Constructionism, Ethics, and Creativity: Developing Primary and Middle School Artificial Intelligence Education

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Abstract

Children growing up in the era of artificial intelligence (AI) will have a fundamentally different relationship with technology than those before them. As AI changes how we live, work, and play this raises the critical question, *"How do we best prepare students to flourish in the era of AI?"*
In order to create a future where a diverse and inclusive citizenry can participate in the development of the future of AI, we are developing powerful K-12 AI education curricula that emphasize constructionist learning, designing with ethics in mind, and developing a creative mindset. Children will need all of these skills to thrive in the AI era. Here, we describe the tools we created and studies we conducted to build curricula that embody these core principles.

Figure 1: To learn about AI, children trained and interacted with robots like Jibo (left) and PopBots (right).

1 Introduction

Over the past several years, we have seen the revolution of many industries due to rapid adoption of artificial intelligence (AI) in services and products. It is imperative that formal K-12 education prioritize AI literacy and teaching children to leverage AI and creativity to solve problems [Zimmerman, 2018]. All children should be able to identify examples of AI in their world, grasp how common AI algorithms function, use these algorithms to solve problems meaningful to them, and evaluate the impact of AI systems on society. This paper describes the K-8th grade curricula we have developed and evaluated toward enabling children to understand AI, learn about ethics, and think creatively.

2 Background

2.1 Artificial Intelligence Education

There are a number of commercial and research platforms for children's computational thinking. However, the majority of these platforms do not teach children about big ideas in AI such as how computers perceive the world, represent knowledge, reason and learn about the world, [Touretzky *et al.*, 2019]. Within the past three years, only a few platforms have emerged that focus on teaching AI to grade school children. Most of these are for advanced high school students and none are designed for children younger than 7. These platforms and curricula include *Cognimates, Machine Learning for Kids, Calypso for Cozmo, ReadyAI's AI-in-a-Box, Snap! AI Extensions*, and *Teachable Machine* [Lane, 2018; Druga, 2018; Touretzky and Gardner-McCune, 2018; Kahn *et al.*, 2018; Google, 2018]. These platforms leverage existing AI engines to enable children to do hands-on projects. However, none intentionally teach ethics or encourage creative mindsets. To our knowledge, we are the first to develop curricula that do both of these things and are accessible to young children.

2.2 AI + Ethics Education

It is imperative from an economic and justice standpoint that children understand AI and can build their own projects with it. However, focusing solely on the technical aspects of AI and machine learning is not enough. Researchers have shown that prominent machine learning algorithms, often advertised as "neutral" or "objective" systems, to be biased against women, people of color, and low-income individuals [Buolamwini and Gebru, 2018; O'Neil, 2016]. For this reason, many researchers and professors have argued that ethics must be taught in situ with undergraduate and graduate technical curricula [Skirpan *et al.*, 2018]. Similarly, we believe that we must train the next generation of technologists to see AI not only as a tool, but also a technolgoy of ethical and societal import.

Preteen students are typically developmentally ready to grapple with ethics and moral reasoning. Kohlberg's Theory of Moral Development asserts that children between the ages of 10 and 13 children are capable of reasoning about conformity, authority, social order, and reciprocity [Kohlberg and Hersh, 1977]. To our knowledge, we are the first to develop curricula to teach AI primarily through the lens of ethics.

2.3 Fostering Creativity in School

Children not only need to understand how AI works, but also be able to think creatively about how *they* want it to work. In computational thinking and AI education, students are constantly problem-solving. This increases the importance of fostering children's ability to think creatively. However, in 1968, Torrance found that students' creativity across the globe begins to decline around age 6, and slumps further in the fourth grade [Torrance, 1968]. One suggested reason for this slump is overly-structured school curricula and lack of play based learning activities in educational practices [Alves-Oliveira *et al.*, 2017; Guilford, 1950].

We define creativity as the ability to generate ideas that have *novelty*, highlight new and different themes, and *value*, boost problem solving [Boden, 2004]. We seek to help children develop a creative mindset through interaction with a robot. Robots are increasingly being used in education, and have shown to be effective tutors and learning companions [Belpaeme *et al.*, 2018]. Social robots, in particular, have previously been used as learning tools to foster positive learning behaviors, such as curiosity [Gordon *et al.*, 2015; Park *et al.*, 2017], growth mindset [Park *et al.*, 2017], grit, persistence, and attentiveness [Belpaeme *et al.*, 2018]. In some of these studies, this is accomplished by having the robot model the desired behavior. For example, Park demonstrated how a robot exhibiting curiosity and a growth mindset can leads to children demonstrating these behaviors in later tasks [Park *et al.*, 2017]. In our work, we explore if a robot exhibiting creative thinking can help foster creativity as a learning behavior in young children.

