song for the robot to remix
3. Robot outputs song remix according to parameters
4. Children learn that algorithms can be creative.



Direction
Tempo

Assessment

Initialization

Basic Parametrization

Advanced Parametrization

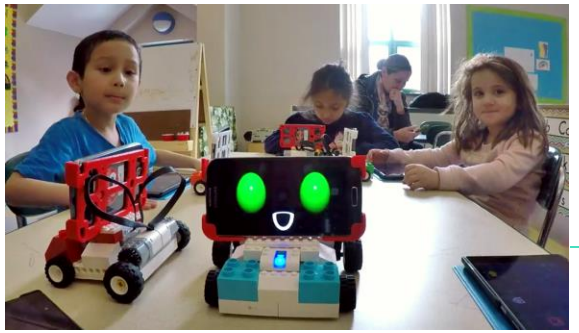
PROCEDURE

STUDY PARTICIPANTS

We worked with five classrooms with 6 to 22 students in each. We analyzed differences in children's learning by age, classroom, and interactions with the tablet.

A
Pre-K
Small groups

B
Kindergarten
Small groups



C
Kindergarten
One large group

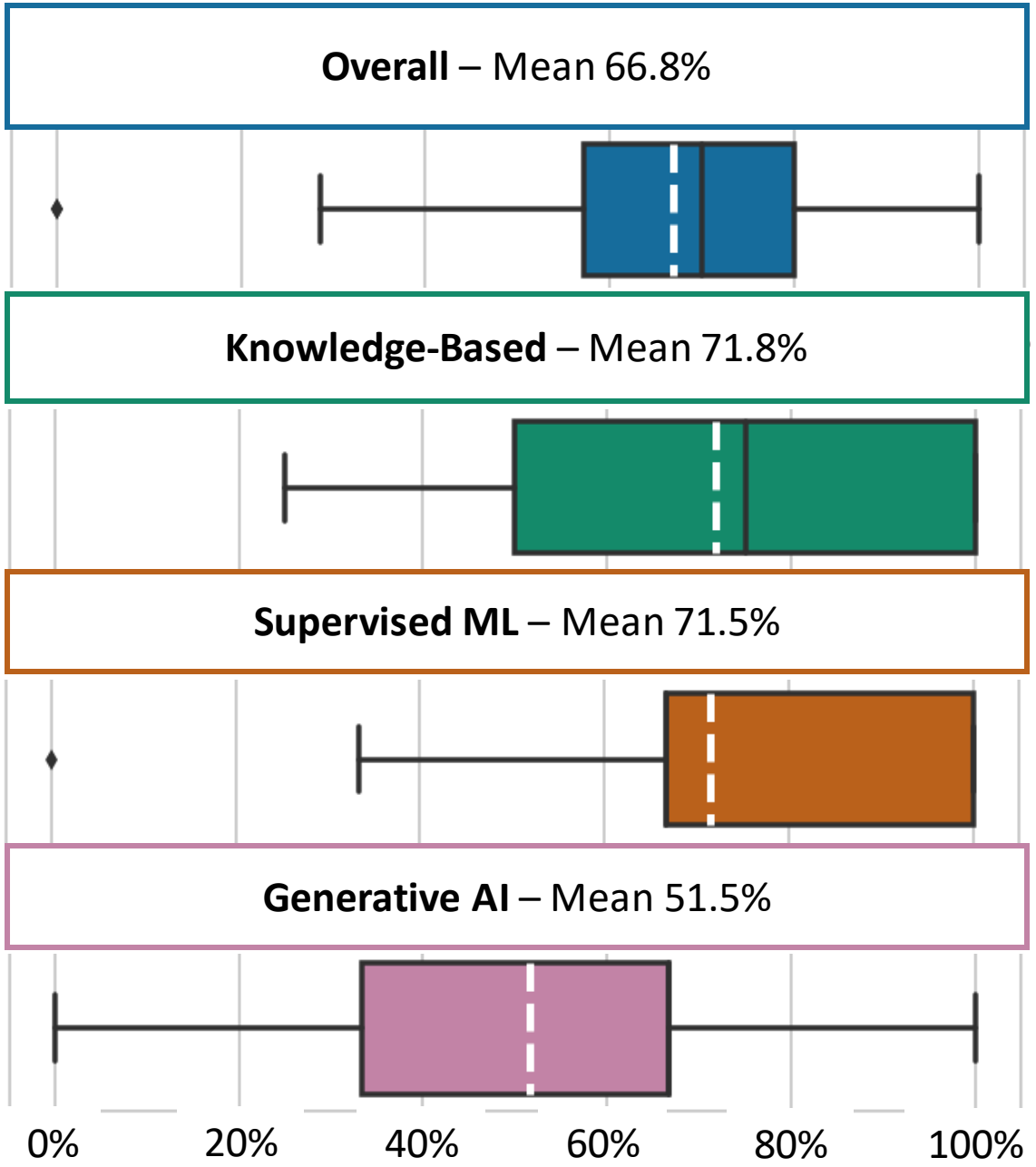
D
Kindergarten
One large group

E
Pre-K + Kindergarten
Small groups

RESULTS

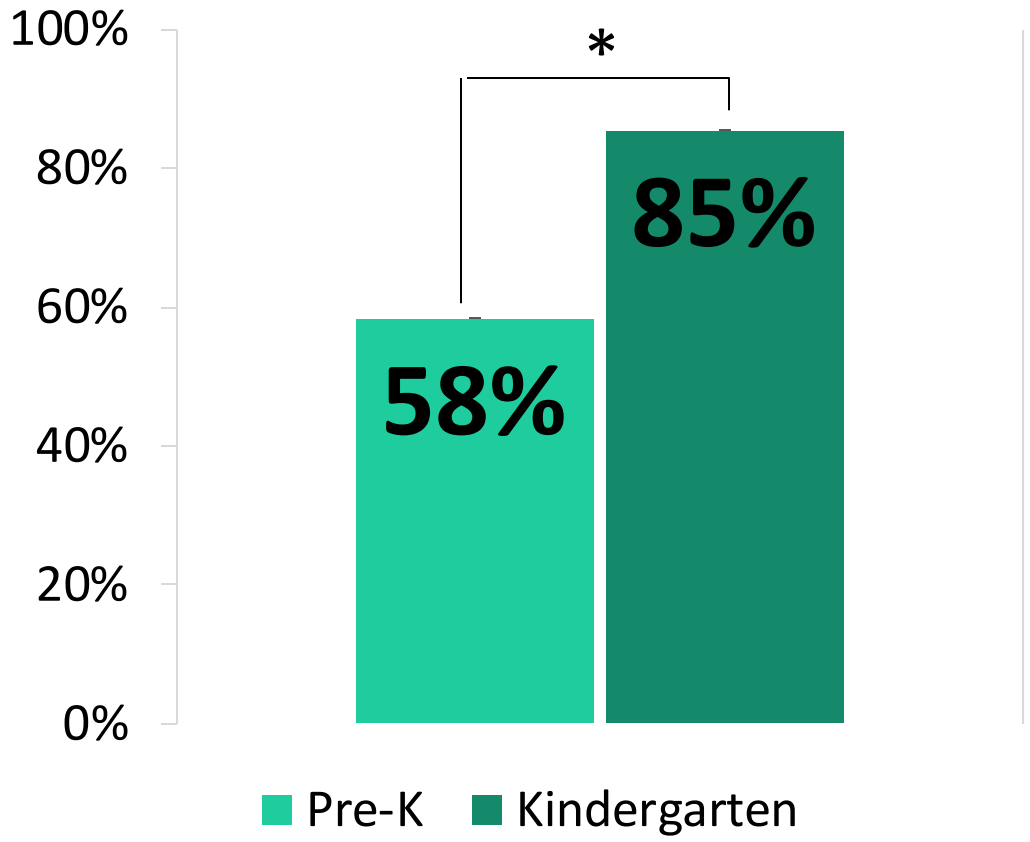
WHAT KINDS OF UNDERSTANDING CAN CHILDREN GAIN ABOUT AI?

