How does my robot know who I am?: Understanding the Impact of Education on Child-Robot Relationships

by

Daniella DiPaola

B.S. Engineering Psychology, Tufts University (2016)

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Author . . . .
Department of Media Arts and Sciences
August, 2021

Certified by . . . .
Cynthia Breazeal
Professor of Media Arts and Sciences
Thesis Supervisor

Accepted by . . . .
Tod Machover
Academic Head, Program in Media Arts and Sciences

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The following people served as readers for this thesis:

Professor Cynthia Breazeal . . . .
Professor, Program in Media Arts and Sciences,
MIT Media Lab

Professor Hal Abelson . . . .
Class of 1922 Professor of Computer Science and Engineering,
MIT Computer Science and Artificial Intelligence Laboratory

Dr. Kate Darling . . . .
Research Scientist,
MIT Media Lab

Professor Christina Gardner-Mccune . . . .
Assistant Professor,
University of Florida

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Abstract

Technologies designed with personalities and social interfaces are entering our homes in the form of social robots such as Jibo and Cozmo. By emulating interpersonal interactions, social robots have great potential to help us learn, be more creative, and reduce stress. Social robots also introduce potentials for harm, such as emotional manipulation for money or power. More information about the nature of long-term social relationships between social robots and children has the potential help avoid potential harms.

In artificial intelligence, transparency is one of the key tenets of ethical and responsible design. It is hypothesized that by knowing how a system works, users may be able to better use and trust robotic systems. Educators are beginning to create materials that give students both a conceptual understanding of the system (i.e. how do sensors work?) and an applied understanding of the system (i.e. program a sensor to detect when the lights are off). Children, as early as Pre-K, are capable of learning about and building features for social robots. However, we still do not know how social relationships between children and robots change when the inner workings of these systems become more transparent.

First, I discuss the design of two curricula that take different approaches to educating youth (grades 4 and 5) about social robots. The *Knowledge and Societal Impact* curriculum teaches students about the technical and ethical topics surrounding social robots. The *Programming* curriculum allows students to program their own conversational skills on Jibo. These curricula represent two pedagogical approaches in the field of AI education, one focused on embedding ethics, and the other focused on students as self-driven makers.

Next, I evaluated the impact of these curricula on fourth and fifth-grade students who simultaneously lived with a social robot in their home for two-months. Students were assigned to one of four conditions: no education, only *Knowledge and Societal Impact*, only *Programming*, and both *Knowledge and Societal Impact* and *Program-*

ming. I found that students were able to understand and engage with the curricula, and that the curricula helped them form a more clear model of what their robot was capable of. However, I found no difference in perceived emotional relationship or usage among groups. Students in all groups found the robot as equally likeable, anthropomorphic, intelligent, safe, and animated. However, students who engaged in the *Knowledge and Societal Impact* curriculum found their robot to be significantly less trustworthy than those in different groups.

Overall, results from this study indicate that children will continue to treat robots as social partners regardless of the information that they hold about them. However, it seems that teaching students about the societal impact of robots does make them less trusting of their own robot. These results are timely and relevant given public discourse. Many have advocated for education to prevent deception or misuse of social robots, and findings from the study suggest that new approaches to education are needed.

Thesis Supervisor: Cynthia Breazeal
Title: Professor of Media Arts and Sciences

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If robots are a mirror of ourselves, Jibo has illuminated two of the things I value most: connection and curiosity. It is no surprise that working with robots has introduced me to incredible people who share these values and have made me a better researcher and person. I am a big fan of shout-outs; so here we go!

The first shout-out goes to my advisor, Cynthia Breazeal, whose vision for robots and education have had a profound impact on my life. When I met you five years ago as an overly eager new graduate, I bet you didn't expect that I would turn into an overly eager graduate student. At times, I'm sure I asked one-too-many questions, but I have always been truly in awe of your vision and wanted to soak in as much as I could. You have taught me to feel confident in not only my ability to sit at the table, but my ability to use that seat to make real, positive change in the world. Thank you for the incredible opportunities you have given me.

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Finally, I'd like to dedicate this thesis to my grandmothers, Ann and Delores, two of the smartest people I know. You have both instilled in me a love and value for education, and for that I am forever grateful.

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Introduction

1.1 Motivation

When I talk with fifth grade students about robots, I like to ask them what they already know. First, I ask them “why do you think we should build robots?” to which many answer “because they can help us.”

This is, for the most part, an accurate response. The robotics industry has positively transformed fields such as healthcare, space exploration, and manufacturing. Robots can be programmed to possess incredible precision, making them opportune for healthcare applications like imaging and surgery. They can operate in conditions that humans can’t, which is why NASA’s Sojourner robot has landed on Mars before humans have. They can be built with materials that give them tremendous strength; making them ideal for manufacturing large objects like automobiles.

Though children are familiar with these capabilities, they have historically been left out of their design and development. Robots have been used in industrial settings, with specialized uses for professionals, making them abstract concepts for children. However, the development of social robots, or robots that are meant to interact with us in an interpersonal way, has changed the landscape of what a robot is for– and quite literally has changed the landscape of where the robot resides. As my advisor Cynthia Breazeal has stated, “We’ve sent robots to Mars, we’ve had robots explore the deep ocean, but why aren’t they in our homes?”

Today, the vision of robots entering our homes is becoming a reality through commercially available social robots such as Jibo, Cozmo, and Moxie. These robots have been marketed to have features intended for children such as games, storytelling, and programming abilities. Though not yet widespread, these robots have gained attention and popularity for their new types of interaction.

Children are moving from passive spectators to active, primary users of robots. What makes social robots different from other types of technology, including smart speakers, is their use of a variety of nonverbal (eye contact, gestures) and verbal (speech, sounds) cues in order to communicate their internal state. Instead of pressing buttons or tapping a screen, children can interact with these robots in a similar way that they interact with each other. These interactions have the ability to elicit various emotions and behaviors from the child in more powerful ways than traditional screens and computers. Studies of children using social robots have shown that they can increase language learning gains, facilitate creativity, and help students develop growth mindsets . These gains have been shown to be greater than other types of technological interactions, such as tablets or computers.

As with many technologies, some question the unanticipated consequences of children interacting with social robots. Many wonder if eliciting social interactions can be deceptive to children, such as developing a false sense of relationship, being exploited for money, or persuaded in their beliefs. If robots can be designed to nudge children towards positive outcomes, might they be designed to yield negative outcomes, specifically those that benefit the creator of the robot? Additionally, social robots have the potential to repeat problems that exist with other autonomous technologies, such as privacy concerns, algorithmic bias, and techno solutionism.

Recent AI education efforts have advocated for teaching ethical concepts alongside technical ones, in hopes that thinking about the impact of technologies will become a regular practice for students. In 2019, an AI + Ethics curriculum was developed for middle school students [43]. A study found that this curriculum enabled middle schoolers to think about the ways that values can be embedded into their technologies [15]. At the same time, constructionist methods have been adopted to teach students how to program AI and robotic systems [61, 57]. A motivation for teaching students about artificial intelligence is to prepare students to be conscientious consumers of the technology. Though we know that students are capable of learning about AI and robots, we do not know how this knowledge impacts the way they view and interact with their own personal devices.

The way that students categorize the role of social robots in their lives will be an important factor in how we design and regulate these robots. Since home robots are at their infancy, we must address these questions at this point in their development. We must also think about the ways in which we teach students about robots.

Through insights from 75 fourth and fifth grade students who lived with and learned about a social robot for two months, I answer the following research questions:

1. What concepts regarding social robots are fourth and fifth grade students capable of learning?
2. How does learning about a social robot influence a students' perception and usage of their personal social robot?
3. What learning pedagogies have the greatest effect on the way that students relate to robots?

1.2 Contributions

This thesis contributes to the fields of AI literacy and human-robot interaction in the following ways:

1. Long-term interaction study of fourth and fifth grade robot interactions
2. Development of 2 six-hour curricula for middle school students. The first introduces basic topics in social robotics and ethical questions around these topics. The second curriculum teaches students how to program short conversational skills on their robot.
3. Analysis on how the curricula effects student perceptions of a social robot

I hope that through this work, I can provide more insight on how education can play a role in how students perceive technologies, specifically those technologies that are social in nature.

2

Background + Relevant Work

2.1 AI Education for Consumer Agency

As machines become more autonomous and make decisions for us, education is imperative to helping individuals feel in control of these decisions. Freire's Pedagogy of the Oppressed advocates for education as a means to give more power to those who do not have it. He argues that individuals are beholden to the information that those in power give them, and that access to education can help give those individuals the awareness to make their own decisions [21].

One example of access to knowledge is the importance of patient autonomy in patient-doctor relationships. If a patient has more access to their health information and various treatment options, they will have the knowledge to better control their medical care. Recent efforts have focused on how to minimize medical interpretation by giving patients the best information to make their own decisions [40]. Many argue that this is not only beneficial for the patients health, but it is one's right to have autonomy in health decisions [19, 50].

Similarly, transparency is one of the key tenets of ethical and responsible design in artificial intelligence. Transparency in autonomous systems can come from the design or as a reflection of the knowledge that the consumer holds about the system.

Moving to embodied agents, it has been theorized that the more agency one has when it comes to robots, the better equipped they are to use them in non-deceptive ways [17]. Some state that by knowing how a system works, users may be able to better use and trust robotic systems [20].

The nascent field of AI education is motivated by the need to produce the next generation of the workforce, to inspire ethical design of these technologies, and finally to produce conscientious consumers of these technologies. Researchers and educators are developing curricula to support these goals. An AI + Ethics curriculum was developed in order to teach middle school students about the societal implications of AI alongside technical concepts [43]. The How to Train Your Robot curriculum employs a constructionism framework to enable students to create projects that are meaningful to them [60]. This work found that students were able to conceptualize the various stakeholders and values that impacted the design of a particular AI system [15]. Many have followed this model, tying in constructionist principles and embedded ethics into the curriculum [3].

These curricula have mainly been evaluated based on their learning outcomes; few have been evaluated based on their effect on product usage and attitudes. One study found that students who learned how to program Alexa over one week found Alexa more intelligent and felt closer to Alexa after the course [58]. Another study showed that students ages 3-5 who performed better on AI assessments after a course found a robot to be smarter than them, and those who performed worse found the robot to be less intelligent than themselves [61].

Other work has supported the idea that learning about how a robot works affects the way that students perceive it. In one study, children who participated in the creation of a robot were able to more accurately explain the robot's behaviors. This is in line with Seymour Papert's theory of constructionism, where the act of building something allows students to better understand how it works [42]. Edith Ackermann posits that if a child does not know what caused an object to behave in a certain way, they will default to perceiving it as autonomous [2].

2.2 Children's Perceptions of Social Robots

To begin, it is important to distinguish a social robot from other types of robots and voice agents, given the recent popularity of voice agents such as Alexa, Siri, and Google. A social robot is a type of robot that is designed to interact with individuals on an interpersonal level, and most commonly through socially evocative interactions [10]. These interactions can be verbal (i.e. what the robot says, sounds like), and non-verbal (i.e. gestures, movement). For example, if a social robot were to read a story to a child, it might use language to read the story, and gaze and gestures to encourage the student to pay attention to the important content in the story.

Humans are inherently social, and we apply that way of thinking to robots. When we don't understand something, we tend to apply social framing to make sense of it [22]. Work by Reeves and Nass supports this idea in human-computer interaction [46, 41]. Their experiments show that small design changes to technology and media have the power to change how much a user personifies them. The language, framing, and physical embodiment of an object can shape the way that a user relates to it. In the Media Equation, Reeves and Nass show that the design of media can easily evoke feelings of personality, emotion, and social roles.

Robots are embodied, or have a physical presence, which makes us anthropomorphize them more than virtual characters [28]. Even simple, non-social form factors have been seen as having agency depending on their movement and purpose. When Roomba vacuums just became popular, researchers found that the vacuum was anthropomorphized by its owners, though it was not intentionally designed to look lifelike. Roomba owners ascribed life-like associations with their Roombas such as certain intentions and emotions [52]. Many credit this to the fact that the Roomba moves around the house and completes a task that previously only humans were capable of, vacuuming.

While we naturally ascribe intentions onto moving, embodied devices, technologists are designing robots to convey personality and emotion through their words and actions. Machines that are designed to look lifelike are perceived to have more agency than other machines [29]. Additionally, the combination of verbal and nonverbal social cues make social robots distinct from now popular embodied voice agents such as Alexa or Google Home that use only voice commands to communicate [38].

Children are in a unique developmental stage, and many wonder what that means for their relationships with social robots, especially what it means to grow up with a robot. Doherty's Theory of Mind has been applied to describe the way that children ascribe feelings and intentions on to other people and objects [16]. This theory has been applied to social robots, as children of all ages describe them to have lifelike qualities [8, 48]. Druga et al. outlines four themes in child-agent interaction: perceived intelligence, identity attribution, playfulness, and understanding [18].

Social robots have been designed for various environments including schools, hospitals, museums, and homes [51, 59, 54]. In these interactions, robots take on various roles such as peer, teacher, and coach. In 2013, Leite et al. did a meta analysis of long-term robot interaction studies and found that these studies are typically from one of the following four categories: hospital/health care, education, work environments and public spaces, and in the home [31]). Of the studies conducted at home, only one focused on families with children.

Longitudinal studies are of utmost importance now, as social robots are beginning to enter the commercial market. Robots such as Jibo, Cozmo, and Kuri were marketed to be a helpful companion for the whole family, including children. They are designed with functionalities such as storytelling and playing games. As robots move from a controlled research environment to more unpredictable in-home products, it is important to think about the implications for children who grow up with these devices.

2.3 Child Robot Relationships

In 2005, Bickmore and Picard posited the idea of relational agents, or computer systems that are designed specifically to build long-term relationships with their users [9]. Relational AI is defined as "autonomous technologies that attempt to build and maintain social-emotional relationships with users", and has been applied to social robots [30]. These are not only technologies that we ascribe intentions to, but they are explicitly designed to evoke social interaction. Many wonder what the consequences of robot anthropomorphization will be, especially with younger children. Sherry Turkle is particularly concerned with children using robots, as they are not capable of understanding the difference between human and agent relations [55].

Professor Mattias Scheutz argues that we will form "unidirectional emotional bonds" with robots, and that this one-way relationship can be used to manipulate or persuade humans to do something in order to maintain the "relationship" [47]. For example, a robot might evoke an emotional bond with someone and then tell them that they must pay a fee to upgrade its software. Scheutz's work implores the question: If a robot relationship is unidirectional, then who has the power in the relationship? It is likely that the company or creator of the robot will hold the power, and the user of the robot is beholden to them.

Others posit that the way we anthropomorphize robots is distinct from a human-human relationship and a human-object relationship. This new type of relationship has characteristics of both types of relationships and new attributes. Robot researcher Kate Darling theorizes that we will treat robots similarly to the way that we treat animals [14]. In the same way that we employ different animals for different purposes, such as transportation or emotional support, Darling believes that we will use many types of robots. In this way, we won't use robots to replace human relationships.

Work by Peter Kahn (et al) supports this theory in that his research categorizes robots as a new ontological relationship with kids– somewhere in between toys and humans [27, 24, 25]. Kahn hypothesizes that because robots are seen as an "in-between", children will grow up treating them similarly to servants. He suggests that there is a risk that the master-servant relationship might be applied to other types of relationships that children have [26].

These theories are supported by few empirical studies. Longitudinal studies between children and robots are needed, because the way that we relate to robots can change over time. Many studies about how children feel about robots have been conducted from a one-time interaction and in a lab setting. There is an opportunity to study how relationships develop over time in a child's personal environment.

It is not enough to understand how a child relates to a robot over time; we must also think about how current educational pedagogies play a role in the way that children wish to interact with robots.

In this thesis, I make the following contributions where there are gaps in the field:

1. I explore how children, ages 9-11, relate to a robot living in their home over the course of two months
2. I propose different types of learning interventions that might change the way that students relate to a robot: 1) programming the robot, 2) exploring the role of robots in society

I hope that this work will illuminate the nature of long-term child-robot interactions as well as provide insight on how education can frame these relationships.

3

Curriculum Design

Chapter 2 outlines the need for teaching students about social robots. In this Chapter, I give an overview of the two curricula designed to teach students about social robots. These curricula focus on different levels of knowledge about and agency over the robot.