3 Constructionism: PopBots

PopBots, previously described in the literature, is the first robotic toolkit developed for children ages 4-6 to learn about AI [Williams *et al.*, 2019b; Williams *et al.*, 2019a]. Figure 1(right) shows the social robot learning companion embodied by a mobile phone (for the robot's socially expressive face) and LEGO blocks (for the robot's body, sensors and motors). The social robot serves as both a programmable artifact and a guide that steps students through AI algorithms, teaching them about AI through social interaction. The PopBots curriculum uses creative learning activities to teach students three AI concepts: knowledge-based systems, generative AI, and supervised machine learning.

These activities, using the interfaces in Figure 2, build off of the constructionist pedagogy: hands-on and project-based learning that allows children freedom to explore. Children learned knowledge-based systems by teaching the robot the rules of rock, paper, scissors and then playing against it. They learned generative AI by setting pitch and tempo parameters to define musical emotions, like excited music is fast in tempo and high in pitch. Then, children had the robot remix music in different emotional styles. Supervised machine learning was illustrated by having students develop training and test sets to teach the robot to differentiate healthy and unhealthy foods.

We evaluated the PopBots curriculum with 80 Pre-K and Kindergarten students who had no prior AI or programming experience. They spent four sessions working through each of the PopBots activities then completing an AI post-test. We found that the curriculum was effective for helping children understand AI. The median score on the 10 question AI assessment was 70%. Developmental factors like age and Theory of Mind skills often made a difference in what children understood. There was a slight difference between Pre-K (Median= 63.3%) and Kindergarteners (Median= 70.0%). This suggests that a further improvement to this system would personalize more to each child's developmental stage.

Figure 2: Interfaces for PopBots AI activities. a) Interface for telling the robot which moves beat which in rock, paper scissors. b) Interface for defining the tempo and pitch parameters for emotional music remixes. c) Interface for labelling foods as healthy or unhealthy.

4 Ethics: AI + Ethics Curriculum

Building on the constructionist pedagogy of PopBots, we developed hands-on, largely unplugged, AI activities to teach middle schoolers about the ethical ramifications of AI. The AI + Ethics Curriculum consists of three lessons.

The first lesson introduces AI, datasets, supervised machine learning, and the notion of algorithmic bias. Using Google's Teachable Machine [Google, 2018], students train a cat-dog classifier with two datasets: first, a biased dataset where cats are over-represented, and a second with equal, diverse representation between both dogs and cats. Students then compare accuracy between the classifiers and discuss which outcome is fairer. This activity leads into a discussion about a video highlighting the occurrence of bias in facial recognition algorithms [Buolamwini and Gebru, 2018].

The second lesson introduces two concepts of Cathy O'Neil's: algorithms as opinions and stakeholder analysis using an ethical matrix, as in 3 [Hanna Gunn, 2019]. First, students develop an algorithm for making the "best" peanut butter and jelly sandwich. After which, students discuss what is meant by "best": is it the most delicious, the healthiest, the quickest to make? The discussion transitions to stakeholders in their PB&J: perhaps the child eating the sandwich, their parent, their doctor or dentist, and even a grocer who supplies different varieties of peanut butter.

The third and final lesson culminates in a paper prototyping activity shown in Figure 4 where students redesign YouTube's recommender system by first identifying stakeholders in the

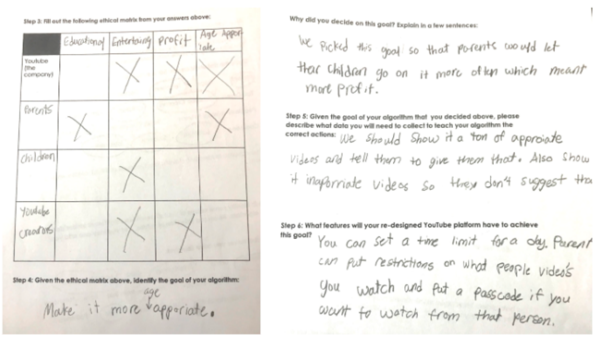

Figure 3: An example of a student's ethical matrix around YouTube's recommendation system. The student identified stakeholders and potential values those stakeholders might have. Using this analysis, students determined that their recommendation algorithm should prioritize age-appropriateness as this would increase children viewership and increase profit.

system, identifying the values of those stakeholders, and then using an ethical matrix to determine what the goal of their version of YouTube's recommendation algorithm should be.