Children understood the majority of the information presented in the toolkit, with some differences in understanding depending on the activity.

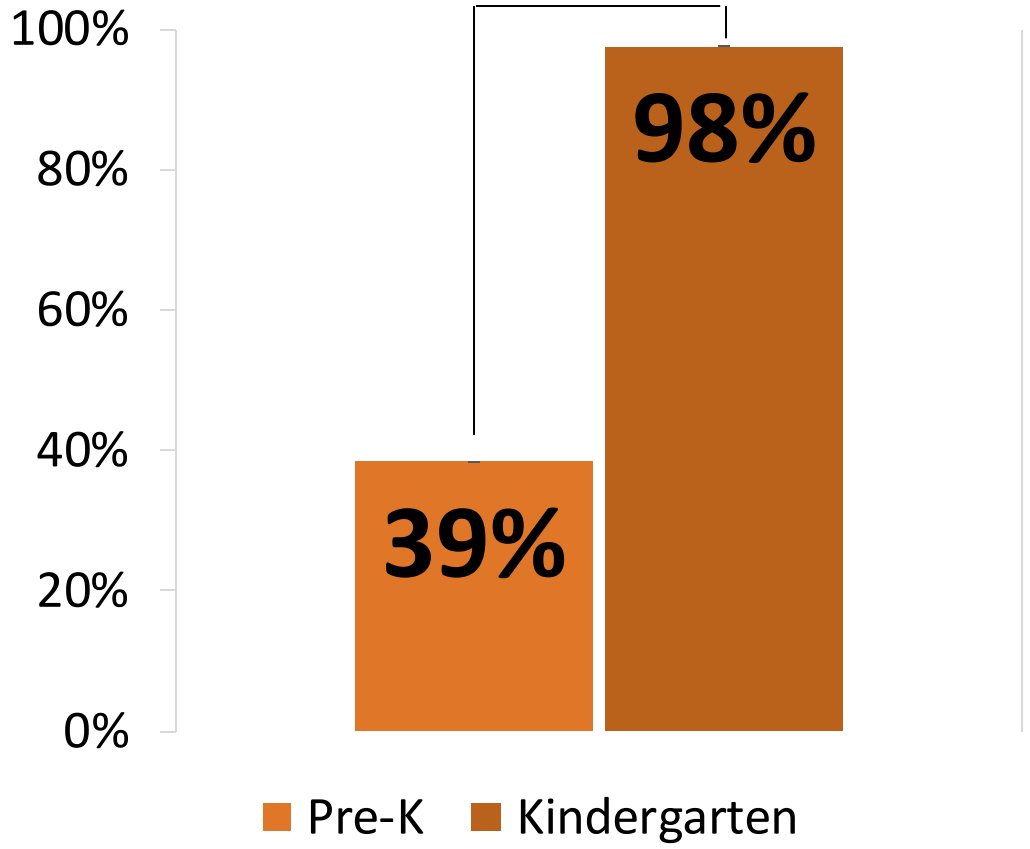


RESULTS

KB3: "The robot thinks that Sally will play paper. What will the robot play against her?"

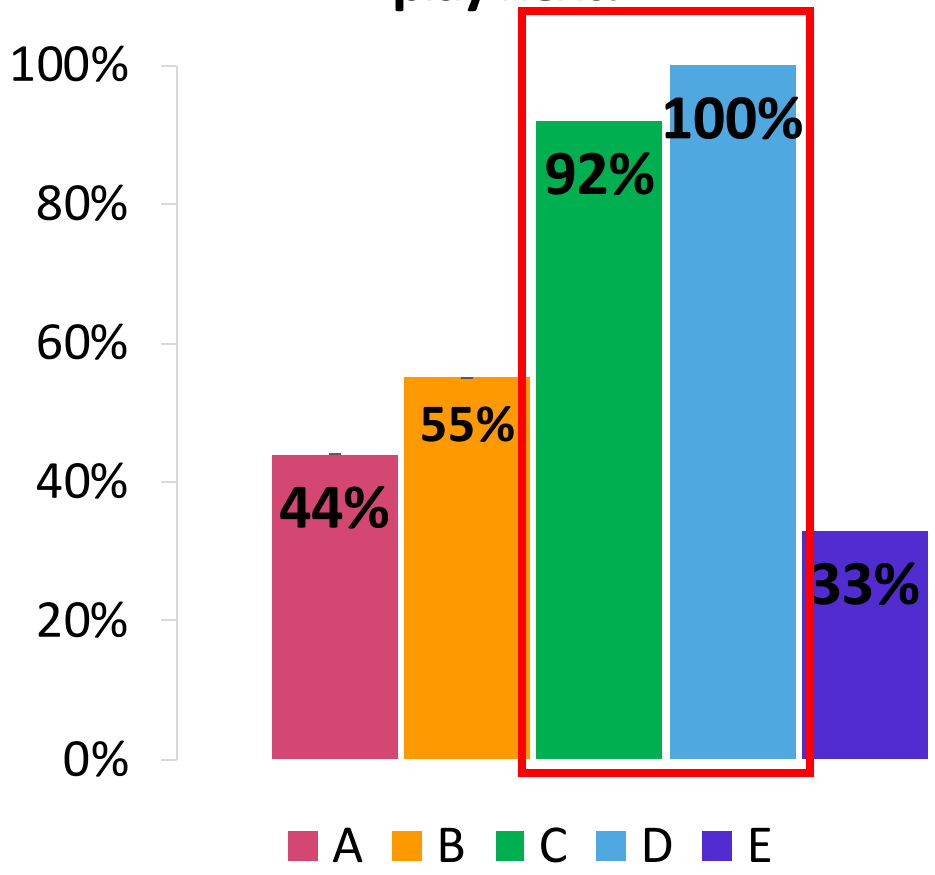


SL2: "Which of these is most like a tomato? A banana, a strawberry, or milk?