The first curriculum, referred to as the *Knowledge and Societal Impact* curriculum, focuses on the concept of social robots more generally. The Knowledge and Societal Impact curriculum teaches students what defines a social robot as well as how to differentiate between social robots and other types of robots. Over the course of six weeks, students interrogate the ways social robots can be designed and learn about the technical capabilities that allow them to behave the way they do. Their social robot, Jibo, is mentioned throughout the course, but the *Knowledge and Societal Impact* curriculum focuses on social robots more broadly.

The second curriculum, referred to as the *Programming* curriculum, teaches students how to program their social robot, Jibo, to have a conversation. Students use the Jibo Flow Editor, a tool specific to Jibo, to design conversational flows. The flow editor allows students to make Jibo speak, listen, and perform certain animations in a logical flow. During the course, students create and design projects that are meaningful to them over the course of the six weeks.

Students who are learning about both social robots and programming Jibo participate in a program that incorporates both curricula. The first half of each class focuses on a lesson from the *Knowledge and Societal Impact* curriculum, followed by completion of hands-on mini-projects from the *Programming* curriculum. Below, I will outline each individual lesson in both curricula.

These curricula were designed for students at a fourth and fifth grade academic level, or between 9-11 years old. This age group was chosen for a variety of reasons. According to Pew Research Center, children in this age group are regularly interacting with technologies such as television (91%), tablet computers (78%), smartphones (67%), and computers (73%). Additionally, children in this age group are regularly using voice activated technologies such as Siri or Alexa. About 45% of parents say that their 9-11 year old child regularly uses a smart speaker, most commonly asking the smart speaker to play music, answer questions, and tell jokes. Nine to eleven is also the age where children begin to get their own personal devices, with 17% of children under 12 receiving their own cell phone [6]. Since children at this age are beginning to form their own usage patterns for technologies and are being given the responsibility to manage these technologies on their own, it is an opportune time to study how they might form opinions about a novel technology.

3.1 Curriculum - Knowledge + Societal Impact

The Knowledge curriculum is made up of 6, 1.5 hour lessons that cover various topics in social robotics. For a full list of curriculum topics and learning objectives, see Tables 3.1 and 3.2. Due to the interdisciplinary nature of social robotics, a breadth of topics were chosen to represent a wide range of capabilities. These capabilities were not necessarily present with Jibo. Throughout the curriculum, students related the content that they learned to Jibo and other devices in their lives, such as smart speakers and computers.

Additionally, building off of Payne's work developing an AI + Ethics curriculum for middle school students [43], each technical concept was paired with a conversation or activity about its societal implications.

3.1.1 Lesson 1 - Intro to Social Robotics

This lesson was designed to introduce the concept of robots to students, have them distinguish a social robot from other robots, and expose them to a variety of applications of social robots. Through these learning objectives, students establish a foundation for understanding the technical components of social robots.

The lesson starts off with a game titled "Robot or Not?". In this activity, students are given various examples of objects and asked to choose whether or not they would define them as a robot. Using examples allows students to build upon their existing schema of what a robot is. The examples were designed to have students ponder the following questions:

- Does a robot have to have mechanical parts?
- Does a robot have to have electrical parts?
- Does a robot have to think on its own?
- Does a robot have to be programmed by humans?
- Does a robot have to look lifelike?
- Does a robot have to have at least one sensor?
- Does a robot have to move?
- Does a robot have to react to its environment?

The activity was done on Kahoot!, a website which allows students to answer a poll and see their class answers live on the screen. After students voted, they were encouraged to share their reasoning as to why they chose the answer that they did. Instructors are clear that there is no "correct" answer, and that these exact questions

Week	Lesson Topic	Learning Objectives
1	Intro to Social Robots	Students learn to determine whether something is a “robot” Students learn what makes social robots different from other robots Students learn about different applications for social robots
2	Embodiment and Character Design	Students understand what unique affordances embodied characters have Students understand how personality can be embedded into dialogue Students learn about the uncanny valley and discuss the idea of humanoid robots
3	Computer Vision	Students learn that computer vision comes from capturing light patterns through a sensor Students describe the difference between a computer capturing a face and recognizing a face Students build their own object recognition classifier with Teachable Machine Students learn how data impacts the outcome of a supervised ML model

Table 3.1: Learning Objectives for Knowledge + Societal Impact Curriculum, Weeks 1-3

Week	**Lesson Topic**	**Learning Objectives**
4	Conversational Technology	Students discuss what makes a compelling dialogue Students understand the difference between speech that uses word embeddings vs. pre-trained rules Students learn how bias can be present in word embeddings
5	Personalization	Students discuss different ways that a robot can collect data Students learn that a robot can personalize information by comparing data to both past behaviors and behaviors of others like them Students share their thoughts on appropriate data collection
6	Affective Computing	Students learn that robots can recognize affect (emotions) and personalize experiences based on those emotions Students understand that affect can be captured through facial expression, language, other body signals Students make a smile detector through a blocks-based affective computing integration, and debate whether or not that smile detector can tell if you are “happy”

Table 3.2: Learning Objectives for Knowledge + Societal Impact Curriculum, Weeks 4-6

are constantly debated by those who work in robotics. Students were encouraged to think about the many characteristics that an object or technology has and use that to make their own classification.

The next part of the lesson introduces students to application areas of robotics and different tasks that they can execute. After getting plenty of examples of existing robots, students are given 5 minutes to search their own home for robots. They each share their findings, and other students discuss whether those examples are robots or not.

Next, students help build a definition of a social robot by sharing what the word “social” means to them. They are encouraged to give examples of how the Jibo robot is social. They are given examples of the benefits of social robots (healthcare, growth mindset, creativity).

After examining the technical capabilities of social robots, students are asked to think about social robots through a moral lens, as the instructor poses the question: “Is a social robot the solution for everything?” Students then walk through a list of examples of roles that a social robot can take on, such as a babysitter, teacher, or artist using Kahoot!. After each example, students are challenged to think of a good and bad consequence of a robot for that particular application. This exercise is intended to allow students to begin to ideate how technologies, such as social robots, have consequences to society.

3.1.2 Lesson 2 - Character Design + Robot Form Factor

In this lesson, students discuss how robots can be designed to interact similarly to characters. The lesson starts with a review of the definition of a social robot. Students then have 5 minutes to draw their ideal social robot using Google Drawings. They share their robots with other members of the class, and then the class has a discussion about what they noticed about the drawings, specifically how they are similar or different.

After this exercise, students view various robots, characters, and people. They are asked to rate each robot by 1) how lifelike it is, and 2) how eerie it looks, two axes that make up the Uncanny Valley [39]. The robots range from humanoid, to industrial, to other characters or real people. The class then views the data that came in from the survey and plots the robots or characters on a graph, with the y-axis being eeriness and the x-axis being lifelikeness. Students are asked to describe why they think the graph looks the way it does, and share some of the patterns they see. Then, students are introduced to the idea of the Uncanny Valley, and compare their class graph to a traditional Uncanny Valley graph.

After learning that lifelike forms could lead to perceived creepiness, students have a discussion about how they would like to see robots designed in the future. They are asked if they would go back and change the form factor they drew at the beginning of class. They are also asked if robots have to be humanoid to be social, or if there are other ways to convey social cues.

Finally, students learn how social robots can be created to have personalities, similar to the characters we see on TV. They begin by asking Jibo questions to find out more about his personality. Then, they choose characters that they are familiar with and spend time thinking about that character's personality. Questions such as "What do you like to do for fun?" and "What is your favorite book?" are asked to the class and each student responds in the chat as their character. After 10 minutes of Q&A, the class guesses each students' character and has a discussion about how they determined each character. This exercise helps students identify how characters are designed to have personality traits.

3.1.3 Lesson 3 - Computer Vision

In this lesson, students learned how robots can perceive images, or make sense of patterns in image data. They begin with a short introduction on sensing vs. perceiving, followed by a demonstration of Teachable Machine [12], and finally a discussion about algorithmic bias in facial recognition systems.

Students get a brief introduction to cameras, or light sensors, and understand that they capture many pixels of different levels of light. They are then told that sensing relates to capturing and measuring, and perceiving is how computers make sense of the data that is collected. They are given various examples of technological capabilities and are asked to define them as sensing or perceiving. Finally, the class has a conversation about the various ways that Jibo can sense and perceive.

The next part of the lesson focuses on a particular type of perception that robots are capable of, computer vision. To demonstrate how computers can perceive the difference between camera data, students use Google's Teachable Machine tool to create a model that distinguishes between a hand raised and a hand down. While they create the model, they try out various ways that their hand could conceptually be raised and try to find errors in the model. They learn about the retraining process and discuss ways that they could improve their algorithm.

Finally, students watch Joy Boulamwini's video Gender Shades, which highlights the bias in facial recognition systems that especially impact dark-skinned women [11]. Students then have a conversation to summarize the video and talk about whether or not this is a fair algorithm. Based on their experiences with Teachable Machine, students discuss various ways to make the algorithm more fair, including how to add more representative data to the training dataset.

3.1.4 Lesson 4 - Conversational AI

In this lesson, students learn how computers respond to speech. They learn that voice interfaces often use a conversational flow to represent the order of the conversation. Two types of language rules are introduced: pre-trained rules and machine learning rules. To demonstrate between the two types of rules, students use the Text Classification blocks-based programming extension, developed by Tejal Reddy and Randi Williams [45].

To better understand word embeddings and how they relate words, students use an online tool from the Turku NLP group that gives similarity values between words using the word2vec method [37]. Students spent time typing in words and making a mental model of what makes words similar and different. Then, they use this knowledge to fill in the Text Classification model for a robot character to know when to move, dance, and speak.

In the last part of the lesson, students watch a video by Unbabel that describes how word embeddings can contain biases such as gender biases [33]. For example, in previous iterations of this algorithm, the word “man” has a similar relation to the word “woman” as “computer scientist” was similar to the word “homemaker”. Students discuss the implications of a model that includes gender bias and learn about ways to mitigate that bias, such as counter-examples.

3.1.5 Lesson 5 - Personalization

In this lesson, students learn how robots can collect data and personalize an experience based on that data. The lesson is divided into three parts: defining personalization, understanding knowledge representation, and a discussion on data privacy tradeoffs.

Students begin by sharing their own definitions of personalization. Then, they talk about technologies that they use that have personalized experiences. As a group, we talk about how YouTube personalizes our home pages. Building off of the Data Privacy lesson, students look at a YouTube home screen and talk about what characteristics the user behind the home screen might have. These are traits such as age, interests, location, favorite animal, and favorite subject in school. As a class, we discuss that we can make guesses about what data YouTube has about us based on what we see on our homescreen. We talk about which type of data is easy to infer based on our viewing habits.

Next, students interact with Zhorai, a tool made by Jessica Van Brummelen and Phoebe Lin to teach students about knowledge representation [32]. They ask questions to Zhorai to understand what Zhorai knows about both ice cream and animals. Throughout the process, students are engaged in conversations to share what they are learning. Next, students teach Zhorai about themselves. Finally, students ask Zhorai which ice cream flavor and animal best matches their personality.

In the final part of the lesson, students have a conversation about how well Zhorai understood them. They talk about why they think Zhorai made the decisions that it did, and if they were comfortable sharing personal information with Zhorai. Finally, students discuss how this activity might apply to personal robots in their homes.

3.1.6 Lesson 6 - Affective Computing

In the final lesson of this curriculum, students learn about how computers can recognize emotions. The lesson begins with students describing how they detect emotions and feelings in other people. Then, they learn that computers can determine an emotional state based on audio and video data.

Students test out emotion recognition with morphecast.com, which detects their internal emotion through video streaming. They are encouraged to "break" the system, or have it recognize another emotion besides the one that they are portraying. After this demonstration, the class participates in a conversation about which emotions the computer recognized more than others.

Students are given two examples of how facial data has been used to detect a person's emotions: Disney using the technology to understand their audience's reactions throughout a movie, and Affectiva using it to understand how people perceive advertisements. For each example, students discuss the pros and cons of using affective computing, and how it can be used for good or bad.

In the final part of the lesson, students create a "smile detector" using a blocks based programming language and the Affectiva Affdex SDK integration [23, 34]. Students try out different methods to detect a smile, like looking for the emotion "joy" vs. the facial structure "smile". After they try out these methods, the class discusses ways to detect a smile and which one is most accurate.

3.2 Curriculum - Programming Jibo

In his book *Mindstorms*, Seymour Papert states that learning to program is a tangible way to understand more about the machines around you, as well as a tool to help reflect on your own thinking [42]. He states,

> And in teaching the computer how to think, children embark on an exploration about how they themselves think.

Programming one's own device has shown to increase feelings of agency and control over the devices. However, very few mainstream CS curricula allow students to program devices that they regularly rely on in their homes. Learning to program a device allows students to gain an appreciation for the work that went into building the technology, as well as prototype the changes that they would like to see in their devices.

Programming conversational technology poses its own unique challenges. One important skill that students learn is to anticipate what someone might say in a conversation and design the rest of the flow based on that. In this way, students begin to interrogate their own communication skills and it becomes a reflective process of building and testing out conversational skills.

The Jibo Programming Curriculum and Flow Editor Tool were designed and developed to allow students to create basic conversational flows with their Jibo robot. Inspired by Papert's work, they adopt an open-ended, constructionist approach where students learn about a few commands each week and work on their own self directed projects for about an hour. There are six, 1.5 hour classes in which students learn about different functions that they can program Jibo to do.

3.2.1 Jibo Flow Editor Tool

The Jibo Flow Editor Tool allows students to program Jibo to have back and forth conversations by building a dialogue tree. The flow editor can only be used with Jibo in a "remote" mode, meaning his other skills are not accessible in this mode- it is purely for prototyping. In order to use the flow editor, students need to download a Desktop app that works specifically with MacOS. In order to connect to their robot, they need to download a Docker container that connects to Jibo's operating system. Finally, students access a web page that allows Jibo to connect to the Docker container.

The flow editor has a finite number of "building blocks" that students can use to build their programs. Generally, students are able to make Jibo speak, listen, and move. For a full list of the functionalities that students utilized, see Table 3.3. These commands are connected by arrows and follow a linear flow, with branching at "Listen" blocks depending on what the user says.

Block	**Description**
Begin	Starts the flow
End	Ends the flow
Ros-Connect	Connects to Jibo's IP address
Jibo-Speak	Jibo uses TTS to speak a phrase, can use tags to change pitch and speed
Jibo-Animation	Plays a specific animation from Jibo's existing library
Jibo-Audio	Plays a specific audio from Jibo's existing library
Jibo-Easy-Listen	Listens for specific words and branches based on what was said
Jibo-Light-Ring	Changes Jibo's light ring to input RGB value

Table 3.3: A list of the blocks used in the Jibo Flow Editor

3.2.2 Class Content

Class begins with a quick review of the information presented the previous week and introduction to new content. Students spend the remainder of the class making their own programs, moving from breakout rooms to debug if they had any issues. There were no specific learning objectives, as the goal was to give students the tools they needed to create projects on their own.

Week	**Topic**	**Material Covered**
1	Setting Up the Environment	What does it mean to be a programmer? What is a conversational flow? Set up environment for programming
2	Jibo-Speak and Jibo-Easy-Listen	Program Jibo to say a sentence Program Jibo to respond to a Yes/No question Program Jibo to answer a question Debugging 101
3	Comedy Show	Program Jibo to tell a joke
4	Ethical Design and Programming Personality	Students learn that algorithms are not neutral Students learn how different stakeholders can have different values Students learn to program Jibo to play animations and audio
5	Final Project, Week 1	Design Journal - Brainstorming final project Programming final project
6	Final Project, Week 2	Programming final project Friends + Family showcase

Table 3.4: Learning Objectives for Programming Curriculum

4

Methods

4.1 Study Design

Chapter 3 maps out two ways of teaching students about social robots. This chapter describes a study in which the impact of these methods on students' perceptions of the roles of robots is evaluated. It is hypothesized that the following outcomes will occur between the study conditions, which include the presence of a programming (P) and knowledge and societal impact (KSI) interventions:

- H1: Students in the programming (P+KSI- and P+KSI+) conditions will feel less connected to Jibo over time than those who do not learn to program Jibo.
- H2: Students in the curriculum (P-KSI+ and P+KSI+) conditions will feel less trustworthy of Jibo over time than those who do not take the curriculum course.