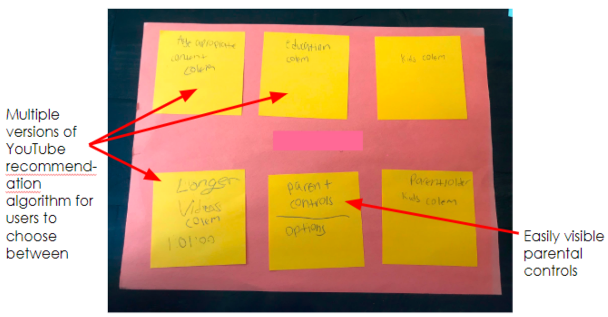

Figure 4: A paper prototype of "age appropriate YouTube." Students included visible parental controls as well as multiple recommended feeds with clear goals for users to choose between (e.g. an algorithm that recommends longer videos as opposed to an algorithm that prioritizes educational content).

We evaluated this curriculum with 225 middle school students in grades 5 through 8 across three 45-minute sessions. These students had no prior formal AI or programming education. Students filled out pre- and post-tests with each lesson, and activity worksheets during the lesson. Students showed a capacity to engage with the material at varying levels. When asked how AI could be bad, students shared sentiments like "I learned that some AI, like facial recognition, has trouble identifying darker people and females," showing that they understood the finding in Buolamwini and Gebru's work as unfair. Many more students responded to this question with concerns about the future of work "Yes, it can take jobs from humans" or concerns about a robot apocalypse, "Also, there's terminator." It is clear that future instruction on the societal impact of AI will need to address narratives from the media.

5 Creativity: Droodle Creativity Game

Given the foundation of the robot toolkit and activities that help children learn about AI, we then explored the role that a social robotic peer can play in helping children think creatively by modeling creative behavior. We developed an interactive game inspired from the Droodle Creativity Task [Severson *et al.*, 2005; Ali *et al.*, 2019]. Within this game, children collaborate with Jibo (Figure 1, left), a social robot that expresses verbal and non-verbal patterns of artificial creativity.

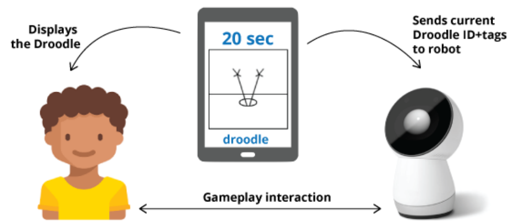

Figure 5: The child and the robot play the Droodle game collaboratively. The Droodles are displayed on the Android tablet. The tablet communicates the current Droodle ID and titles to the robot.

In the game, the child and the robot take turns coming up with titles for a simple, abstract drawing, called a Droodle, displayed on a tablet as in Figure 5. The Droodle Task coding system provides a comprehensive guide to rank the titles provided by participants as 'non-Droodle', 'low-', 'medium-', or 'high-Droodle' by the coder based on their initial reaction, pattern matching, and categories and rationale. For instance, in Figure 5 an example low-Droodle phrase would be '2 lines sticking out of a circle', and an example high-Droodle phrase would be, 'two birds hoisting a package'.

We evaluated 51 participants between the ages of 6 and 10 who played the Droodle Creativity Game with the robot. Participants were divided in two groups - the creative robot condition, and the non-creative robot condition. Participants' and robot's creativity was measured by their fluency, the number of ideas that the participants generated, novelty, the number of unique themes explored through the ideas, and value, the Droodle creativity metric as defined by Kahn et al. [Kahn *et al.*, 2016]. Participants for each condition were balanced based on their pre-test creativity scores and age [Torrance, 1968].

We observed that participants that interacted with the creative robot generated significantly higher number of Droodle titles and expressed greater variety in titles, thus scoring higher on the Droodles' creativity $M = 3.325, SD = 1,16$ versus the non-creative condition $M = 2.416, SD = 0.96$, $p < 0.01$. This demonstrates that our robot interaction was effective in causing children to model the social robot's creative behavior. Furthermore, our robot interaction patterns for artificial creativity is a good model for robot behavior that fosters creativity in children.

6 Conclusions

In this paper, we discussed three projects that engage primary and middle school students in AI education with an emphasis on constructionism, ethics, and creativity. Within each curriculum there are important next steps to be taken. For PopBots and AI + Ethics, we are expanding the curricula to introduce more AI concepts and their societal implications. This involves designing new interfaces and activities for children to explore. In AI for creativity, we have developed and are evaluating new games where children need to produce creative ideas to train their robot to complete tasks. In the bigger picture, we are looking at how insights about our core principles and age ranges can transfer across the three projects.

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