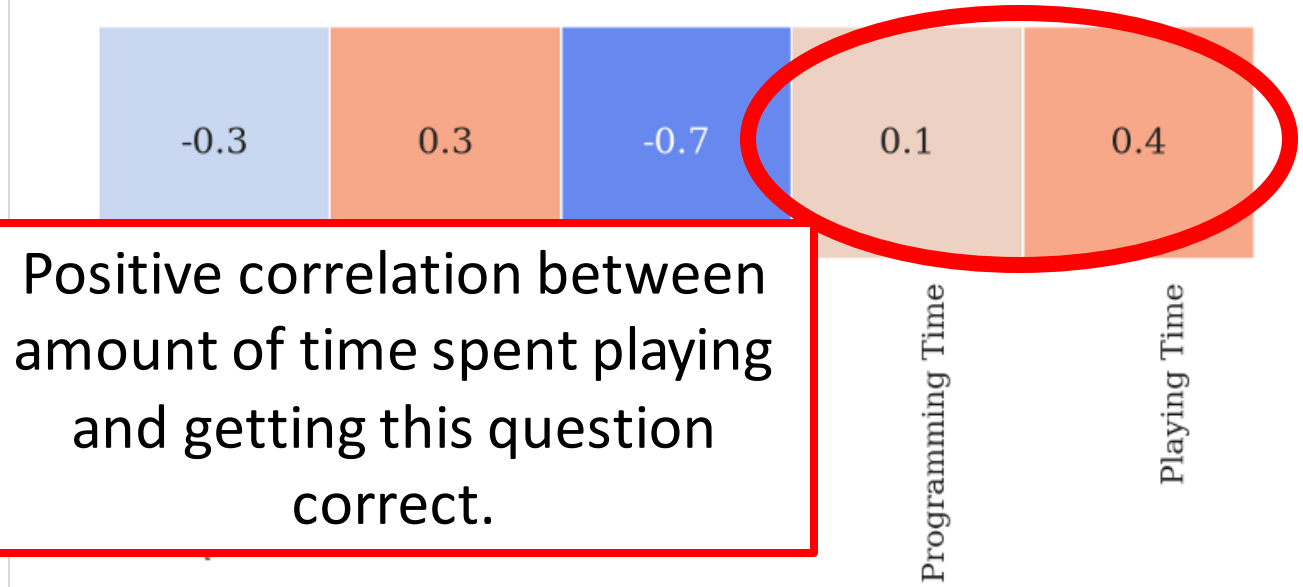


RESULTS

KB2: "Sally plays paper 5 times. What does the robot think she will play next?"



Spearman's Correlation Between Tablet Interactions and Assessment Scores

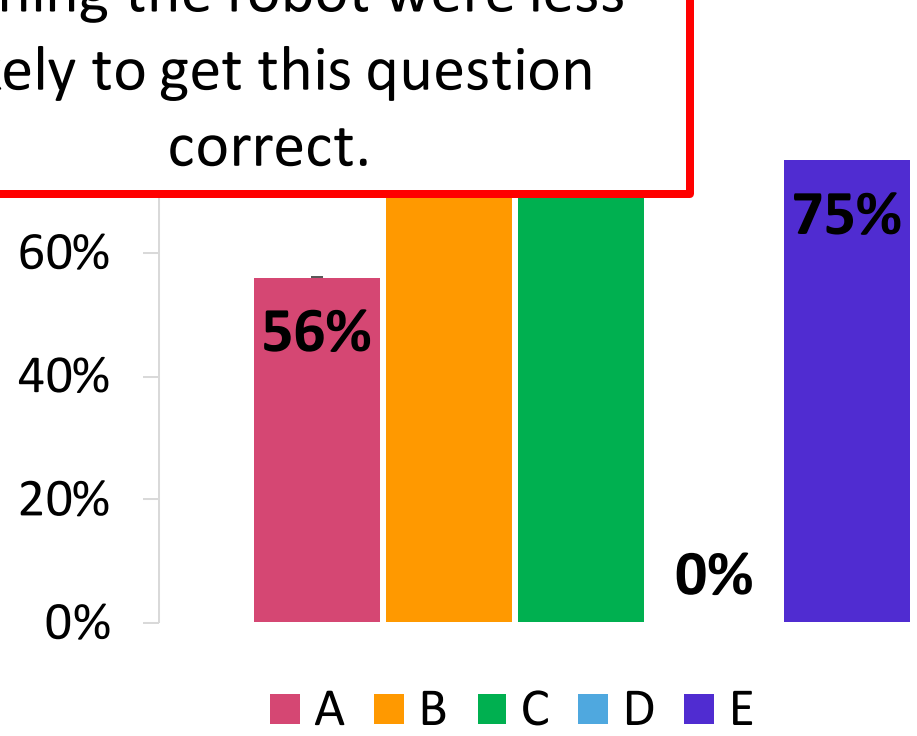


Positive correlation between amount of time spent playing and getting this question correct.

RESULTS

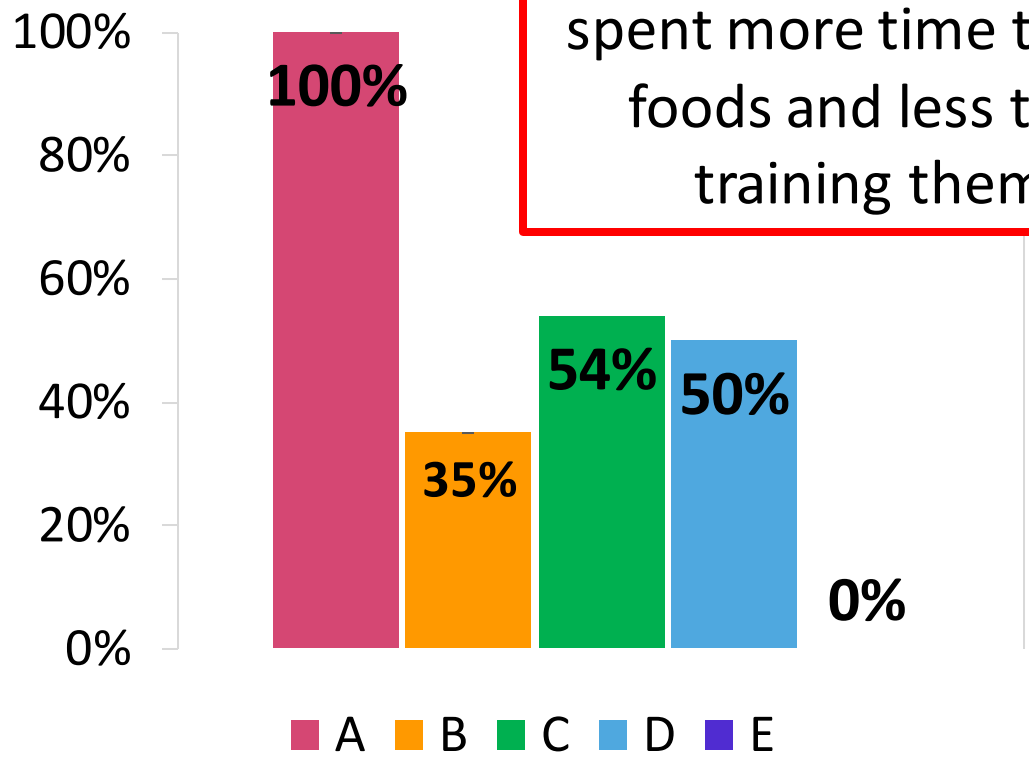
KB4: "We make all of the rules opposite. Sally plays paper while the robot plays scissors. Now who

Children who spent less time training the robot were less likely to get this question correct.