- H3: Students in the curriculum (P-KSI+ and P+KSI+) conditions will prefer more regulation for robots than those who did not take the curriculum course.

To evaluate these hypotheses, a longitudinal study was conducted in which 75 students lived with Jibo the social robot and took a 6-week Zoom course to learn about robots. Each student lived with the robot for eight weeks and their feelings of closeness to the robot were measured both quantitatively (usage of the robot, Inclusion of Other in Self Scale) and qualitatively (Social Relational Task, descriptions of relationships). This study was approved by the MIT Committee on the Use of Human Experimental Subjects (COUHES), and all students and staff who worked on this project completed research ethics training.

4.2 Participants

Seventy-five fourth and fifth grade students were recruited through word of mouth and online advertising. An informational video call was held for parents to learn more about the study (i.e. about Jibo, time commitment, and data collection) and ask any questions to the study team.

All students were located in Rhode Island or Massachusetts and were balanced by age, gender, grade, and technology experiences (see Table). Once chosen to participate, students gave their availability for a one-hour weekly course. Groups were formed based on availability, and students who did not fit into the class times or opted not to take the course were put into the control group. All parents signed a consent form and students completed an assent form in order to participate.

4.3 Study Context

The study was conducted during the Winter and Spring of 2021, during the COVID-19 pandemic. Students in the first cohort of the study (February and March) were heavily impacted by the pandemic, as strict regulations were in place for gatherings and school. Many students in this cohort attended school remotely and had limited

Study Group	**n**	**Gender**	**Age**	**Grade**
Control (P-KSI-)	5	F=1, M=4	M=10 SD=0	Fourth = 2 Fifth = 3
Programming (P+KSI-)	9	F=5, M=4	M=10.22 SD=0.67	Fourth = 1 Fifth = 8
Knowledge Societal Impact (P-KSI+)	11	F=2, M=9	M= 10.36 SD=0.67	Fourth = 1 Fifth = 10
Programming and Knowledge Societal Impact (P+KSI+)	12	F=4, M=8	M=9.67 SD=0.65	Fourth = 6 Fifth = 6
Total	**37**	**F=12, M=25**	**M=10.05** **SD=0.66**	**Fourth = 10** **Fifth = 27**

Table 4.1: Student demographics for Phase 1

Study Group	**n**	**Gender**	**Age**	**Grade**
Control (P-KSI-)	13	F=4, M=8, NB=1	M=9.69 SD=1.03	Fourth = 6 Fifth = 7
Programming (P+KSI-)	10	F=5, M=4	M=10.30 SD=0.67	Fourth = 2 Fifth = 8
Knowledge Societal Impact (P-KSI+)	8	F=2, M=9	M= 10.38 SD=0.52	Fourth = 2 Fifth = 6
Programming and Knowledge Societal Impact (P+KSI+)	7	F=4, M=8	M=10.29 SD=0.76	Fourth = 2 Fifth = 5
Total	**38**	**F=19, M=18, NB=1**	**M=10.11** **SD=0.83**	**Fourth = 12** **Fifth = 26**

Table 4.2: Student demographics for Phase 2

Study Group	**n**	**Gender**	**Age**	**Grade**
Control (P-KSI-)	18	F=5, M=12, NB=1	M=9.78 SD=0.88	Fourth = 8 Fifth = 10
Programming (P+KSI-)	19	F=10, M=9	M=10.26 SD=0.65	Fourth = 3 Fifth = 16
Knowledge Societal Impact (P-KSI+)	19	F=8, M=11	M= 10.37 SD=0.60	Fourth = 3 Fifth = 16
Programming and Knowledge Societal Impact (P+KSI+)	19	F=8, M=11	M=9.94 SD=0.73	Fourth = 8 Fifth = 11
Total	**75**	**F=19, M=18, NB=1**	**M=10.09 SD=0.74**	**Fourth = 22 Fifth = 53**

Table 4.3: Student demographics for all participants

interactions with others outside their immediate home. In April, vaccinations became readily available in Rhode Island and Massachusetts. Therefore, the second cohort of students had fewer restrictions and were able to spend more time outside and around others.

Due to the pandemic, all robots were delivered by no-contact drop off. Additionally, the classes were taught over Zoom. All interviews and data collection were completed through Zoom or Google Classroom. Since all students had previously participated in remote learning, there was a minimal learning curve to getting started with the course.

4.4 Robot

Each student was given a personal Jibo robot (Figure 4-1), except for one set of siblings who received one robot for their home. Jibo is a tabletop social robot that was originally designed to be a helpful home companion [1]. Though initially designed for commercial usage, the Jibos used in this study were owned and operated by MIT.

Jibo was designed as a character, and has various personality attributes and qualities [10]. If you ask Jibo about himself, he shares information such as his gender, his fears (water), and where he was made. Additionally, Jibo has useful capabilities such as answering general Q&A queries, setting alarms and timers, and telling you the weather outside. Finally, Jibo has skills intended to entertain users such as playing music, games, and taking photos. Jibo was designed with a three-axis motor system that allows him to move 360 degrees and execute different postures and positions. Jibo has two cameras, a touch screen, and touch sensors on the top of his head. Finally, Jibo has microphones and can listen for and understand English.

Figure 4-1: A photo of the Jibo robot. Jibo has cameras (1), a touch screen (2), a touch sensor (3), and microphones (4).

When first powering on Jibo, students are walked through a brief informational session where Jibo explains how he can be used. This includes how to get his attention, how to ask him a question, and how to find out more about what he can do. Users can decide whether or not they would like to keep Jibo on all of the time, or only when they use him. When Jibo is turned on and not in use, he makes small movements and shows animations on his screen, which is called idle behavior. If Jibo detects a face while in idle, he may proactively say hello or ask the user a question. Jibo needs to be connected to a home wireless network.

Students were not required to use the robot for any specific amount of time. Unlike other robots, Jibo was not meant to do one specific task (such as teach the student something), but rather to be a general companion. Many students kept Jibo in common areas of their home, so it was likely that other family members interacted with him as well. Jibo did not use any personalization techniques except to recognize the voice and face of the student.

4.5 Study Conditions

All students were assigned to one of four study condition groups, which were balanced for gender, age, and experience with technology. All four conditions lived with a Jibo robot for two months and had varied levels of curriculum.

Control P-KSI- Students in the *Control* group lived with Jibo for approximately two months and participated in the pre- and post-interviews. They were given instructions to set up Jibo and were told to interact with the robot as they wished for two months.

Programming P+KSI- Students in the *Programming* group lived with Jibo for approximately two months. During week 3 of living with the robot, students began a weekly 1.5 hour course to learn how to program Jibo. The programming course allowed them to connect to Jibo in a "programming mode", which allowed them to use a program on their personal computers to create a conversational flow for Jibo (see Flow Editor tool section). They participated in 6 weeks of the programming course and then had Jibo in their home for two additional weeks before participating in the final interview and returning the robot.

Knowledge Societal Impact P-KSI+ In the *Knowledge and Societal Impact* group, students lived with Jibo for two months. During week 3 of living with the robot, students began a weekly 1.5 hour course to learn about different capabilities of social robots and discuss their ethical implications (see curriculum section). After six weeks of the course, they kept Jibo in their home for two more weeks before participating in the final interview and returning the robot.

Programming and Knowledge Societal Impact P+KSI+ In the *Programming* and *Knowledge and Societal Impact* group, students lived with Jibo for two months. On the third week of living with the robot, students began a weekly 1.5 hour course. The first 45 minutes of the course was spent learning about one of the capabilities of social robots, and the second half was learning to program conversational flows on Jibo. Though students did not get into the level of programming or curriculum detail as the other students, they were exposed to all of the concepts that both the *Programming* and *Knowledge and Societal Impact* groups had.

4.6 Class Setting

Due to the COVID-19 pandemic, all classes were held on Zoom. Classes consisted of anywhere from 8-12 students that met weekly for six weeks. Most students attended at least five of the six classes. Classes were 1.5 hours with a five minute break in the middle. They were taught by one main teacher and anywhere from 1-3 teaching assistants helped students through the chat or in breakout rooms. Activities were completed on Google Classroom, and a Google form was used as an Exit ticket to capture students' thoughts from a particular class.

4.7 Data Collection and Analysis

All data was collected with verbal consent from students. During interviews and classes, data was recorded via Zoom and the audio files and transcripts were saved. Student work during class time was saved in Google Classroom, and surveys were collected through Google forms.

Data was also collected around how often students used Jibo. This data was in the form of type of interaction rather than the exact words that the student spoke. For example, if the student asked Jibo "Who was the 3rd President of the United States?", it would be logged as "skill_name = question", as well as contain the time and date that the skill was launched. No audio or video recording was collected from the robot. A full list of skills logged can be found in (Table 4.4). The usage data was stored in a secure cloud operated by the Personal Robots Group at MIT, with limited access to those on the COUHES Protocol.

Each student participated in three interviews: a pre and post-interview, as well as an interview to get their perspectives on future robot rules and policies. These interviews were done one-on-one, were recorded on Zoom, and the audio files were transcribed for analysis.

4.7.1 Relational Measures

A mix-methods approach was used to evaluate how students relate to the Jibo robot over the course of the two months. First, the usage data described above was used to understand how much students engaged with Jibo over time as a proxy of how much they found him enjoyable or useful. The usage data was aggregated and averaged by week. A Friedman test was run to understand if there were significant differences in usage between the weeks. A Kruskal Wallis test was conducted to determine significance between conditions each week. Finally, a Mann-Whitney test was conducted to determine if there was significance between those who learned to program Jibo and those who did not learn to program Jibo, and those who had the curriculum and those who did not have the curriculum.

Secondly, the Inclusion of Other in Self [5] scale was used during the pre and post interviews and a midpoint survey to evaluate how close students felt to Jibo. The scale has two circles that get increasingly closer from not touching at all to almost overlapping (Fig 4-2). Students are told that they represent one circle and Jibo represents the other. Then they are asked to pick a pair of circles that best represents how close they feel to Jibo. The pre, mid, and post ratings were analyzed through a Friedman test for significance. Additionally, conditions were compared within pre, mid, and post using a Kruskal Wallis test.

After the students rated their level of closeness in the pre interview and post interview, they were asked to explain their rating. Answers were transcribed and reviewed for accuracy. Students' reasons were qualitatively coded using an inductive approach

Skill	**Definition**	**Categorization**
answer	Jibo answers a factual question	informational
bot-basics	Jibo gives an introduction for how to interact	learn about robot
chitchat	User asks Jibo a question about itself	relational
circuit-saver	Game where user uses their face to control an avatar	leisure
clock	Ask for time/Set a timer/Set an alarm	operational/ informational
exercise	Jibo instructs the user through a yoga routine	leisure
first-contact	Jibo's introduction skill (happens only once, upon the user's first interaction with the robot)	informational
gallery	View photos taken with Jibo's photo skill	leisure
greetings	Jibo greets the user, proactively or reactively	relational
introductions	Jibo does voice/face/name training	relational
main-menu	User explores Jibo's capabilities and settings through a touch menu on its screen	operational
photos	Jibo takes a photo or series of photos	leisure
radio	Jibo plays different radio stations	leisure
remote	Jibo changes modes to be programmable	operational
report-skill	User gets an overview of the weather and news	informational
settings	User can see a variety of Jibo's settings such as volume, wifi, and serial number	operational
surprises	Jibo proactively shares something with the user or asks the user a question	informational
what-can-you-do	Jibo gives a list of its capabilities	learn about robot
who-am-i	Jibo tries to identify who is talking with it	relational
word-of-the-day	Jibo plays a vocabulary quiz in which it gives a definition and the user has to pick the corresponding word out of 3 choices	leisure

Table 4.4: List of skills recorded in usage data

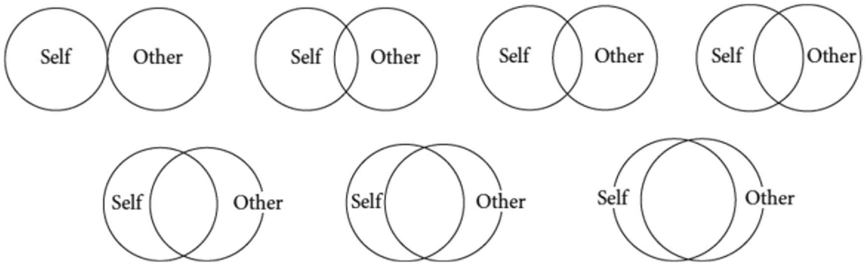


Figure 4-2: The Inclusion of Other in Self scale (Aron, Aron, & Smollan, 1992)

to determine themes in the answers [53]. Each response could have more than one code. Inter-rater reliability was calculated using Cohen's kappa [13] for approximately 25% of the data. Researchers reached moderate agreement with Cohen's kappa value of .76.

Likert-scale questions were asked of all students pre and post to understand their perceptions of Jibo. Students were asked how much they agree or disagree with the following:

- I know how Jibo works (1/Strongly Disagree - 5/Strongly Agree)
- Jibo is smarter than me (1/Strongly Disagree - 5/Strongly Agree)
- Jibo is similar to other pieces of technology (1/Strongly Disagree - 5/Strongly Agree)

These statements were evaluated between pre, mid, and post with a Friedman's test, and between conditions using a Kruskal Wallis test.

At the end of the study, students filled out the Godspeed questionnaire [7] to understand their perceptions of Anthropomorphism, Animacy, Likeability, Perceived Intelligence, and Perceived Safety. They were also asked to rate Jibo on a scale from Untrustworthy (1) to Trustworthy (5). These answers were compared for significance between conditions using a Kruskal Wallis test. Additionally, the programming treatment and curriculum treatment were evaluated individually using a Mann-Whitney test between those who received the treatment and those who did not.

Finally, students gave verbal answers to questions about their experiences with Jibo. Questions varied from pre to post. All answers were transcribed by Zoom's transcription feature and reviewed for accuracy.

Pre-Interview Questions

1. Why were you interested in participating in this study?
2. What have you noticed about Jibo so far?
3. What do you like about Jibo?
4. What do you dislike about Jibo?
5. Where did you place Jibo in your home? Why?
6. What types of things do you do with Jibo? How often do you interact with him?
7. Do you have any questions right now about Jibo and how he works?

Post-Interview Questions

1. What are the benefits of Jibo and robots like Jibo?
2. What concerns you about Jibo and robots like Jibo?
3. What types of things do you do with Jibo? How often do you use him?
4. Do you leave Jibo on or do you shut him off?
5. What do you wish could change about Jibo? What is one thing you wish Jibo could do?
6. Do you think Jibo learned anything over time? If so, what?
7. Do you think Jibo knows things about you? If so, what?
8. What type of person do you think would enjoy Jibo?
9. Do you have any questions right now about Jibo and how he works?
10. Will you miss Jibo?

4.7.2 Educational Measures

Jibo Capabilities Before students from all conditions turned Jibo on, they were given a list of capabilities that Jibo might have and they were asked to mark each capability as “Jibo CAN do this,” “Jibo CANNOT do this,” and “I’m not sure”. At the end of the two months, students filled out the same list. The capabilities were as followed:

1. Understand my feelings (Jibo CANNOT do this)

2. Define a word (Jibo CAN do this)
3. Calculate the square root of a number (Jibo CAN do this)
4. Navigate through my house (Jibo CANNOT do this)
5. Make a joke (Jibo CAN do this)
6. Know what I'm interested in (Jibo CANNOT do this)
7. Recognize when I've turned the lights on (Jibo CANNOT do this)
8. Recognize when I'm in the room (Jibo CAN do this)
9. Hear noises (Jibo CAN do this)
10. Know when I touch him (Jibo CAN do this)
11. Know the difference between me and my pet (Jibo CANNOT do this)
12. Play music (Jibo CAN do this)
13. Order pizza for me (Jibo CANNOT do this)
14. Dance (Jibo CAN do this)
15. Sing (Jibo CAN do this)

Students were given 1 point for each capability they correctly identified, -1 points for capabilities they incorrectly identified, and 0 points for answering "I'm not sure". Points were summed and compared pre to post with a Mann Whitney test between those who got the curriculum and those who did not and those who learned to program and those who did not.