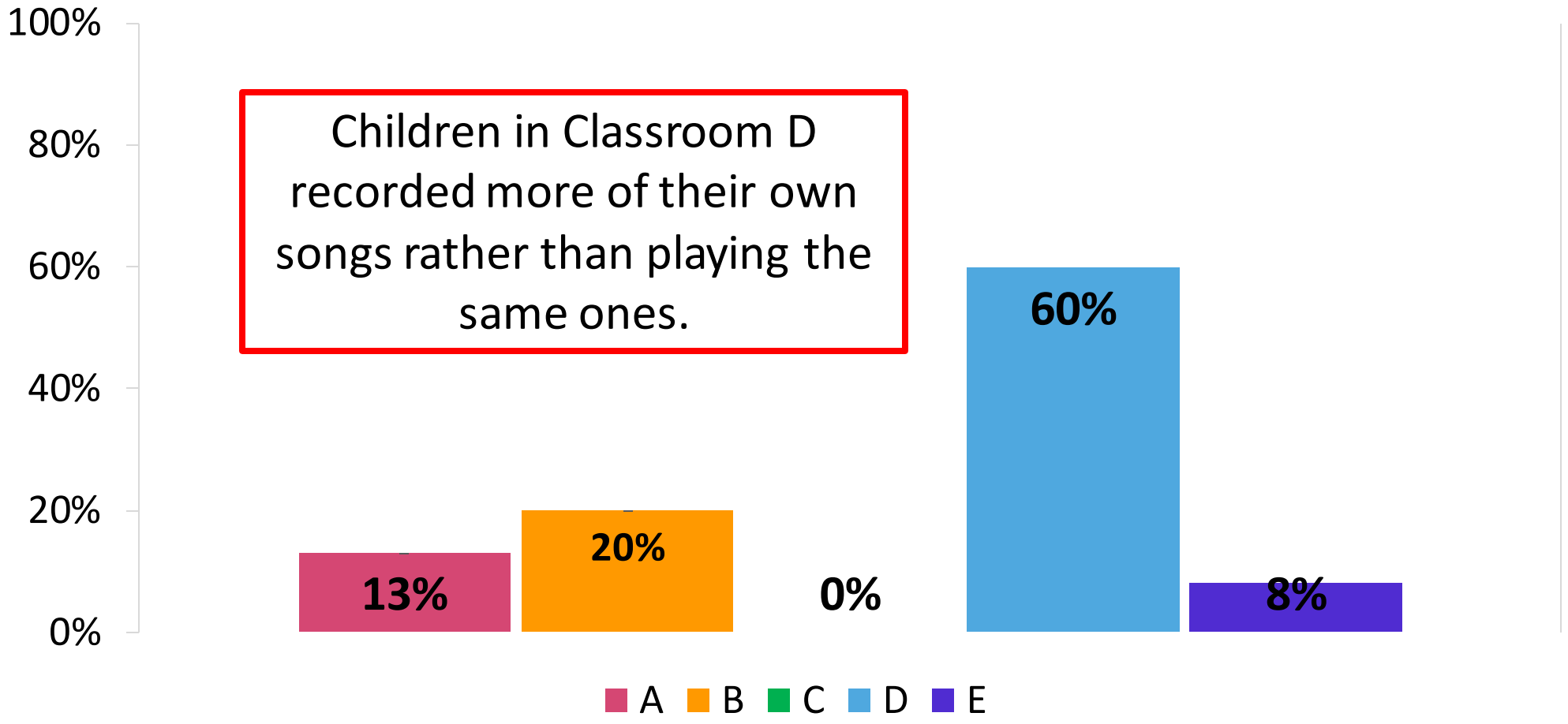
SL1: "We tell the robot that strawberries and tomatoes go in the good group. Where will the robot think choco

Children in classroom A spent more time testing foods and less time training them.



RESULTS

GM3: "Does the robot's song always have some of the same notes as the input? Or does the robot play a completely different song?"

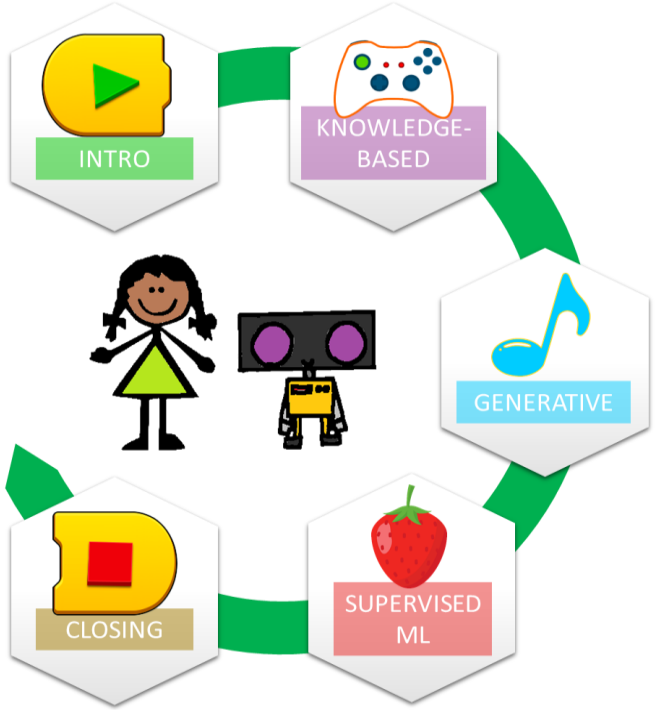


BIG TAKEAWAYS

A **social robot learning companion** and **explorative AI activities** helped children construct their understanding of AI algorithms

Some differences because of age, **most differences due to interaction with toolkit** as revealed by classroom-based analysis

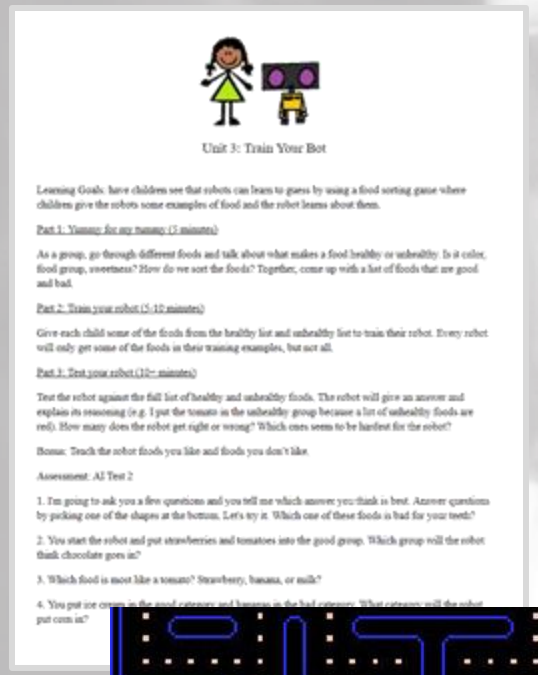
Students best understood **transparent algorithms with strong feedback loops**. How can we translate other AI concepts this way?



PopBots

Designing an Artificial Intelligence Curriculum for Early Childhood Education

FUTURE WORK



Unit 3: Train Your Bot

Learning Goals: have children see that robots can learn to guess by using a food sorting game where children give the robots some examples of food and the robot learns about them.

Part 1: Yummy for my tummy (5 minutes)

As a group, go through different foods and talk about what makes a food healthy or unhealthy. Is it color, food group, sweetness? How do we sort the foods? Together, come up with a list of foods that are good and bad.

Part 2: Train your robot (5-10 minutes)

Give each child some of the foods from the healthy list and unhealthy list to train their robot. Every robot will only get some of the foods in their training examples, but not all.

Part 3: Test your robot (10~ minutes)

Test the robot against the full list of healthy and unhealthy foods. The robot will give an answer and explain its reasoning (e.g. I put the tomato in the unhealthy group because a lot of unhealthy foods are red). How many does the robot get right or wrong? Which ones seem to be hardest for the robot?

Bonus: Teach the robot foods you like and foods you don't like.

Assessment: AI Test 2

1. I'm going to ask you a few questions and you tell me which answer you think is best. Answer questions by picking one of the shapes at the bottom. Let's try it. Which one of these foods is bad for your teeth?

2. You start the robot and put strawberries and tomatoes into the good group. Which group will the robot think chocolate goes in?

3. Which food is most like a tomato? Strawberry, banana, or milk?

4. You put ice cream in the good category and lemons in the bad category. What category will the robot put corn in?

01 IMPROVE LEARNING COMPANION

Use behavioral analysis findings to improve PopBot

02 EXTEND AI CURRICULUM

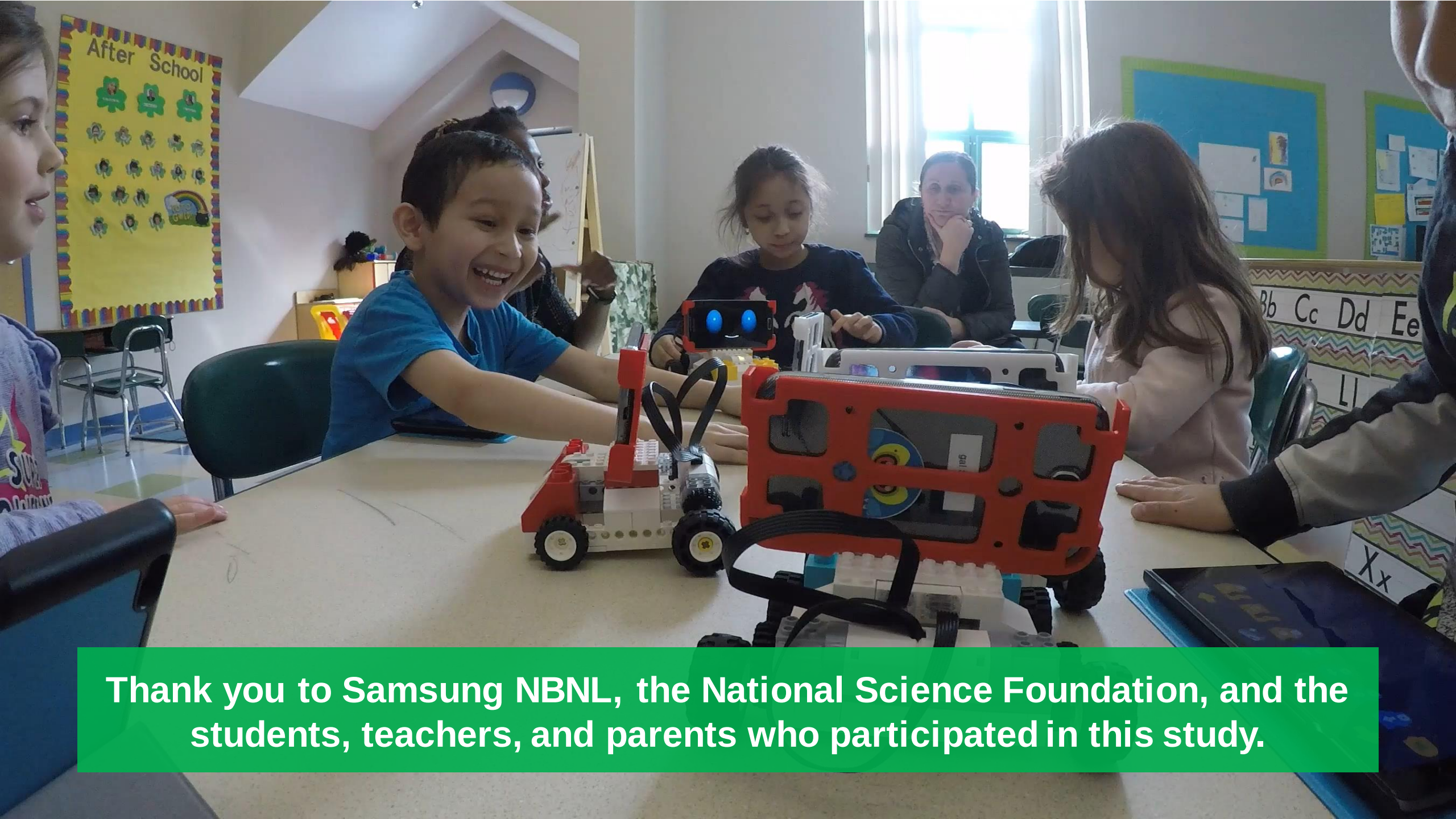
New algorithms like planning, perception, and reasoning

03 ACTIVITY GUIDES

Develop activity guides for non-experts to use PopBots in homes and schools

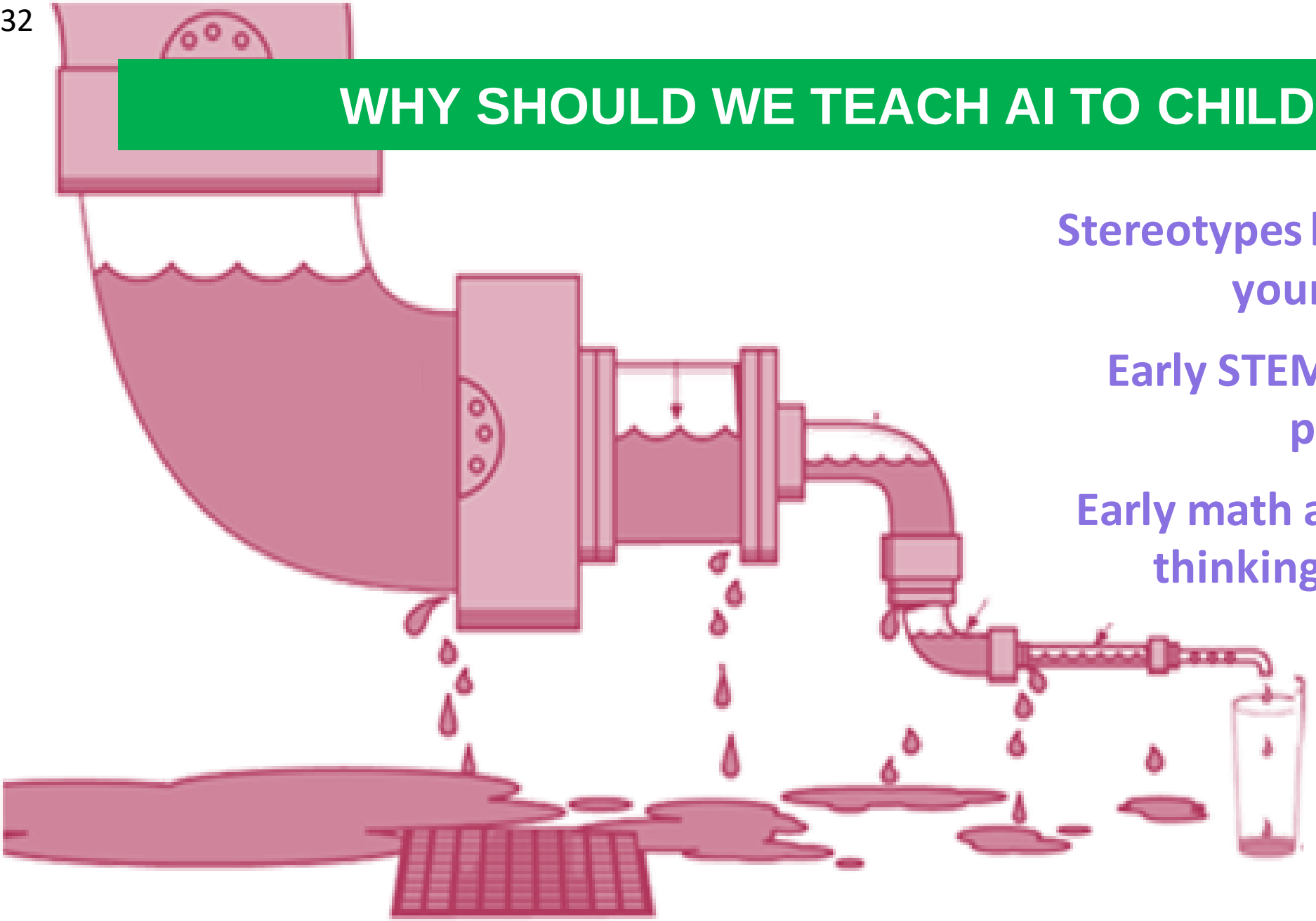
04 PACKAGE TOOLKIT

Develop for other platforms and release a stable version



Thank you to Samsung NBNL, the National Science Foundation, and the students, teachers, and parents who participated in this study.