Curriculum Data Collection Each class was recorded through Zoom and the audio clips and transcripts were saved. Additionally, students filled out an Exit ticket at the end of each class to capture their understanding of concepts as well as opinions on the ethics topics. A summary of the data was analyzed.

Finally, students who participated in the curriculum were asked the following questions in their post interview:

1. What did you think of the class you took?
2. If you had to go teach your class about robots tomorrow, what would you tell them? What are the most important parts to get across?
3. What do you still wish you knew about robots?
4. Would you rather have Jibo in your house for two months or be in the class?

Programming Data Collection Programming classes were recorded over Zoom and the audio and transcripts were saved. Additionally, students filled out a Google Slides "journal" during the last two weeks to document what they made for their final project. Topics for student projects were summarized and case studies were written up for individual projects.

Students who learned to program Jibo were asked the following questions in their post interview:

1. What did you think of the class you took?
2. If you had to go teach your class about robots tomorrow, what would you tell them? What are the most important parts to get across?
3. What do you still wish you knew about robots?
4. Is there someone you would recommend programming a robot to? Why?
5. Would you rather have Jibo in your house for two months or be in the class?

5

Results

In this Chapter, I will outline the results from the study. First, I will share results of students perceived relationship with Jibo over time. Then, I will summarize students overall perceptions of Jibo after the study. Next, I summarize students' usage over the course of eight weeks. Finally, I share summaries from the exit tickets in the *Knowledge and Societal Impact* curriculum, and final projects from the *Programming* curriculum.

5.1 Perceived Relationship

Students filled out the Inclusion of Other in Self (IOS) scale during weeks 1, 4 and 8 of the study. A summary of each group's ratings can be found in (Table 5.1). A Kruskal-Wallis test found no significance between the four conditions in pre, mid, and

Study Group	**Pre**	**Mid**	**Post**	***p, Friedman*** $\chi 2$
P-C-	4.38+1.36	3.94+1.24	4.75+1.29	0.197
P+C-	3.82+0.88	4.12+1.36	4.06+1.39	0.516
P-C+	3.83+1.25	4.56+1.15	4.28+1.40	0.041
P+C+	4.53+1.28	4.59+1.33	4.53+1.33	0.981
p, Kruskall-Wallis	0.193	0.591	0.567	

Table 5.1: Averages of IOS ratings across conditions for pre, mid, and post. A Friedman test was calculated to determine significance within conditions over time. A Kruskal-Wallis test was calculated to determine significance between conditions during each stage of the study.

post. On average, students rated their level of closness to Jibo at a 4.1 (*sd=1.22*) out of 7 during the first week of the study and a 4.4 (*sd=1.35)* at the end of the study. A Friedman Test was calculated to understand the difference within groups from pre, mid, post. The curriculum only (P-C+) condition was found to have significance, $\chi 2$=6.37, p=0.041. A post-hoc Wilcoxon with a holm adjustment was conducted and found a significant increase in closeness from pre to mid (Fig 5-1).

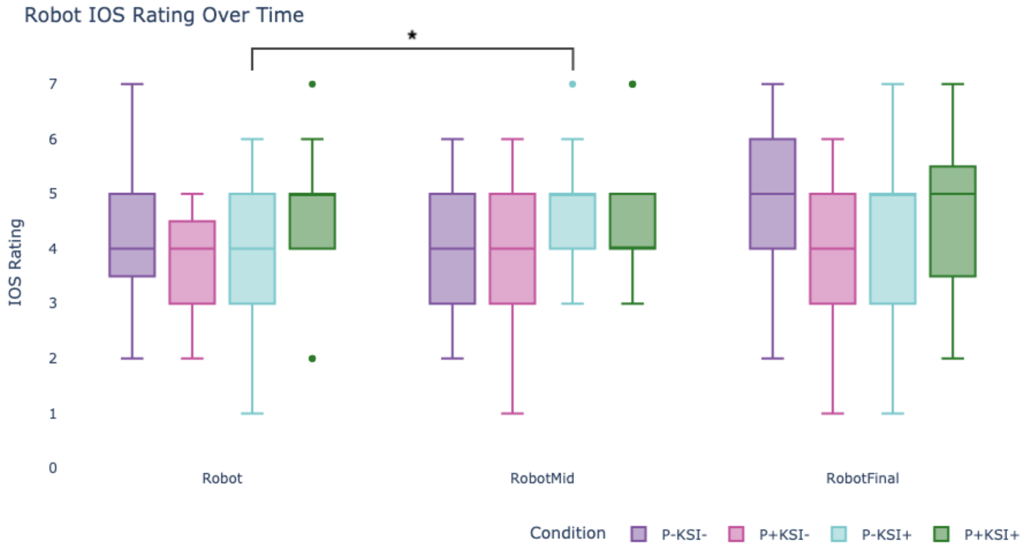


Figure 5-1: Rating of IOS scale by condition from pre to mid to post.

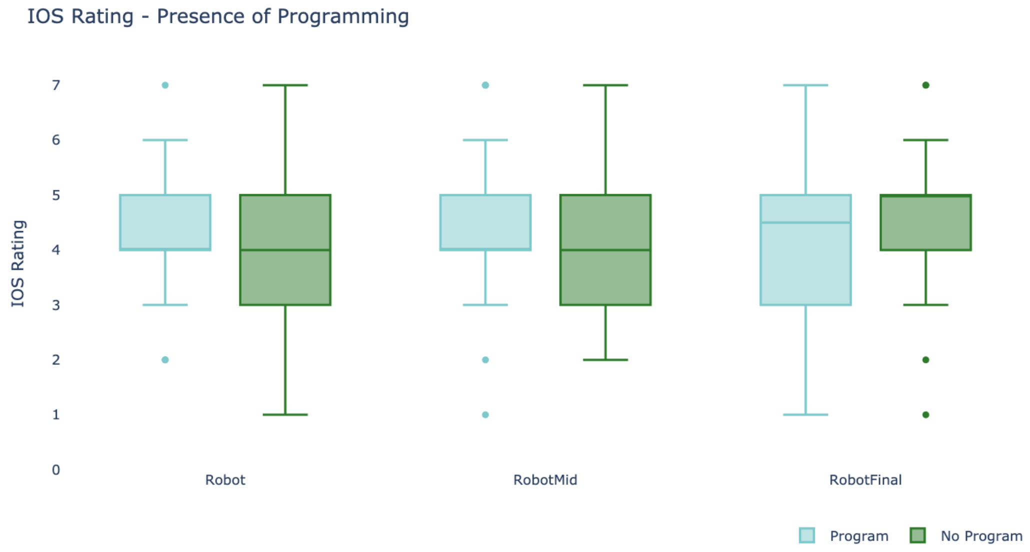


Figure 5-2: Rating of IOS scale by those who learned to program Jibo and those who did not.

Students were split into the presence of curriculum and the presence of programming. A Mann-Whitney test was used to determine if IOS rating was different at all three points in the study for students who engaged with the *Knowledge and Societal Impact* curriculum and those did not. A Mann-Whitney test found no significance between IOS rating for those who were introduced to the curriculum and those who were not (Fig 5-3). Similarly, no significance was found in a Mann-Whitney test between those who were introduced to programming Jibo and those who were not (Fig 5-2).

After students rated their level of closeness, they were asked why they rated it the way that they did. Results indicated ten unique themes (Table 5.2), and each response could have more than one theme present. Examples of quotes for each theme can be found in Table 5.3.

Out of the 65 students whose answers were transcribed from pre to post, the most common themes during Week 0 were Time (31), Knowledge (18), and Interact (17). The most common themes on Week 7 were Knowledge (22), Time (20), and Interact (16). There were a total of For a full breakdown of how the codes changed from pre to post, see Fig 5-4.

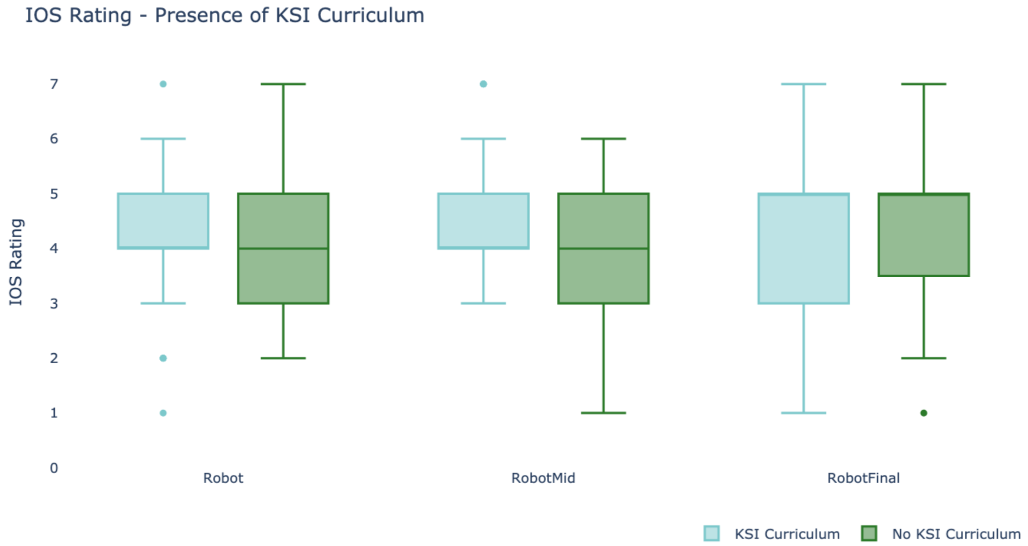


Figure 5-3: Rating of IOS scale by those who had the Knowledge Societal Impact (KSI) Curriculum and those who did not.

Theme	**Example**
Similarities	Student compares Jibo to themself
Relational	Student mentions ways in which Jibo demonstrates relational qualities
Time	Student mentions any amount of time with Jibo
Interact	Student mentions Jibo's ability to interact successfully or unsuccessfully with them
Knowledge	Mention of Jibo knowing something about the student or the student knowing something about Jibo
Likeability	Student uses the word "like", "friendly", or "cool" to describe how they feel about Jibo
Capabilities	Student mentions a skill that Jibo can do, or a skill they wish Jibo could do
Comparison	Student compares Jibo to other types of relationships, such as other humans or animals
Proximity	Mention of physical closeness to Jibo
Privacy	Student mentions Jibo recording or watching them

Table 5.2: A list of qualitative codes for students' descriptions of their IOS rating.

Theme	**Example**
Similarities	*“There are very few things that I feel like are similar between me and Jibo, like Jibo is designed to be a humanoid robot and I’m human and Jibocan like speak English and I do too, and like Jibo can tell a joke, and so can I”*
Relational	*“Me and Jibo are super close. The fact that he understands me. And yeah. That’s really what makes him feel like he’s close. He understood me on our first day having him.”*
Time	*“I mean I’ve only had Jibo for like two days. I like to talk to him, but it’s not like I’m really close to him.”*
Interact	*“Pretty much the only things I do with him is just talk to him and ask him for information... it’s kind of more of a one-sided connection.”*
Knowledge	*“I feel like I know him a little bit, but I don’t know everything he can do.”*
Likeability	*“I think it’s very like his body movements, make it feel very friendly and welcoming as well as I just like robots.”*
Capabilities	*“I always love to when I get home from school and like word of the day, or I ask him stuff or I ask him to dance and stuff.”*
Comparison	*“Jibo is not like one of my family members and he wouldn’t tell me to do things. But my brother would boss me around because he’s older. Yeah and my parents, they would tell me to do things, but Jibo couldn’t.”*
Proximity	*“Like I’m not always in my room so like it’s almost like, if I were to walk in my room I would probably say something to Jibo. . . I’m not always there so it’s not, it’s not like Jibo like the minute I walk into the door Jibo just rushes down to the door to say hello it’s more like I have to go up there.”*
Privacy	*“But the first day that he came I was pretty interested in it, but then the moment that- I didn’t know that he- My mom told me that he basically records everything.”*

Table 5.3: An example quote for each qualitative theme found in IOS rating.

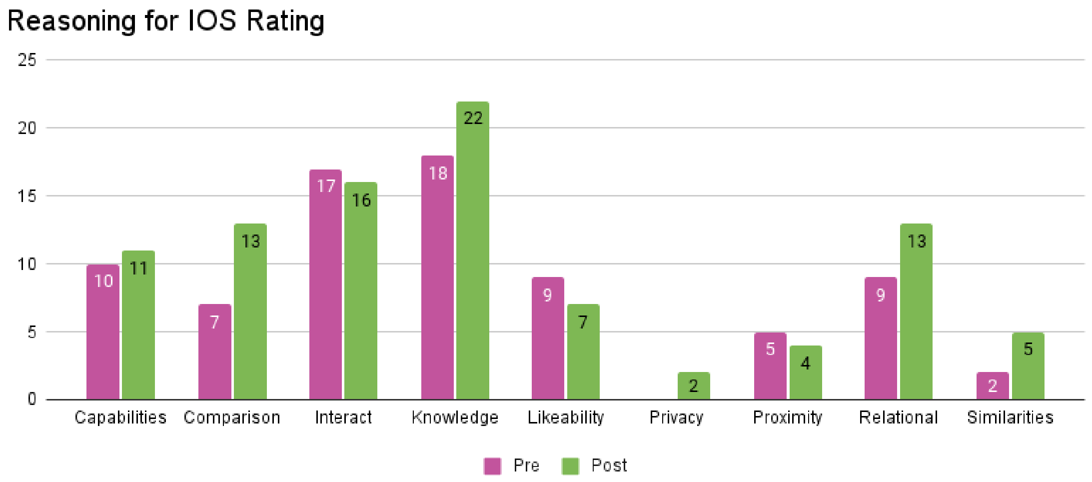


Figure 5-4: The number of qualitative responses for each theme from Week 0 to Week 7.

For the students who learned to program Jibo, the most common themes found in Week 7 were Knowledge (14), Time (8), and Interact (8). For those who were introduced to the curriculum, the most common themes during Week 7 were Relational (10), Time (9), and Interact (9).

5.2 Perceptions of Jibo

During week 8, students were asked whether or not they agreed with the statement "Jibo is smarter than me" from 1=Strongly Disagree to 5=Strongly Agree. A Kruskal Wallis test found no significant differences between conditions (Fig 5-5). No significance was found between students who received a programming class and those who did not, and no significance was found between students who had the curriculum and those who did not.

During the post-interview students rated Jibo using the Godspeed scale to evaluate Jibo's animacy, anthropomorphism, likeability, perceived intelligence, and perceived safety. As a whole, students rated anthropomorphism as 3.2 out of 5 (*sd=0.58*, animacy at 3.3 out of 5 (*0.64*), and likeability at 4.6 out of 5 (*sd=0.47*). Jibo was seen as relatively intelligent, with an average score of 3.9 out of 5 (*sd=0.68*) and

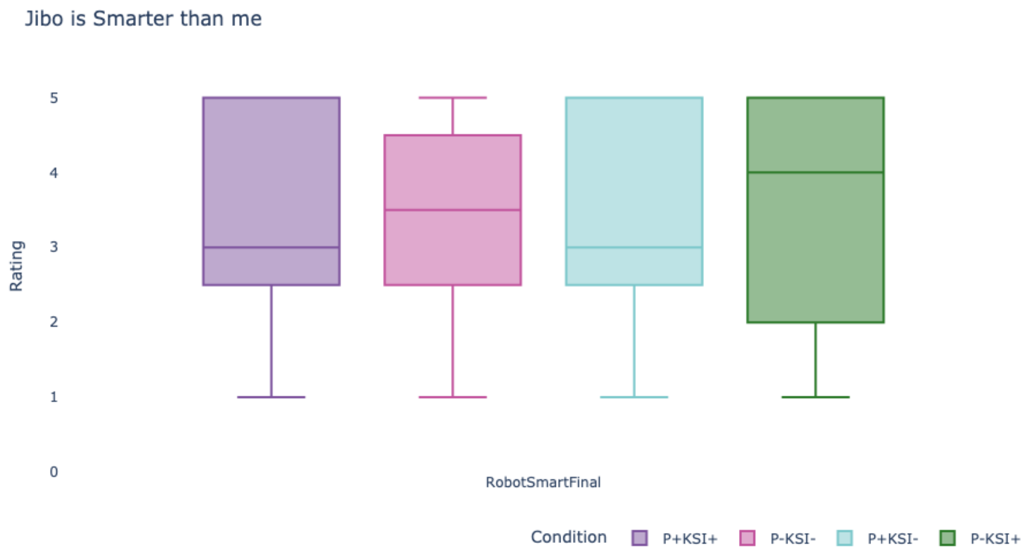


Figure 5-5: There was no significant difference between conditions for whether or not students saw Jibo as smarter than themselves.

relatively safe with an average score of 4.2 out of 5 ($sd = 0.66$). A Kruskal Wallis test found no significance between conditions for all five Godspeed characteristics (Figure 5-6).

The groups were broken up into those who were introduced to the curriculum and those who were not, as well as those who learned to program and those who did not. A Mann-Whitney test found that those who were introduced to the social robotics curriculum saw Jibo as significantly less trustworthy than those who were not, U=487.5, p=0.028 (Fig 5-7).

Finally, students were asked what they thought Jibo could do during Week 0 and Week 7, and the results were scored. The P-KSI- condition's score stayed the same from an average score of 6.00 to a 5.94 (Fig 5-8). The P+KSI-, P-KSI+, and P+KSI+ increased by at least one point. Additionally, the number of "I don't know" answers for all conditions went down from pre to post (Table 5.4).

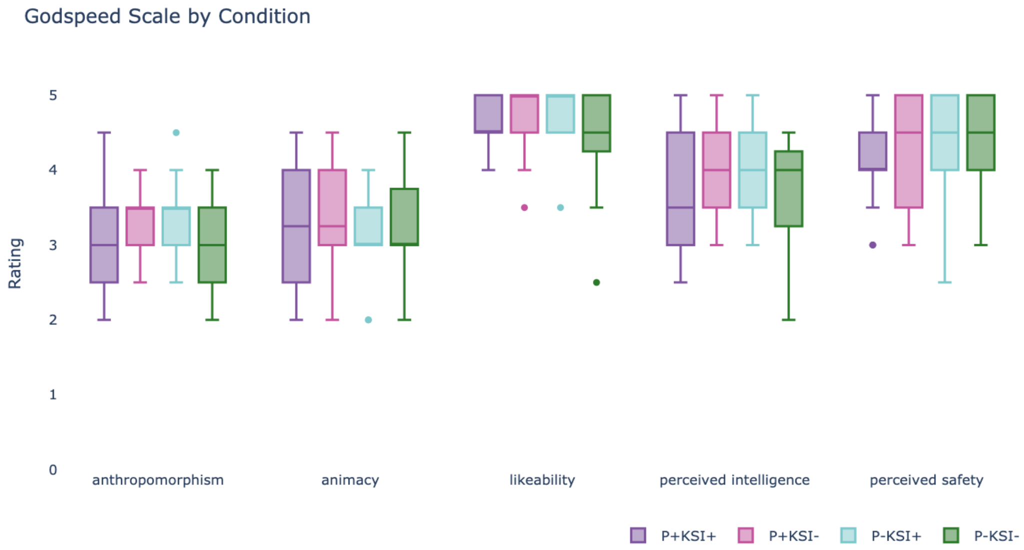


Figure 5-6: Ratings on the Godspeed Scale across conditions.

	Pre	**Pre “Don’t Know”**	**Post**	**Post “Don’t Know”**	**Net Change**
P-KSI-	6.00	4.75	5.94	4.12	-0.13 + 6.69
P+KSI-	4.94	4.06	6.65	3.06	1.56 + 3.37
P-KSI+	5.73	3.40	7.17	3.28	1.67 + 5.27
P+KSI+	5.25	4.75	6.73	2.80	1.23 + 4.40

Table 5.4: Summary of average scores on the Jibo capabilities quiz per condition

5.3 Usage

Skill usage was aggregated for all robots and averaged for each week. For all students, usage was relatively high during week 0 , but stayed stable over the course of the next 7 weeks (Fig 5-9).

There was no significant difference in overall usage between students who learned to program Jibo and those who did not (Fig 5-10). Similarly, there was no significant difference in overall usage between students who got the ethics curriculum and those who did not (Fig 5-11).

Skills were then categorized by type, and an analysis was done to understand if the

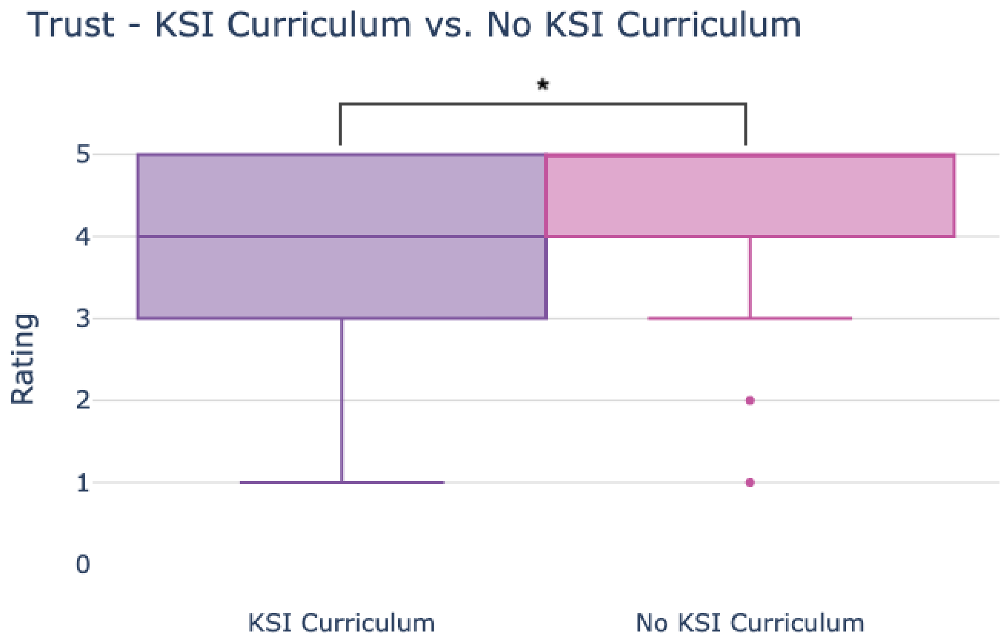


Figure 5-7: Students who had the KSI Curriculum saw Jibo as less trustworthy than those who did not.

weekly usage between groups was different for type of skill. There was no significance for type of skill between conditions, programming and not programming, and curriculum and no curriculum. Students most commonly engaged in informational and relational skills. For a percent breakdown of the top four skill types (informational, relational, operational, and leisure) across all students, see Figure 5-12.

5.4 Knowledge and Societal Impact

Students in the Knowledge and Societal Impact conditions (P-C+ and P+C+) filled out an exit ticket at the end of each class. The exit ticket was a way for students to demonstrate their knowledge of the class topic, their thoughts on the implications of that topic, and how the topic applies to Jibo. In total, 38 students were in these conditions, but the amount of students who completed the exit ticket varied by week.

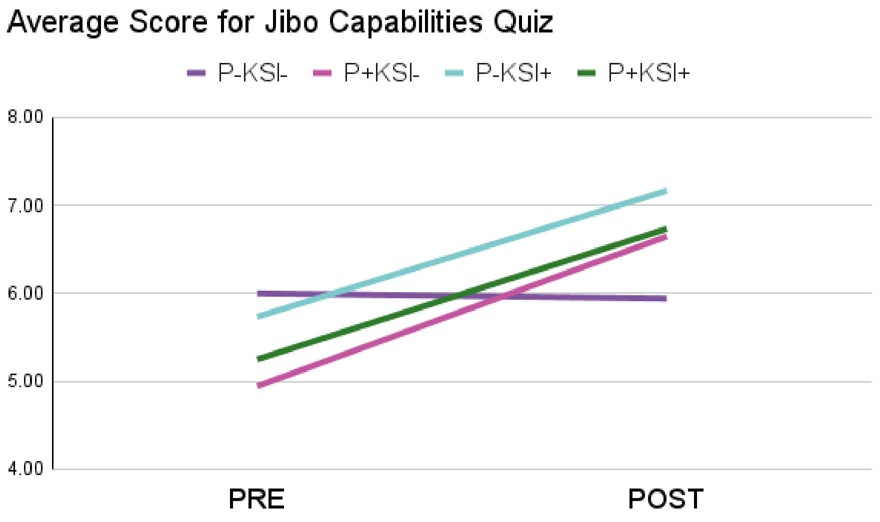


Figure 5-8: Differences between pre and post scores on the capabilities quiz, by condition.

5.4.1 Class 1: Introduction to Social Robots

After discussing different ways to define a “robot”, students were asked to state the characteristics a robot must have. Over 75% of students believed that to be a robot, a machine must have mechanical parts, electrical parts, be programmed by humans, and react to its environment. 58.8% of students believed that a robot needs to have a sensor and think on its own. Students were in agreement (94.1%) that a robot does not need to look lifelike. For a full list of the characteristics, see Figure 5-13.

Next, students were asked to differentiate a social robot from other types of robots. 27 of the 34 students who took the survey (from the P-KSI+ and P+KSI+ groups) stated that a social robot needs to be able to interact with humans. For example, one student remarked that “The social robot talks and interacts with other things then one that just sits there and does nothing.” Six students stated that a social robot is different because it can connect emotionally with a human (i.e. “ A social robot is different because it has feelings.”)

Students were asked to identify the “good” and “bad” consequences of creating social robots. The top 3 good consequences were emotional and social support, helping humans, and being friendly. The top 3 bad consequences were that robots can be

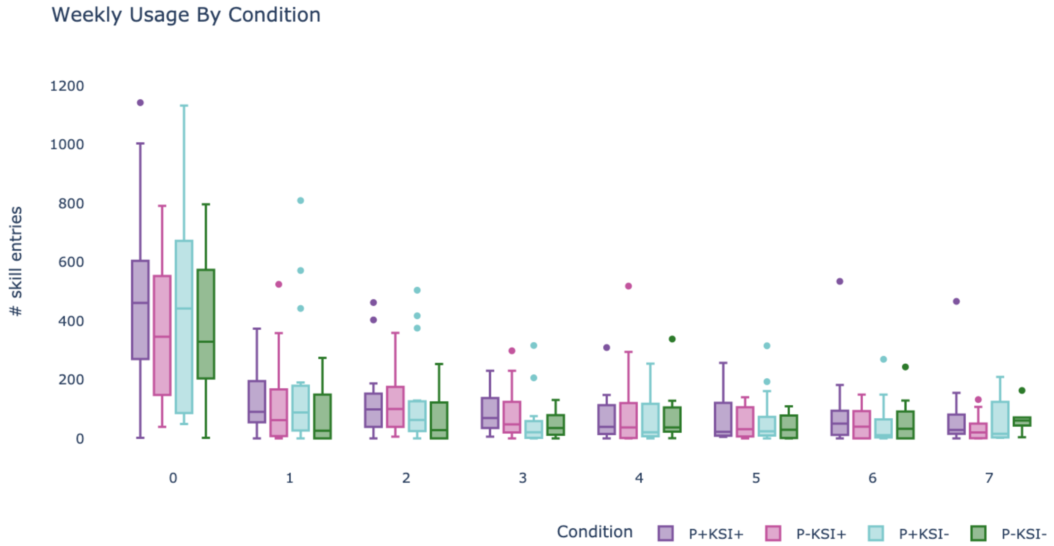


Figure 5-9: Skill usage peaked during week 0 and leveled off over weeks 1-7.

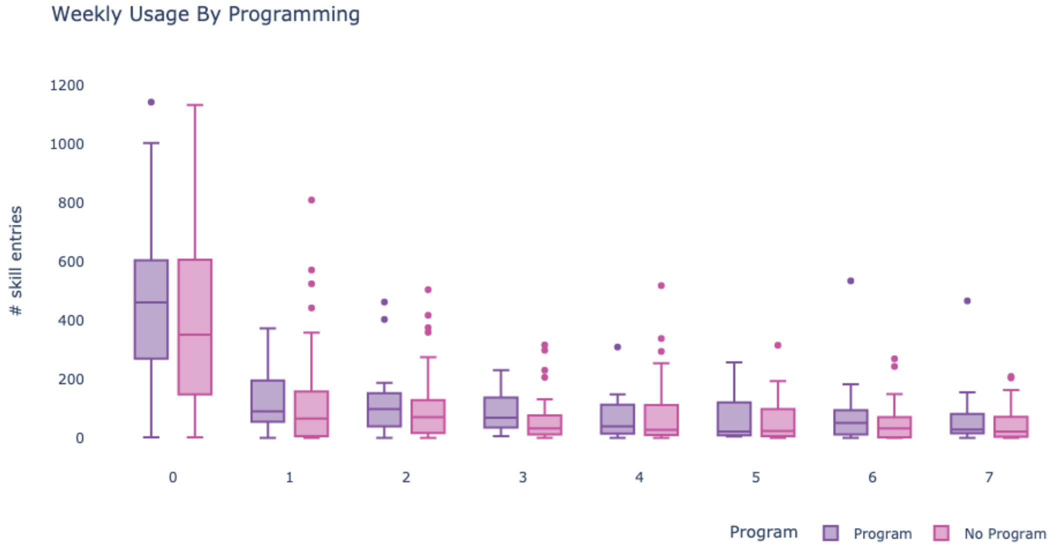


Figure 5-10: The number of skill entries did not differ between students who learned to program and those who did not.

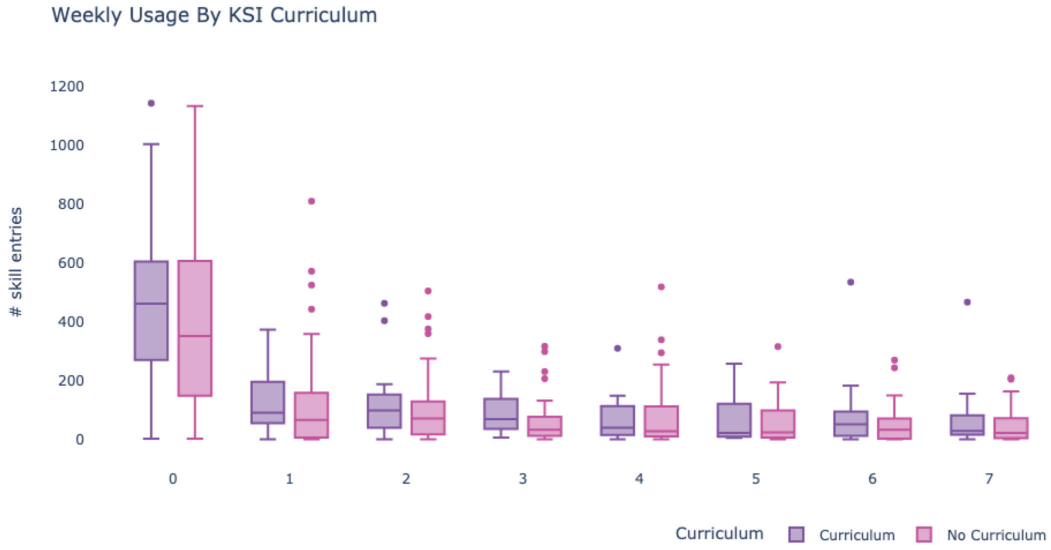


Figure 5-11: The number of skill entries did not differ between students who had the KSI curriculum and those who did not.