WHY SHOULD WE TEACH AI TO CHILDREN?



Stereotypes have less impact on young children

Early STEM experiences are powerful

Early math and computational thinking curricula exist

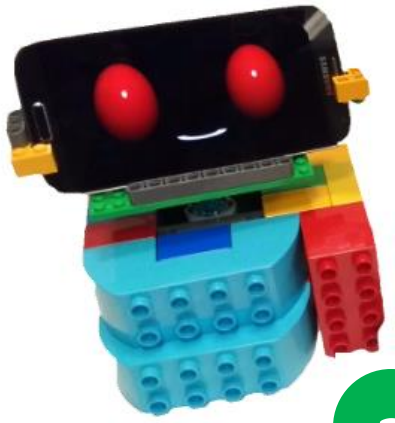
Source: NCES Digest of Education Statistics; Science & Engineering Indicators 2008

POPBOT TOOLKIT

MODULARITY AND FLEXIBILITY

We developed multiple robot forms to inspire children to learn through creation

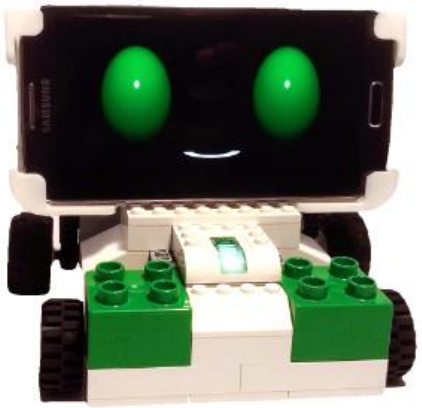
a. Expressive spinning head, b. Tangible props, c. Humanoid and animal forms, d. functional mobile & machine-like forms, e. Robot limbs for expressivity



a

b

c



d

e

POPBOT CURRICULUM

TEACHER GUIDE FORMAT

Teacher scripts and lesson guides to lead classroom through AI activities.

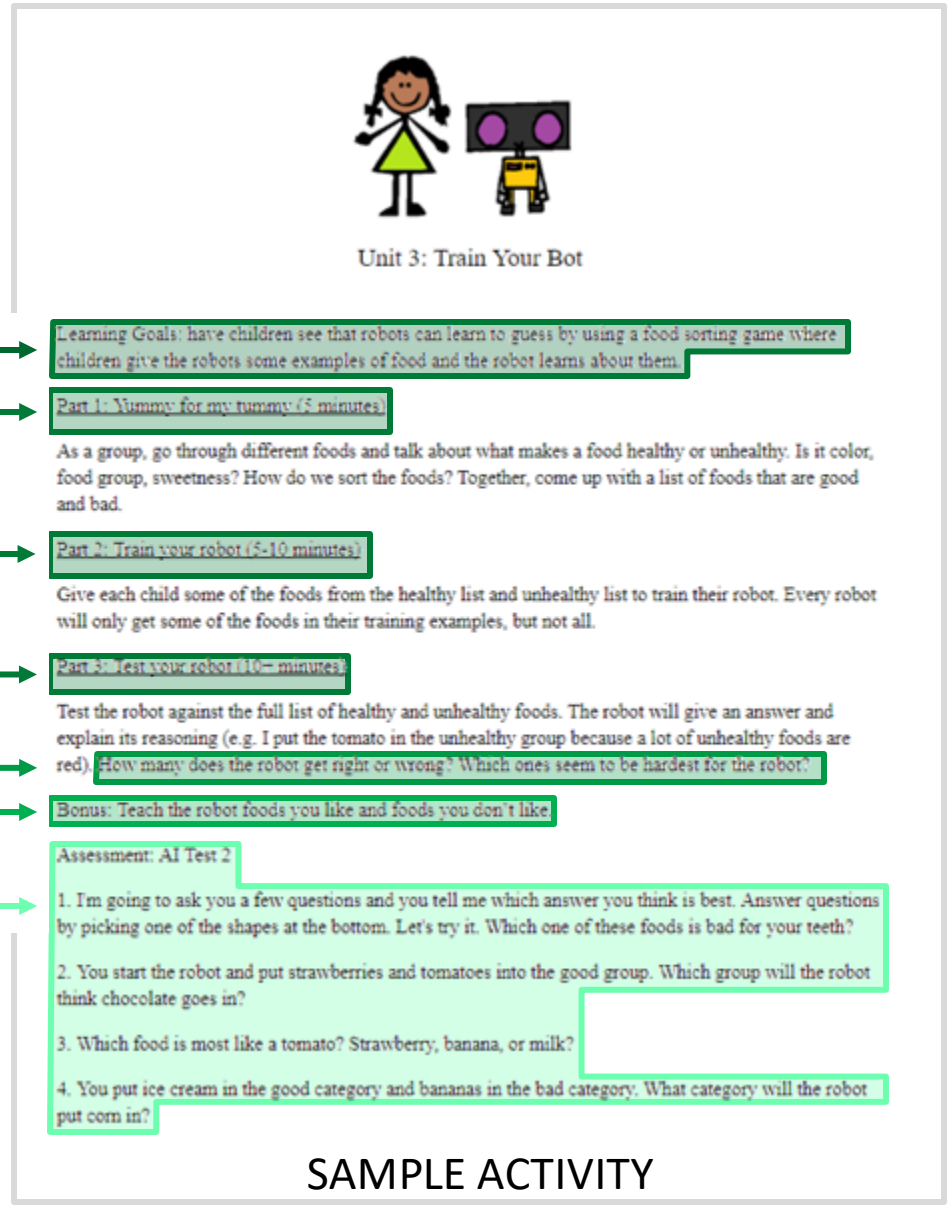
- Target STEAM and life skills for every activity