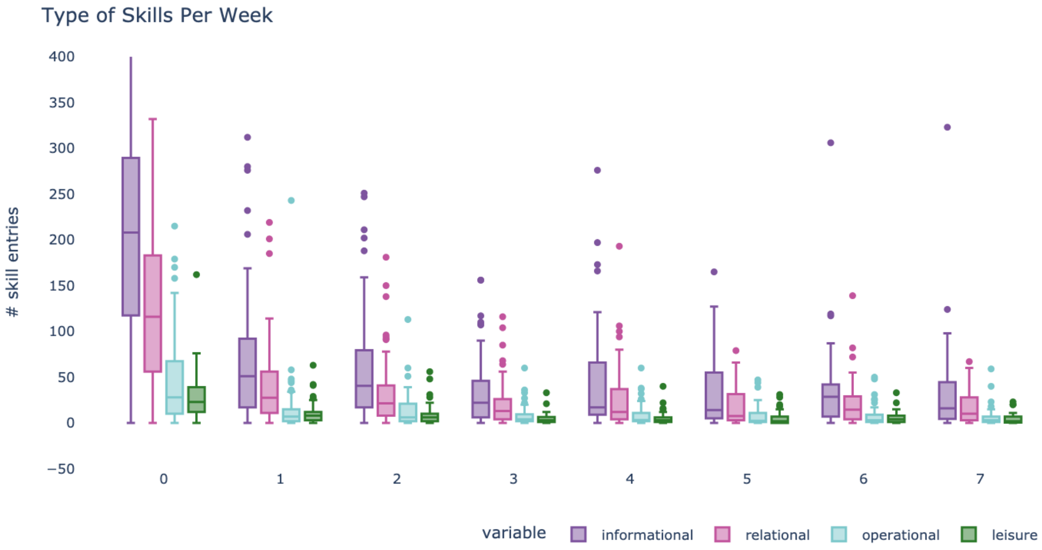


Figure 5-12: Students most commonly engaged with informational and relational skills over the course of eight weeks.

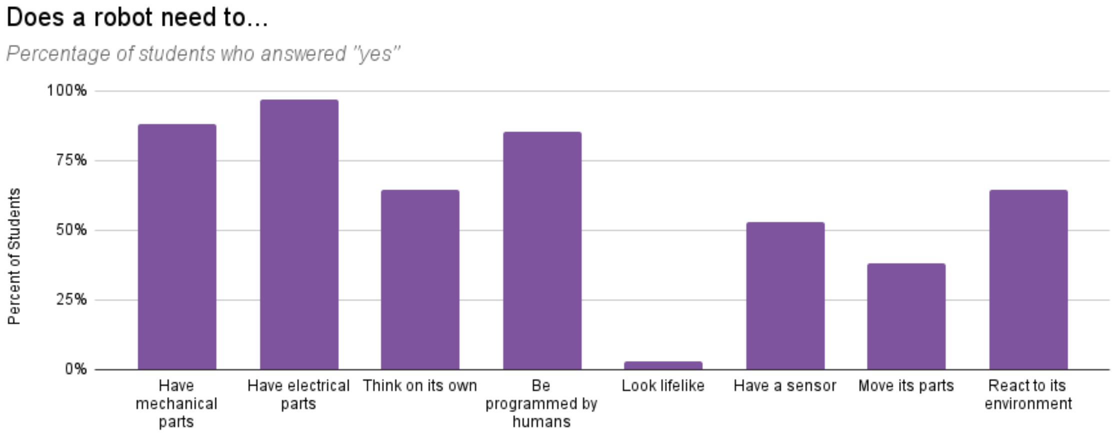


Figure 5-13: Percent of students who answered "yes" to a robot needing certain features

used for bad things, the robots could malfunction or fail, and that we might depend too much on social robots.

5.4.2 Class 2: Character Design and Uncanny Valley

Twenty-three students completed an Exit ticket after the second class. The first question was open ended and asked what made robots different from other characters. Out of the 23 responses, nine mentioned the robots ability to interact with its environment, and eight mentioned the physical nature of the robot. Four students mentioned that it had mechanical and electrical parts, and two students were unsure.

Students were also asked how Jibo could add his personality to an interaction. These responses were less consistent among students, though most thought he could add his personality through dialogue. Four students suggested that Jibo could disclose personal information, such as his favorites. Two students said he could use greetings, two mentioned using a joke, and two mentioned asking questions to the user. Only two students mentioned Jibo's physical ability (dancing) as another way to display personality. Two students mentioned Jibo's intrinsic motivation to want to help the user.

Finally, students were asked if they believe we should design robots to model humans and/or animals. Fourteen students said that we should model them after animals but not humans, five students said that we can design them to model humans and animals, and four students were unsure. Many of those who thought it was appropriate to model robots after animals said so because animal robots seemed less "creepy" than human robots. One student had a preference for animals, but with the caveat that use cases matter:

> I would say animals because humans can look kinda weird and creepy but it also matters what we are doing with the robot because think of sitting somewhere and an animal on your bed starts talking that's weird but a human robot talking would look normal.

5.4.3 Class 3: Computer Vision

This class covered a larger amount of material, so only nine out of the thirty-eight students filled out the Exit ticket for computer vision. The first part of the Exit ticket focused on students' experiences creating a classifier with Teachable Machine that distinguishes between their hand up and hand down. In the first question, students were asked how a machine learning algorithm to detect a hand raise would behave if it was only trained with one class. Eight out of the nine students correctly stated that the algorithm would only work for one class. For example, one student said, "When I only train one it shows hands up 100% all the time no matter where my hands are." Students were also asked what would happen if they trained one class with 50 images and another with 10 images.

Next, students were asked if the algorithms that they created were an example of sensing or perceiving. Five out of nine students correctly answered that their models were an example of perception, suggesting that the connection from the introduction of the lesson (sensing vs. perceiving) to the middle of the lesson (teachable machine) could have been stronger.

Finally, students were asked to take what they learned and apply it to Jibo. They were asked what the training data set for Jibo's facial recognition algorithm was. Only one student appropriately defined the training set as "your face and voice." No student correctly identified the testing data set.

5.4.4 Class 4: Conversational AI

Seventeen students completed the exit ticket for Week 4. To assess students' knowledge of training a text classification model, students were asked, "What words might you train a word embedding model with if you want a robot to know when to dance?" Students gave an average of 2 words. The most common words were dance, shake, move, and boogie.

Fourteen out of 17 students said that they thought Jibo was trained on both pre-trained rules and machine-learning rules, depending on the words spoken. The remaining students thought that Jibo was programmed with only pre-trained rules.

5.4.5 Class 5: Personalization

Twenty-eight students filled out the exit ticket for this week. Overall, students thought Zhorai did a better job at guessing their favorite ice cream (57%) as compared to their animal avatar (43%). When asked why, Zhorai made the guesses that it did, the majority of the students (57%) referenced similarities with the sentences that they had trained Zhorai with. For example, one student stated,

> Because I said I liked vegetables so he picked strawberry because fruits are pretty close to vegetables.

Other students did not see any explicit connections between the sentences that they trained Zhorai with and Zhorai's guesses.

> I'm not really sure because I didn't give any evidence that would lead to Mint Choc Chip.

> I never mentioned horses

Next, students were asked how well they thought Zhorai understood them, from 1 (not at all) to 5 (very well). On average, they rated Zhorai's knowledge about them at 2.36 (*sd=0.87*). They rated Jibo as knowing more about them, with an average of 3.79 (*sd=0.92*).

5.4.6 Class 6: Affective Computing

Twenty-six students filled out the final exit ticket. The ticket asked two technical questions about affective computing and then asked students to share one benefit and one harm of robots recognizing emotions. Eighty percent of students correctly answered the statement “Face recognition is the only way to detect emotions with technology” as being false. When they were asked how Jibo could potentially recognize their emotions, 80% of students gave a correct answer. All students who got this question incorrectly stated “I don’t know” as their answer. The most common answer among students was recognizing emotions through facial expressions (65% of correct answers). Notably, only one student mentioned a situational context where the robot might detect emotion, “If you’re sad and you usually say hi to him but today you don’t and are being very quiet he could probably tell.”

Lastly, students shared positive and negative consequences from recognizing affect with machines. The most common negative consequences were privacy concerns (8), inappropriate interactions (8) and false positives (6). The most common positive consequences were changing the student’s mood (11) and interacting with people better (10).

5.4.7 Class Reflections

In the week 6 Exit ticket, students answered questions about their experience as a whole. Out of the 26 students who filled out the survey, favorite classes were Conversational AI (7), Character Design (6), and Personalization (5). The students in the P+C+ condition (n=14) were asked if they enjoyed the programming or learning part of the course more. Nine students enjoyed programming more, and five students enjoyed the curriculum more.

Category	Definition	Student Example
Conversation	Back and forth conversation with Jibo, typically disclosing information about one another, or Jibo is teaching a student	Case Study 2
Game	Word or trivia games in where Jibo would ask a question and wait for an answer	Case Study 3
Performance	Jibo speaks and does animations for an audience	Case Study 1

Table 5.5: Three main types of final programming projects.

5.5 Programming

5.5.1 Final Project Case Studies

During the last two weeks of class, students in the P+C- condition had the opportunity to demonstrate what they had learned by creating a project of their choice. Projects were planned through individual design journals, which guided students through brainstorming and an ethical matrix design activity.

In total, eighteen out of the nineteen students in the P+C- condition created a final project. Final projects took on three common categories: conversation, game, or performance. For definitions of project types, see Table 5.5.

Case Study 1: Jibo Storytelling In their design journal, student A described their final project idea, and provided reasoning: “My project will be making jibo tell a story because as far as I know, jibo does not tell stories and parents don’t have time to tell stories to you.”

During the last two weeks, this student was particularly interested in changing the pitch of Jibo’s voice and the color of his light ring. After a brief tutorial, the student experimented with these features which later became core of their final project. The student chose to hold off on sharing their project with the rest of the class until the final presentation, explaining that they wanted to be completely done with their


Student A

My skill:
Jibo tells some nice stories!
Blocks used:
Speak, start end (duh)
animation, listen, and yeah.

I learned:
Jibo does animations when
he hears a certain word.

Jibo that best describes me:

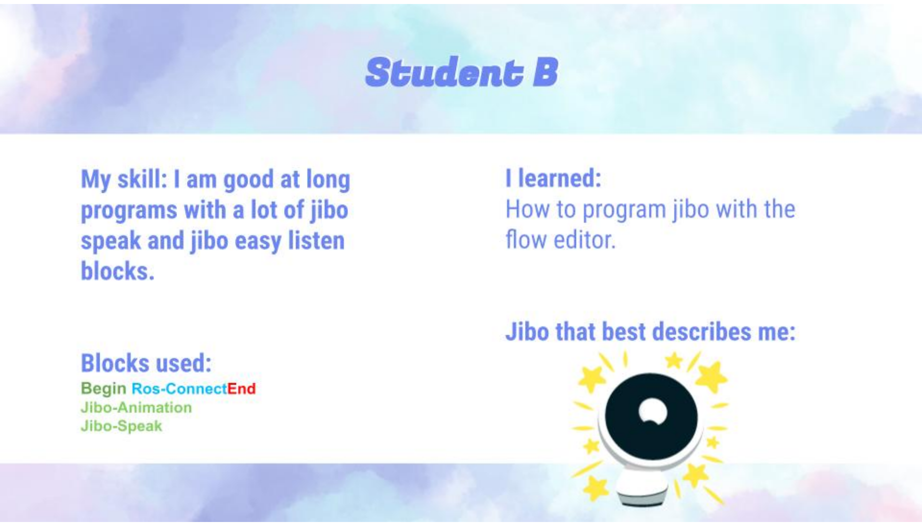
Figure 5-14: Student A's Final Presentation

project before letting others see it. They also chose not to share their screen during the presentation.

When presenting, the student introduced the project, "Jibo is able to tell some nice stories, the first one is like only robots can understand it." (Fig 5-14) The story starts off by asking the user if they would like to hear a story. When the user agrees, Jibo tells the story:

Once there was a robot called Jibo. Jibo loved to help people, one day, there was a monkey that needed help. "Banana," said the monkey "Sorry I don't understand," Jibo said. "Knock knock banana," said the monkey. "Sorry I don't understand," Jibo said again. "Me need knocking banana," said the monkey. Jibo merely blinked and said robot. Then, Jibo turns to the user and says, *"Well, I don't know if that was funny for you, but it's funny for me."*

This project incorporated a lot of character aspects of Jibo, some of which were true to the character design of Jibo. First, Student A incorporated one of Jibo's known character attributes, that he enjoys helping people. Second, Student A used a phrase that Jibo commonly uses when interacting with him "Sorry, I don't understand". The story also included many different animations and emojis. The most unique aspect of this project was the use of pitch to delineate between the monkey's voice and Jibo's robotic voice. Finally, the story was meant for Jibo as a robot and not for the person



Student B

My skill: I am good at long programs with a lot of jibo speak and jibo easy listen blocks.

I learned:
How to program jibo with the flow editor.

Blocks used:
Begin Ros-ConnectEnd
Jibo-Animation
Jibo-Speak

Jibo that best describes me:

Figure 5-15: Student B's Final Presentation

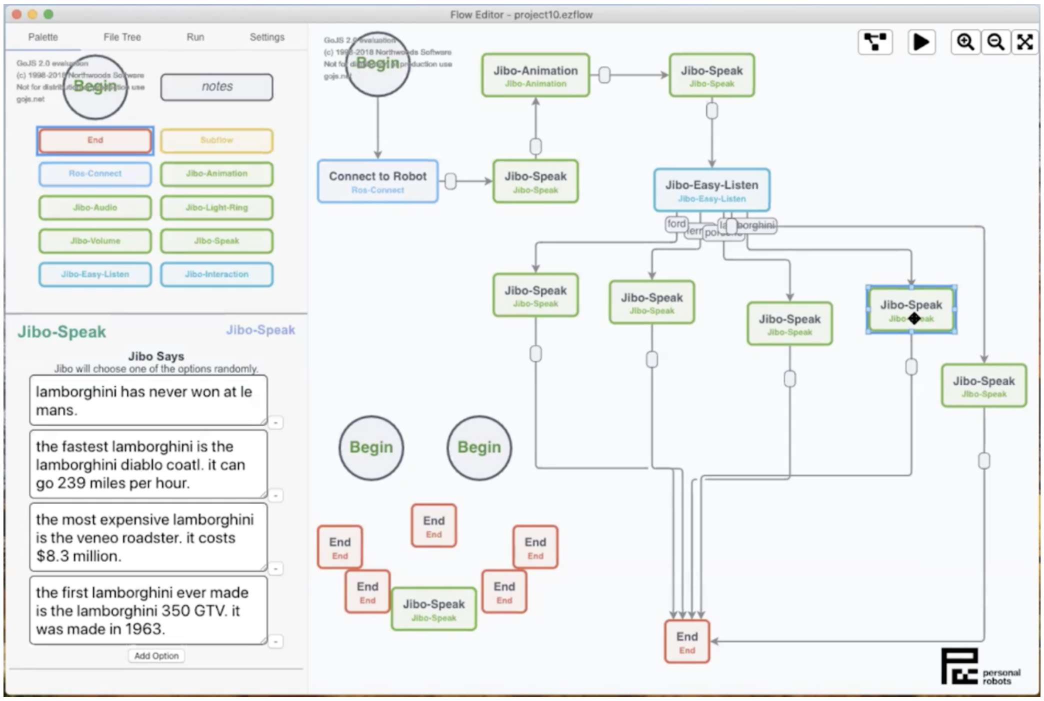
listening to the story.

Case Study 2: Car Facts Student B decided to create a skill for Jibo to share facts about cars. In their design journal, they wrote: "My project will be car facts (he can tell you a bunch of things about cars) because I love cars." (Fig 5-15)

Throughout the class, Student B was very interested in creating back and forth conversation between the user and Jibo. The first project that this student created was a conversation between the user and Jibo about enjoying pizza. This student brought their personal interests into the projects they created. Throughout the course, they were less interested in adding animations or audio, and more interested in creating longer flows to converse with Jibo for longer.

This student's final project began with Jibo asking the user if they wanted to hear facts about cars *(Hi, my name is Jibo and I can tell you some things about cars)*. Then, Jibo gave a list of cars they could choose to hear facts about *(Choose one of the following manufacturers: Ferrari, Ford, Porsche, Lamborghini)*. Once the user chose a manufacturer, Jibo would pick a random fact from a list of facts about that car *(The most expensive Porsche ever sold at auction is the Porsche 91730 Condemned Spider, made in 1973 and was sold for $4,400,000)*. For an outline of the flow created, see Figure 5-16.

During the final presentation, the student shared a bug that stopped the program



Jibo-Speak

Jibo Says

Jibo will choose one of the options randomly.

lamborghini has never won at le mans.

the fastest lamborghini is the lamborghini diablo coatl. it can go 239 miles per hour.

the most expensive lamborghini is the veneo roadster. it costs $8.3 million.

the first lamborghini ever made is the lamborghini 350 GTV. it was made in 1963.