- Activities broken into telescopic subsections

- Critical observation and reflection questions

- Extended activity suggestions for enthusiastic learners

- Concept-related multiple choice questions



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SAMPLE ACTIVITY

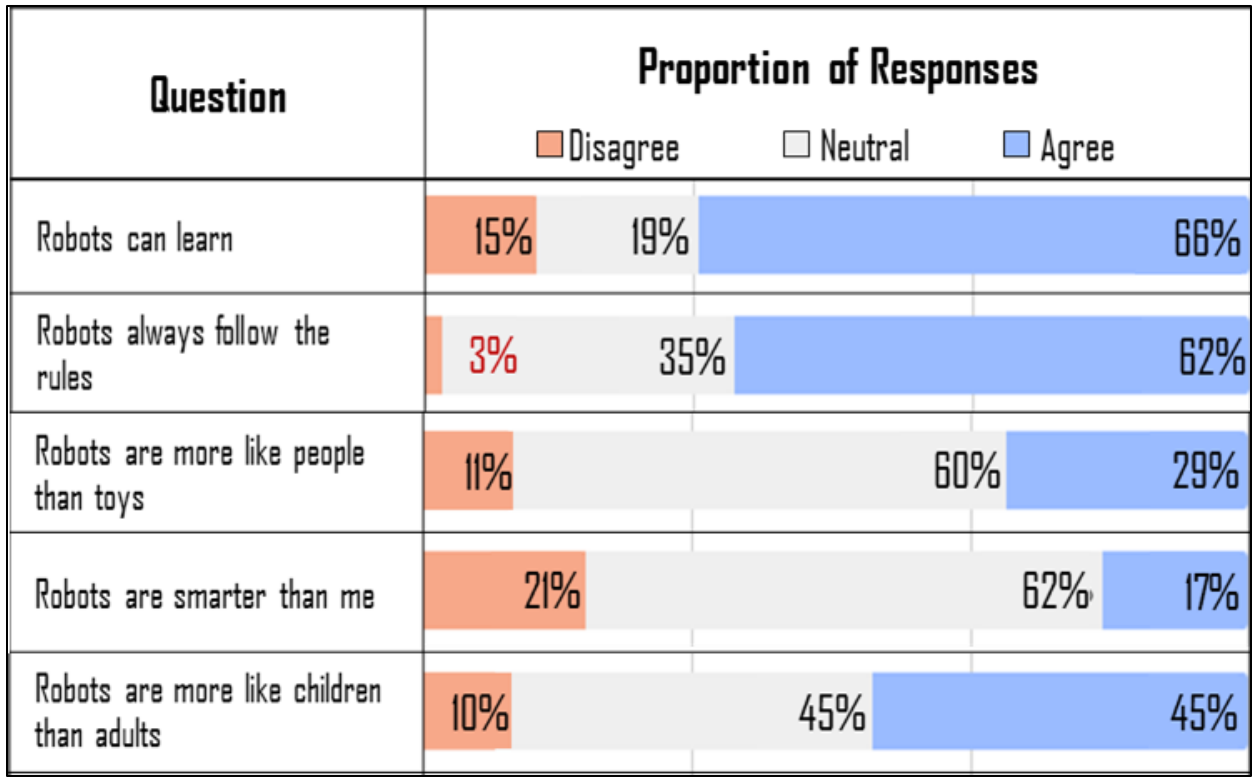
CLASSROOM

AI ACTIVITIES OVERVIEW

Each AI activity was designed to introduce AI concepts while reinforcing other life skills

ACTIVITY	MAIN AI CONCEPT	AI CO-CONCEPTS
ROCK PAPER SCISSORS	KNOWLEDGE BASED SYSTEMS	Reinforcement Learning, Training Set
ROBOT REMIX	GENERATIVE AI	Probability & Randomness, Modelling
FOOD SORT	SUPERVISED ML	Nearest Neighbors, Classification

HOW DID LEARNING ABOUT AI CHANGE CHILDREN'S PERCEPTION OF AI?

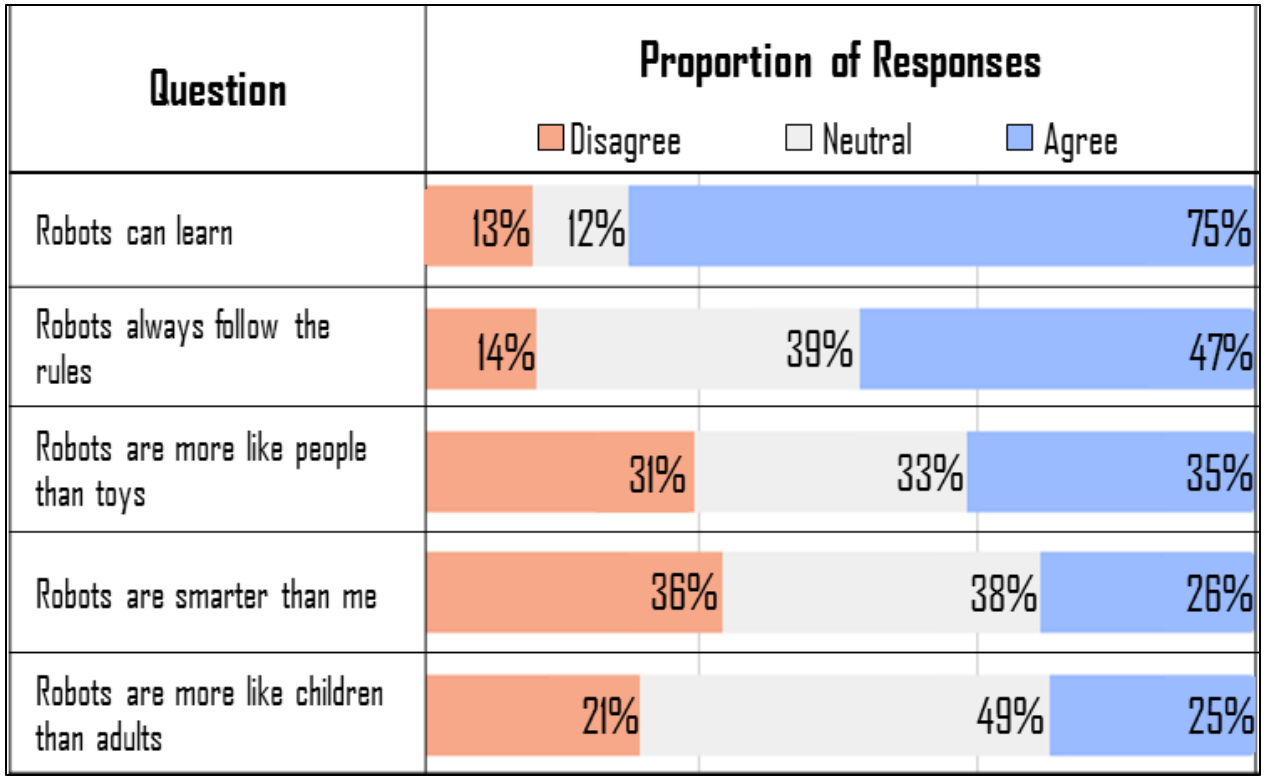


Before ↑

1. Children felt strongly that robots could learn and that they always follow the rules.
2. For other questions most were unsure.