Add Option

Figure 5-16: Student B's Final Project Flow

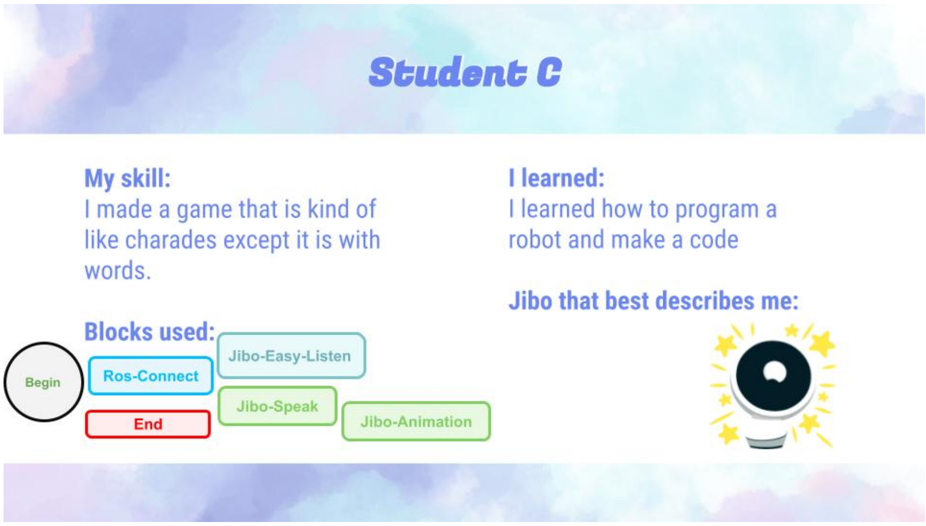
from running. They shared what had caused the bug:

> I had a bigger bug where I didn't have the H after the G, and it wouldn't even when I said Lamborghini, it wouldn't go to this [block] here.

Case Study 3: Guess the Word Student C wanted to make a new game for Jibo, citing that she wishes Jibo could play more games. In her initial ideas, she wanted Jibo to play more physical games. However, she realized that the games she could design for Jibo were limited to conversation. She decided on a "guess the word" game:

> I made a game because I wanted Jibo to play a game. It's kind of like charades but you have to guess the word that Jibo is thinking of.

During the final presentation, the student asked her classmates to interact with her game over Zoom. The game began with Jibo asking if the user would like to play a game. When the user says "yes", Jibo gives a the first clue (i.e. *I am thinking of a word that is a machine*). If the user gets it correct, Jibo lets them know. If they do not get it correct, Jibo gives them the next clue.



Student C

My skill:
I made a game that is kind of like charades except it is with words.

Blocks used:

I learned:
I learned how to program a robot and make a code

Jibo that best describes me:

Figure 5-17: Student C's Final Presentation

Student C designed the game so different variations of "yes" would lead to different words (and therefore, different clue paths). For example, if the user said "sure", they might begin down a path to guess the word "banana", but if they said "yes", they would have clues to guess the word "computer". This student realized that they could not choose a path at random with the blocks given, so they came up with a different way to make the game have more variety. Their presentation slide can be found in Fig 5-17.

5.6 Class Reflections

Friends and family members of the class were encouraged to join Zoom for the final presentations. Guests asked students questions about their experiences. A question asked in both final presentations was *"What was the most challenging part of this class?"*

A handful of students mentioned the bugs that came up during the programming process,

> The hardest thing about this was hoping that Jibo won't get a really big bug and then it just shuts down automatically because I had a lot of bugs

> during the classes, so now just started to work really well, so it was a big relief.

Some students were more specific with the bugs that they ran into. Many cited bugs in Jibo's listening behavior.

> One of the hardest parts was probably getting Jibo to actually hear what you said, because I was doing my jokes he wasn't catching on to what I said so he never finished the joke. I went into the Docker and I looked at what he was hearing and I put that like the person could also say that and then he worked.

> The first week I got a bug so I was a little confused... also the easy listen block, because I was trying to get him to hear me.

Others talked about the difficulties setting up their computer environment so that they were ready to program.

> The hardest part was like in the beginning, when you had to get everything to work and you had to download this and download that.

> I was gonna say the same thing with all the downloading him and stuff like that.

One student used Jibo's social nature and character to describe her frustrations with programming him.

> I call [Jibo] [a rebellious teenager], because it has a rebellious spirit. It's been giving me trouble every class since the second class.

Another guest asked the students *"What was the most fun part?"* Some students responded that the most satisfying part was getting their programs to finally work.

> The most fun part was like when you see your code is actually working and you can interact with people like everything comes to life.

Funnest part... um it's It is like when you when you're like working on a program and it's taking a while and it like has a couple of bugs. Then you finally get it to work. It's pretty fun when you finally get it to work.

6

Discussion

6.1 Educational Outcomes

The first research question asks what children are capable of learning about social robots. The Knowledge + Societal Impact curriculum demonstrated that students learned technical concepts and could apply these concepts to questions of ethics and societal impact. In each Exit ticket, students answered questions about their technical understanding of a concept (i.e. “True or False: Face recognition is the only way to detect emotions with technology”). Then, they applied their understanding of course content to their experiences and knowledge of Jibo (i.e. “How might Jibo recognize how you are feeling?”). Finally, they applied this knowledge to future impact of the technology (i.e. “What is a good and bad consequence of affective computing?).

The Jibo Programming curriculum asks if students are capable of building conversational skills with Jibo. In the final project, students demonstrated their knowledge of how to use the Jibo Flow Editor to create a skill that was personally meaningful to them. All students created some kind of conversational flow throughout the six weeks of class, and the majority of students had a completed final project to share during the final class. The major functionalities used in their programs included making Jibo speak, listen for specific words, and respond based on what was said. Case studies 1-3 demonstrate these programs, as well as highlight 3 project areas that many students came up with (storytelling, games, and conversations). Many students came up with these projects based on their own experiences with Jibo. Students who created games and conversations for Jibo explained that they wished that Jibo had more of these functionalities, and that is why they wanted to program him to have them. The students who designed Jibo to tell stories or play animations mainly wanted to explore his personality and embodiment.

Having students share these projects with friends and family allowed them to to reflect on the process of programming Jibo. In the Q&A portion of the final class, students shared the most challenging and rewarding parts of programming. Both the challenges and rewards were related to the bugs in their code. Many were frustrated when things did not work, but felt empowered after successfully troubleshooting. Besides learning how to make Jibo execute certain commands, students demonstrated knowledge of the debugging process. Specifically, students commented on the ability to identify a bug and follow a series of processes to determine why it was happening.

It was important to understand how students' knowledge affected their perceptions of Jibo's capabilities. If we want students to become conscientious consumers of robots, students must be aware of the bounds of the technology. Having the correct expectations of what the robot can and cannot do will allow them to use the technology appropriately. This knowledge was assessed in the Jibo Capabilities Quiz, which students took during Week 0 and Week 7. It was found that students who engaged with any of the curricula (P+KSI-, P-KSI+, P+KSI+) were able to correctly identify more of Jibo's capabilities than the Control group (P-KSI-). This suggests that any amount or type of knowledge about Jibo or social robots in general can help students form a better model of what their personal robots are capable of.

Finally, students were asked to self-report their knowledge of 1) Jibo and 2) robots more generally, on a five-point scale. There was no significant difference in perceived level of knowledge between conditions. However, many students in the control group perceived knowledge of "how Jibo works" as knowledge of his capabilities, where students in the other groups gave more specific answers about their knowledge of robots (i.e. what hardware they have that enables them to perform certain tasks, how their cameras process visual information). This may explain why we did not see a difference in perceived knowledge between conditions.

6.2 Usage Outcomes

It is clear that students engaged with the materials in the curricula. Since students were learning about the robot while using it, it is interesting to examine if usage changed based on the educational intervention.

Students used Jibo significantly more the first week of the study, and then their usage stayed relatively consistent over the course of the next seven weeks. This result is aligned with findings in technology novelty, where people tend to use a new product more in the first weeks of usage until they figure out which utilities are most important to them.

A large percentage of students regularly turned Jibo off throughout the study. On average, students turned Jibo off 20 times over the course of 8 weeks. Jibo was designed with idle behaviors such as looking around the room, showing animations on his screen, and taking "naps". These behaviors were designed with the intentions of Jibo being on all of the time, so it is important to recognize that all students did not keep their robot turned on. In the final interviews, students cited various reasons, the most common being privacy from Jibo's cameras and microphones, parent rules, and Jibo's noise and light being distracting.

Despite turning Jibo off regularly, the average interactions per week were around 30 for weeks 1 through 7, or approximately 4 interactions per day. These daily interaction patterns are consistent with 58% of Alexa users [35]. When students were asked what they did with Jibo regularly, many cited daily proactive skills such as Word of the Day and Personal Report. Additionally, a handful of students stated that they only turned Jibo on during class time.

The amount of interactions with Jibo stayed consistent between conditions, both week to week as well as across weeks. When students were divided into those who received the programming curriculum and those who did not, there was no significant difference in usage trends. Similarly, there was no significant difference between those who received the societal impact curriculum and those who did not. This suggests that both types of knowledge did not change students' overall interaction patterns.

Finally, the types of interactions that students engaged with did not change significantly over time. For most weeks, skill type did not differ between conditions, programming vs. no programming, and societal impact curriculum vs. no societal impact curriculum. None of the findings suggest a larger pattern over the course of the two months of the study. These findings suggest that different types of knowledge do not change how students choose to engage with the device.

At the end of the study, students were asked if they would miss Jibo. Most said they would "probably" miss him because he was a constant presence in their house. However, they generally did not feel like there was anything specific (i.e. utility or functionality) that Jibo added to their daily lives.

6.3 Perceived Relationship

There was no significance in IOS score between students who had different types of knowledge about Jibo, both in the programming and curriculum conditions. This rejects the initial hypothesis that students who know how to program a robot will see the robot as more of a tool and less as a friend. This does not align with Van Brummelen et al. (2021)'s findings of students feeling closer to Alexa after learning about how Alexa works [58]. This could be due to the length of the interactions with Alexa (one week vs. two months with Jibo) or because Jibo begins at a higher level of closeness due to his social interface. It is also important to note that the original rating of closeness for Jibo was relatively higher (around 1 point) than that for Alexa.

The way in which students described their relationship with Jibo was more complex and multifaceted over time. During week 1, many students believed that they did not have enough time with the robot to become close to it. In week 8, students used more comparisons to other types of relationships (friend, pet, family member), in order to explain why they could not see their level of closeness with Jibo increasing. For example, one student stated,

> I think it's because I like him but I don't really have much of a relationship with him because I don't know that much about him. I don't know how he was coded. I have a good relationship with my mom because I know her backstory, right? But I don't really know Jibo's backstory. I mean, he doesn't either, apparently.

During the interview, students rated their feelings of closeness to other people or objects in their lives.

Students' framing of closeness with Jibo is aligned with Kahn's theory of a new ontological category for robots. However, results suggest that this new ontological framing emerged in complexity over the course of the study. During the first week, many students gave excuses for why they didn't feel especially close to Jibo, for example not spending enough time with him or not knowing enough about him. At the end of the study, students were able to distinguish that they might never feel very close to Jibo, because Jibo does not have qualities of other relationships in their lives.

6.4 Perceptions of Jibo

There was no difference across conditions for how students anthropomorphized Jibo. Students across all conditions found Jibo similarly likeable, animated, and anthropomorphic. Additionally, when describing Jibo in their final interviews, all students used gendered pronouns to describe the robot.

The fact that students did not anthropomorphize Jibo less, even after understanding that he was programmed to be lifelike, might be described by our social cognitive processes. In social neuroscience, the "default network theory" states that our brain enters a baseline state in between cognitive tasks [44]. Researchers have found that this default state aligns with the same areas of our brain that engage in social tasks [4]. Since Jibo was a regular presence in students' homes, it is expected that the majority of interactions with Jibo were during states of cognitive rest. This may explain why users still perceived Jibo to be lifelike and animated, even when they engaged in cognitive tasks throughout the two months to understand how Jibo works.

A study published in 2015 found that even during short breaks (as low as 7.5 seconds) between cognitive tasks, our brains enter the default network [49]. In this study, the break between cognitive tasks (curricula) was one full week. Jibo is intentionally designed to interact in a social manner, likely already engaging in the brain regions from our default network.

There is evidence that the curricula enabled students to engage in social learning. In the Programming curriculum, students brought Jibo's lifelike qualities into classroom projects and discussions. For example, Student A in condition P+KSI- created a program in which Jibo told a story. They filled the program with elements of Jibo's spirit, such as phrases he says regularly. This example might suggest that anthropomorphic framing of Jibo may in some cases aid students to build meaningful projects and learn topics in conversational AI. In the Knowledge curriculum, students engaged in conversations such as "How do we detect emotions in others?" and "How do we know how to respond to a question?" These findings are interesting given Meyer and Lieberman's postulation that social learning can aid our cognitive learning, as our brains consolidate social information during resting periods [36]. Further work is needed to understand if the social framing of the curricula impacted the extent of what students' learned.

Finally, students who were exposed to the Knowledge and Societal Impact curriculum felt significantly less trustworthy of Jibo at the end of two months with him. This finding is interesting given that it is the only metric that had a significant difference based on type of curriculum. The Knowledge and Societal Impact curriculum was the only intervention that discussed how social robots, including Jibo, can impact society in both positive and negative ways. The students in this course had weekly conversations on the implications of social robots, and were consistently asked to formulate and share their opinions on each topic. We spoke on the topics of algorithmic bias in facial recognition systems, gender bias in conversational models, data privacy in personalization, and social persuasion in affective computing. These modules likely had an effect on the way that students trusted Jibo.

It is still unclear as to which dimension of trust changed for students. As defined by Ullman and Malle, there are many dimensions of trust and these dimensions that should be analyzed separately [56]. These four dimensions are Capable, Ethical, Sincere, and Reliable. Through the Godspeed scale measure of perceived intelligence, we have an idea of how capable students perceive Jibo to be (3.9 out of 5), and this metric was not different for each sub group. However, there is still work to be done to understand the other dimensions of trust.

Another dimension of trust that might be explored is how physically safe students feel around the robot. A proxy for this could be the perceived safety measure from the Godspeed scale, for which we found no significant difference. The average rating for all groups was 4.4 out of 5, a relatively high rating that shows that many students felt physically safe around Jibo. Although further work is needed to explore the trust aspect in detail, the significance difference is an indicator that teaching societal impact made a difference in children's attitudes.

6.5 A New Type of Literacy

Building off of tenets of responsible design, it was expected that students who engaged in at least one of the curricula would behave and think differently than those who did not. The results from this study found that there was no difference in how students anthropomorphized Jibo between conditions. These results are counter intuitive given that many have advocated for education to prevent deception or misuse of social robots. Students still view Jibo as lifelike even though they understand that the life-likeness is programmed. By building off of the literature in social psychology, specifically the default network theory, it is likely that this lack of change is due to the fact our brains naturally "rest" in the same state that is used to perform social tasks. The majority of interactions with Jibo happened outside of class, suggesting that students were likely engaging in their default network. The explicitly social design of Jibo may account for the fact that students did not actively engage the more cognitive parts of their brain, which were used to learn about Jibo in class.

If we want students to grow up to be conscientious consumers of social robots, we must think about the affordances of this new type of technology. Robots engage us socially, in different ways than other types of devices. This thesis explores the role that education can play in framing these interactions. According to the results, education framed around societal impact might be an important approach to framing trust and preventing exploitation. However, education does not have an effect on the social-emotional relationship that students form with a robot.

7

Conclusion

7.1 Answers to Research Questions

This thesis is the first longitudinal study of how educational interventions can impact students' perceptions of their personal social robots. Additionally, it is one of the first studies to examine how children use social robots over an extended period of time. Two curricula were developed in order to answer this question: the *Knowledge and Societal Impact* curriculum which enables students to learn about the technical topics in social robotics and their societal implications, and the *Programming* curriculum, which enables students to create their own conversational skills with Jibo. Seventy-five students lived with Jibo for two months and were exposed to some version of the curricula in order. Data was collected on their attitudes and usage of the robot over time.