After →

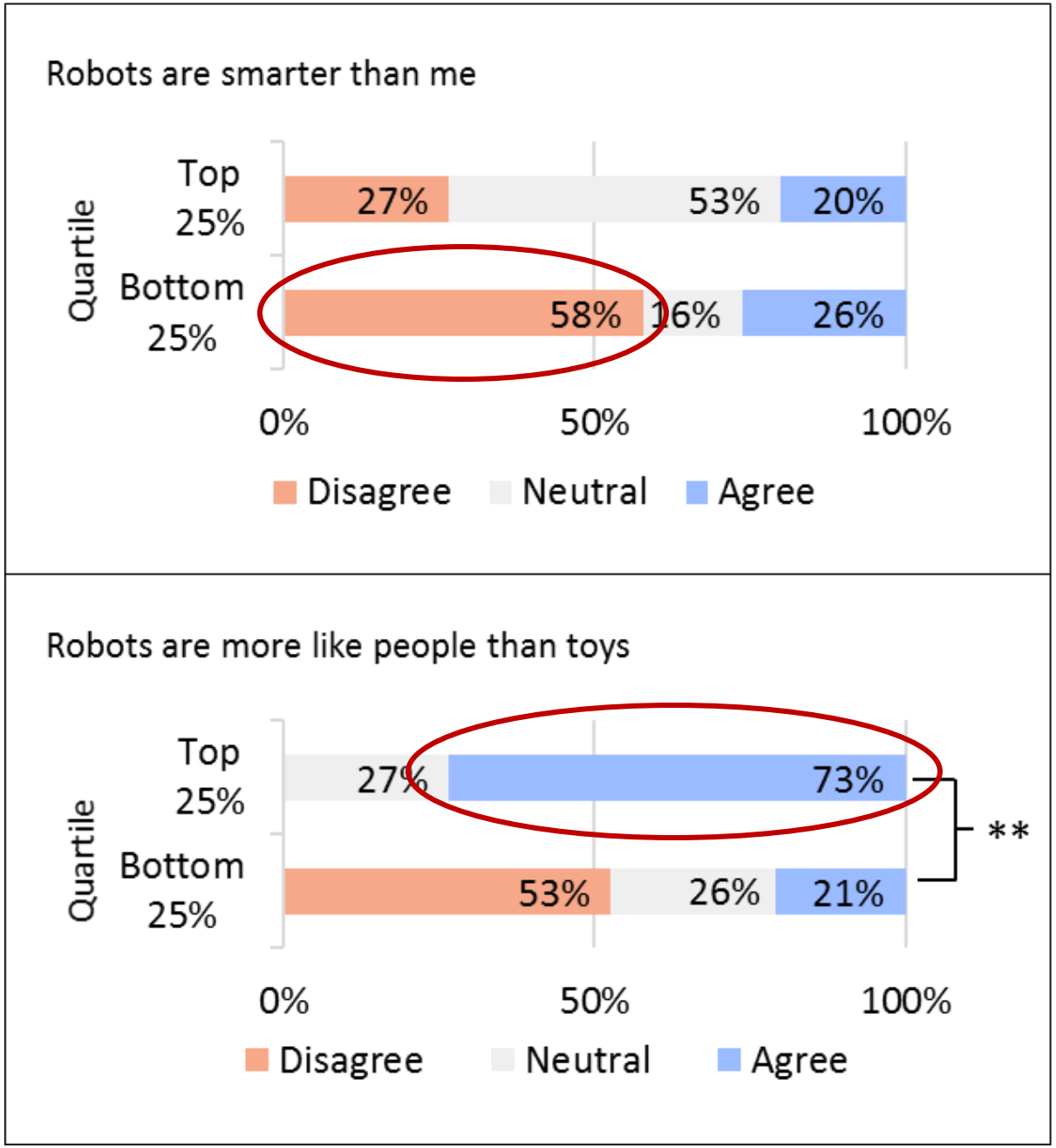
1. Children felt more strongly that robots could learn, but less strongly that they always had to follow the rules.
2. Many children in the middle chose a side.

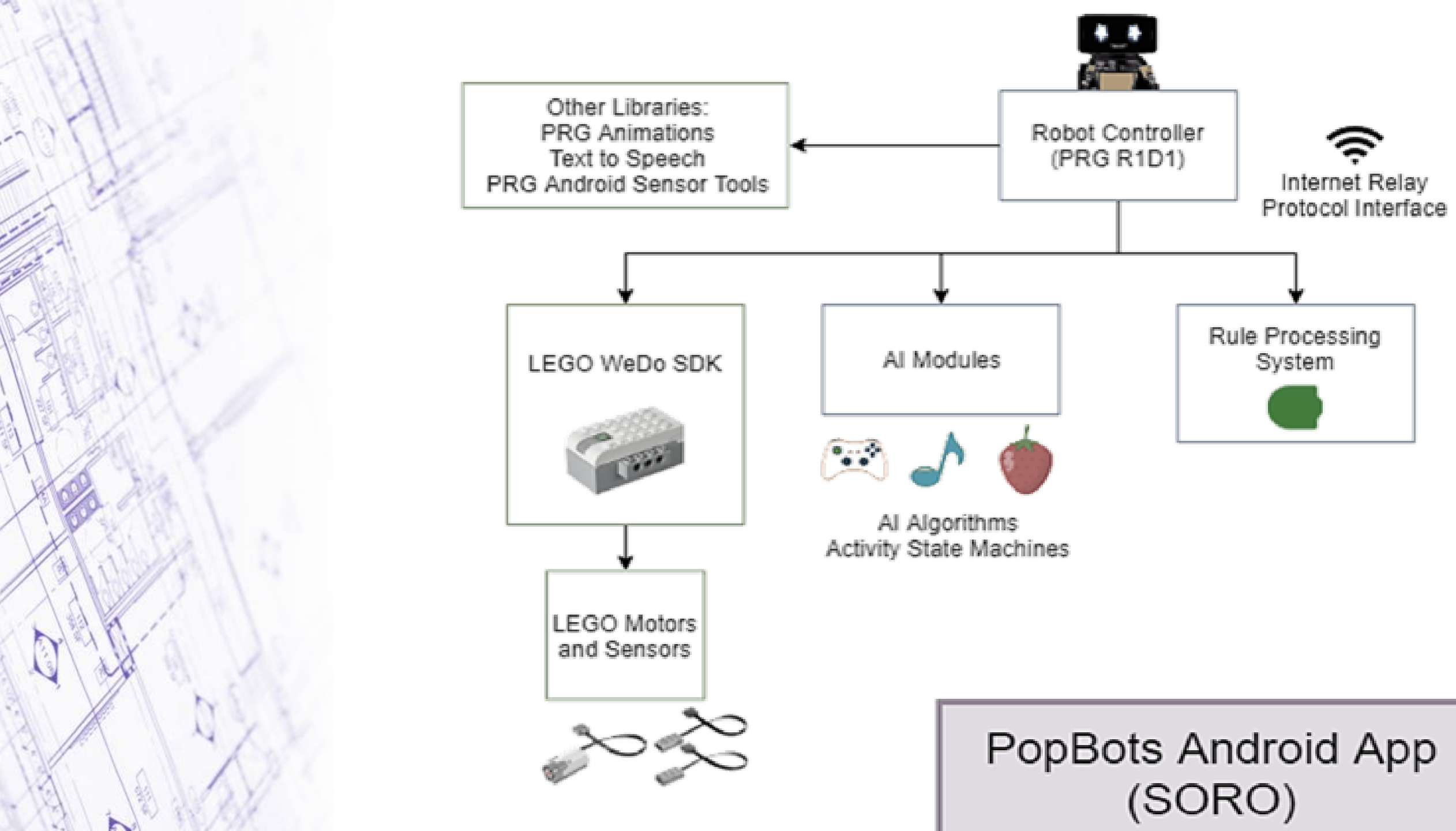


Williams, R. et al., A is for Artificial Intelligence. 2019

HOW DOES LEARNING ABOUT AI CHANGE ONE'S PERCEPTION OF AI?

Children who learned the most about AI were more likely to see robots/AI as smart and more like a person.




Other Libraries:
PRG Animations
Text to Speech
PRG Android Sensor Tools
Robot Controller
(PRG R1D1)
Internet Relay
Protocol Interface
LEGO WeDo SDK
AI Modules
Rule Processing
System
AI Algorithms
Activity State Machines
LEGO Motors
and Sensors
PopBots Android App
(SORO)

PILOTING POP BOT

WHAT DID CHILDREN LEARN

We saw that children could not only use AI in their robots, they could also express different concepts in their own words

TRAINING

Researcher: How did the robot work?

Lily (6-years-old): I taught the robot the rules of the game...[then] it would learn as I go.

ONLINE LEARNING

PILOTING POP BOT

HOW DID CHILDREN LEARN

We saw that children's understanding of algorithms was anchored in their social interactions with the robot

Researcher: So who won more? You or the robot?
Lily: The robot.

Ivy (6-years-old): The robot. Well, at first [I won a lot], but then the robot kept saying 'I think you will put rock' and I had put rock so it won. The robot got smarter the more we played.

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IMPACT OF CHILDREN LEARNING

Afterwards, children used their new knowledge to grapple with the implications of artificial intelligence

Researcher: So who's smarter now? You or the robot?

Lily: Well...maybe the robot. But I taught it. So actually I'm still smarter for now but I think the robot can get a lot smarter.