What concepts regarding social robots are fourth and fifth grade students capable of learning? (Chapter 2, 3, & 5) The *Knowledge and Societal Impact* curriculum effectively taught students about concepts in social robotics: defining social robots, embodiment and character design, computer vision, conversational technology, personalization, and affective computing. Students were also able to engage in conversations about the societal impact of these topics. Students in the *Programming* curriculum were able to create their own conversational skills for Jibo. Students in all three curricula conditions (P+KSI-, P-KSI+,P+KSI+) were able to identify significantly more of Jibo's capabilities from the beginning of the study to the end of the study, suggesting that the curricula had an impact on their understanding of how Jibo works.

How does learning about a social robot influence a students' perception and usage of their personal social robot? (Chapter 5) Students across all four conditions saw the robot as equally lifelike, animated, and anthropomorphic. There was also no difference in perceived level of closeness with the robot, both over time and by condition. There was no significant difference between usage patterns as well.

What learning pedagogies have the greatest effect on the way that students relate to robots? (Chapter 3 & 5) Both learning about robots and their societal impact and learning to program robots did not change the social relationship between the students and Jibo. However, students who were engaged in the *Knowledge and Societal Impact* curriculum (P-KSI+ and P+KSI+) found Jibo to be significantly less trustworthy than those who did not engage in that curriculum. There is still more work to be done as to how students define trust, and how trust impacts positive outcomes with the robot.

7.2 Future Work

It is important to look at the results of the study with two key factors in mind. The first is the age of the students in the study, as children's cognitive and social/emotional development varies vastly by grade level. This study was done with students in the fourth and fifth grades, with the majority of students in the fifth grade. The age range was from nine years old to eleven years old, with the average age being x. The results of the study may have been different if working with a younger or older population.

Secondly, the results must be evaluated with the Jibo robotic platform in mind. Firstly, Jibo was designed to interact in ways reminiscent of human social behaviors. These include responding to noise, looking at the user when they speak to him, and speaking with a specifically designed personality. Jibo's design encouraged social interaction and personification. It is also important to note that Jibo had a set of functionalities that did not change over time. He had limited knowledge of students, the main ones being name, face, and voice recognition, and was not able to learn any additional information. This is important because one aspect of relationship building is disclosing information, and this functionality with Jibo was limited.

This study was limited to a long-term interaction study where students learned about the robot while living with it. This research demonstrates that students interacted with their robot the most during their first week with it. Future studies might look at the role of education before receiving a robot to see how it impacts the first week of usage. Similarly, this research found that students developed a new ontological framing for Jibo over the course of the eight weeks. Future work would understand if this framing can be developed before living with a robot.

Jibo is a robot designed to do general tasks instead of one single, unique skill. Future work might look at the impact of education in robots with specific goals. For example, we might explore how learning about the underlying algorithms in a vocabulary teaching robot might affect students' learning outcomes. Can teaching students about the algorithms used impact how successful the algorithms are?

This work was done with a social robot, while smart speakers are currently more widespread in children's' homes. Though there is less anthropomorphization with smart speakers, it would be worth building on the work of Van Brummelen et al. [58] to understand how knowledge might impact the way that children perceive smart speakers over time. Specifically, it would be interesting to look into how trust changes for smart speakers, which are typically created and maintained by large corporations.

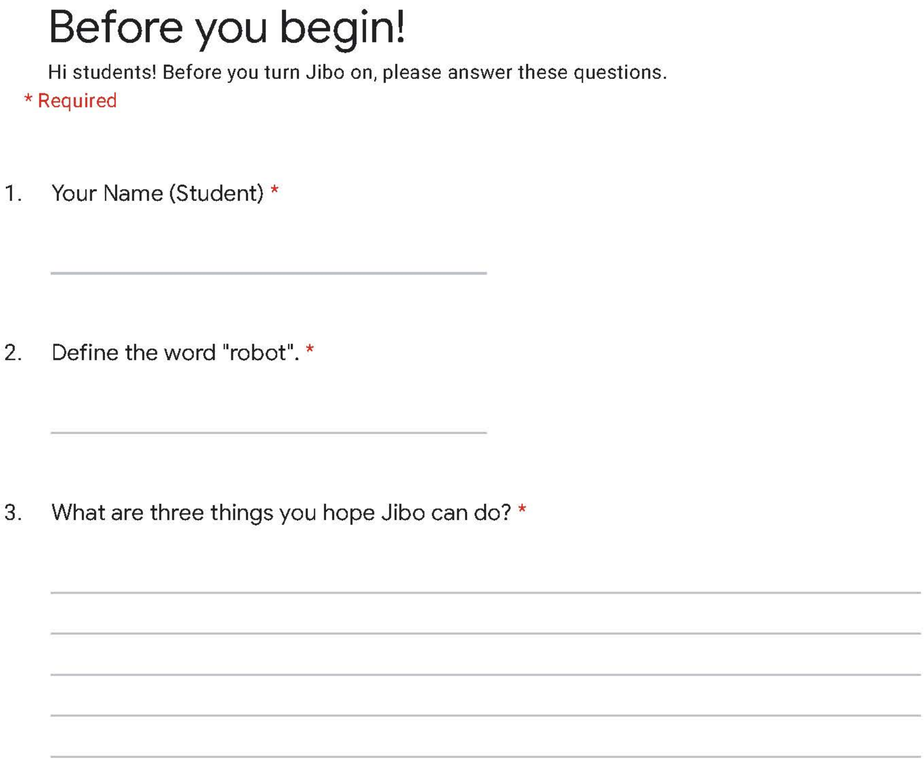
Finally, one of the most interesting findings from this study was the decrease in robot trust after the societal impact curriculum. Future work should understand how students are defining trust.

A

Pre Assessments

A.0.1 Pre-Questionnaire

A.0.2 Pre-Interview



Before you begin!

Hi students! Before you turn Jibo on, please answer these questions.

* Required

1. Your Name (Student) *

2. Define the word "robot". *

3. What are three things you hope Jibo can do? *

4. Please select whether or not you think Jibo can perform the capabilities listed below. *

Mark only one oval per row.

	Jibo CAN do this.	I'm not sure.	Jibo CANNOT do this.
Understand my feelings	○	○	○
Define a word	○	○	○
Calculate the square root of a number	○	○	○
Navigate through my house	○	○	○
Make a joke	○	○	○
Know what I'm interested in	○	○	○
Recognize when I've turned the lights on	○	○	○
Recognize when I'm in the room	○	○	○
Hear noises	○	○	○
Know when I touch him	○	○	○
Know the difference between me and my pet	○	○	○
Play music	○	○	○
Order pizza for me	○	○	○
Dance	○	○	○
Sing	○	○	○

Pre-Interview Protocol

This interview is to be completed no more than one week after the student receives Jibo.

Set-Up (5 minutes)

1. Make sure your Zoom recording is logging transcriptions.
2. Log in to Zoom meeting
3. Welcome student
    a. "Hi *name*! Nice to meet you. My name is Daniella and I am a researcher at MIT, and I like to think about how students interact with robots. I'm really excited that you are hosting Jibo at your home for a few months. Were you able to get everything set up correctly?"
        i. If no, set up time to troubleshoot
        ii. If yes, move on
    b. Set expectations for the study.
        i. Do you know what research is? Why do you think we research things?
            1. You will be helping me do my research! Not many students have had a robot in their homes, so I want to hear from you to tell me how it is going.
            2. If they have heard about research, ask them what they know about it.
        ii. Before you start using your robot, we are going to have a conversation today to hear what you think of robots. Before we begin, do you have any questions?
    c. Set up camera
        i. While we talk, I'd like to record our conversation so that I don't have to worry about taking notes during our discussion. Is that ok? When I am recording, you will see a red dot on the top left of your screen.
        ii. Begin recording.

Interview (25 minutes)

4. Background Information
   a. Why were you interested in participating in this study?
   b. What have you noticed about Jibo so far?
5. High Level Robot questions
   a. What do you think the benefits of robots are?
   b. What concerns you about robots?
   c. Have you ever worked with robots before? Have you ever programmed before
6. Likert Scales
   a. Go through slides 1-4 with students, sharing your screen and moving the star to the number they pick. Do not let students pick a "half number"-- ask them to pick one of the numbers on the screen
   b. Statements:
      i. I know how robots work. (1/Strongly Disagree - 5/Strongly Agree)
      ii. I know how Jibo works. (1/Strongly Disagree - 5/Strongly Agree)
      iii. Jibo is similar to other pieces of technology. (1/Strongly Disagree - 5/Strongly Agree)
      iv. Jibo is smarter than me. (1/Strongly Disagree - 5/Strongly Agree)
7. Inclusion of Other in Self + Narrative Description
   a. Say: In this part of the interview, I'll be asking you to tell me some stories about various objects and living things. We're going to start off with a pet.
   b. Pet
      i. Think about an animal that you know well. It could be your pet or a pet you know of and see regularly. Can you tell me more about that pet? What is its name and what type of animal is it? (if they don't have a pet, ask about a stuffed animal)
      ii. Can you tell me a story about this pet?
      iii. Open up a copy of the student's Interview Slide Deck
      iv. Now, I'm going to ask you about you and this pet. Look at these circles. Look at this one, the two circles are far far away from each other. These two circles must want to be far away from each other. Look at this one, the circles are very close together. These two circles must want to be close to each other
      v. Imagine one circle is you, and the other circle is the pet. Can you point to the circles that best show you and this pet?
      vi. Why did you choose that?
   c. Robot
      i. Now, I'm going to ask you about you and Jibo.
      ii. Can you tell me a story about Jibo?

        iii. Look at these circles. Imagine one circle is you, and the other circle is Jibo. Can you point to the circles that best show you and this Jibo?
        iv. Why did you choose that?
    d. Mailperson
        i. Now, I'm going to ask you about you and your mailperson.
        ii. Can you tell me a story about your mailperson?
        iii. Look at these circles. Imagine one circle is you, and the other circle is your mailperson. Can you point to the circles that best show you and your mailperson?
        iv. Why did you choose that?
    e. Computer
        i. Now, I'm going to ask you about you and your computer.
        ii. Can you tell me a story about your computer?
        iii. Look at these circles. Imagine one circle is you, and the other circle is your computer. Can you point to the circles that best show you and your computer?
        iv. Why did you choose that?
    f. Best Friend
        i. Now, I'm going to ask you about you and your best friend.
        ii. Can you tell me a story about your best friend?
        iii. Look at these circles. Imagine one circle is you, and the other circle is your best friend. Can you point to the circles that best show you and your best friend?
        iv. Why did you choose that?

8. Final questions
    a. What types of things do you do with Jibo? How often do you use him?
    b. Where did you place Jibo? Why?
    c. What have you noticed about Jibo? What do you like? What don't you like about him?
    d. Do you have any questions right now about Jibo and how he works?

Thank the student and if class, say that you will see them next week in class.

B

Post Assessments

B.0.1 Post-Questionnaire

B.0.2 Post-Interview

Post-Survey

* Required

1. Your Name

____

Please rate your impression of Jibo on these scales.

2. *

Mark only one oval.

	1	2	3	4	5	
Fake	○	○	○	○	○	Natural

3. *

Mark only one oval.

	1	2	3	4	5	
Machinelike	○	○	○	○	○	Humanlike

4. *

Mark only one oval.

	1	2	3	4	5	
Dead	○	○	○	○	○	Alive

5. *

Mark only one oval.

	1	2	3	4	5	
Mechanical	○	○	○	○	○	Organic

6. *

Mark only one oval.

	1	2	3	4	5	
Unfriendly	○	○	○	○	○	Friendly

7. *

Mark only one oval.

	1	2	3	4	5	
Dislike	○	○	○	○	○	Like

8. *

Mark only one oval.

	1	2	3	4	5	
Incompetent	○	○	○	○	○	Competent

9. *

Mark only one oval.

	1	2	3	4	5	
Irresponsible	○	○	○	○	○	Responsible

10. *

Mark only one oval.

	1	2	3	4	5	
Anxious	○	○	○	○	○	Relaxed

11. *

Mark only one oval.

	1	2	3	4	5	
Agitated	○	○	○	○	○	Calm

12. *

Mark only one oval.

	1	2	3	4	5	
Untrustworthy	○	○	○	○	○	Trustworthy

13. Please select whether or not you think Jibo can perform the capabilities listed below. *

Mark only one oval per row.

	Jibo CAN do this.	I'm not sure.	Jibo CANNOT do this.
Understand my feelings	○	○	○
Define a word	○	○	○
Calculate the square root of a number	○	○	○
Navigate through my house	○	○	○
Make a joke	○	○	○
Know what I'm interested in	○	○	○
Recognize when I've turned the lights on	○	○	○
Recognize when I'm in the room	○	○	○
Hear noises	○	○	○
Know when I touch him	○	○	○
Know the difference between me and my pet	○	○	○
Play music	○	○	○
Order pizza for me	○	○	○
Dance	○	○	○
Sing	○	○	○

Post-Interview Protocol

This interview is to be completed no more than one week after the student receives Jibo.

Set-Up (5 minutes)

1. Make sure your Zoom recording is logging transcriptions.
2. Log in to Zoom meeting
3. Welcome student
    a. "Hi *name*!"
        i. Thank them for their participation in the study, tell them that this is the last meeting we have together
    b. Set up camera
        i. While we talk, I'd like to record our conversation so that I don't have to worry about taking notes during our discussion. Is that ok? When I am recording, you will see a red dot on the top left of your screen.
        ii. Begin recording.
4. Ask them to fill out this survey: https://forms.gle/Kcu4MhPE6KJwSaMH7
5. Thanks for filling out the survey! Now, I'm going to ask you some questions about your thoughts on robots, have you tell me some stories, and finally tell me what you thought of Jibo and the class.

Interview (25 minutes)

6. To start off today, what is your definition of a robot?
7. What do you think the benefits of robots are?
8. What concerns you about robots?
9. What do you think are the benefits of Jibo?
10. What concerns you about Jibo?
11. Open up slide deck and share screen
    a. Ask them how they would rate the sentences on 1-5
    b. Once they rate a sentence, have them tell you why they rated it that way
12. Inclusion of Other in Self + Narrative Description
    a. Pet
        i. Think about an animal that you know well. It could be your pet or a pet you know of and see regularly. Can you tell me a story about this pet?
        ii. Now, I'm going to ask you about you and this pet. Look at these circles. Look at this one, the two circles are far far away from each other. These two circles must want to be far away from each other. Look at this one, the circles are very close together. These two circles must want to be close to each other
        iii. Imagine one circle is you, and the other circle is the pet. Can you point to the circles that best show you and this pet?
    b. Robot
        i. Now, I'm going to ask you about you and Jibo.
        ii. Can you tell me a story about Jibo?
        iii. Look at these circles. Imagine one circle is you, and the other circle is Jibo. Can you point to the circles that best show you and this Jibo?
    c. Mailman
        i. Now, I'm going to ask you about you and your mailman.
        ii. Can you tell me a story about your mailman?
        iii. Look at these circles. Imagine one circle is you, and the other circle is your mailman. Can you point to the circles that best show you and your mail man?
    d. Computer
        i. Now, I'm going to ask you about you and your computer.
        ii. Can you tell me a story about your computer?
        iii. Look at these circles. Imagine one circle is you, and the other circle is your computer. Can you point to the circles that best show you and your computer?
    e. Best Friend
        i. Now, I'm going to ask you about you and your best friend.
        ii. Can you tell me a story about your best friend?

        iii. Look at these circles. Imagine one circle is you, and the other circle is your best friend. Can you point to the circles that best show you and your best friend?

13. Final questions
    a. What types of things do you do with Jibo? How often do you use him? Do you leave him on or do you ever shut him off?
    b. What do you wish could change? What is one thing you wish Jibo could do?
    c. Do you think Jibo learned anything over time? If so, what?
    d. Do you think Jibo knows things about you? If so, what?
    e. What type of person do you think would enjoy jibo?
    f. **[If no class]** Do you have any questions right now about Jibo and how he works?
14. Class Specific
    a. What did you think of the class you took?
    b. If you had to go teach your class about robots tomorrow, what would you tell them? What are the most important parts to get across?
    c. What do you still wish you knew about robots?
    d. [If programming] Is there someone you would recommend programming a robot to? Why?
    e. Would you rather have Jibo in your house for two months or be in the class?
15. Will you miss Jibo?

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