How to Train Your Robot

Project-Based AI Education for Middle School Classrooms

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ABSTRACT

We developed the How to Train Your Robot curriculum to empower middle school students to become conscientious users and creators of Artificial Intelligence (AI). As AI becomes more embedded in our daily lives, all members of society should have the opportunity to become AI literate. Today, most deployed work in K-12 AI education takes place at strong STEM schools or during extracurricular clubs. But, to promote equity in the field of AI, we must also design curricula for classroom use at schools with limited resources. How to Train Your Robot leverages a low-cost ($40) robot, a block-based programming platform, novice-friendly model creation tools, and hands-on activities to introduce students to machine learning.

During the summer of 2020, we trained in-service teachers, primarily from Title 1 public schools, to deliver a five-day, online version of the curriculum to their students. In this work, we describe how students' self-directed final projects demonstrate their understanding of technical and ethical AI concepts. Students successfully selected project ideas, taking the strengths and weaknesses of machine learning into account, and implemented an array of projects about everything from entertainment to science. We saw that students had the most difficulty designing mechanisms to respond to user feedback after deployment. We hope this work inspires future AI curricula that can be used in middle school classrooms.

KEYWORDS

AI literacy, CS education, machine learning

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1 PROBLEM AND MOTIVATION

Today, a large portion of the United States' population engages with Artificial Intelligence (AI) without realizing it or understanding how the technology functions [10]. Teaching AI to K-12 students, particularly in public schools, is a powerful way to ensure that a diverse citizenry obtains the necessary 21st-century skills they need to flourish in an AI-powered society and economy. We developed the *How to Train Your Robot* curriculum activities and programming platform to bring AI education to public middle school classrooms. The curriculum includes powerful, yet accessible, hands-on activities that allow students to learn about and tinker with machine learning algorithms. In the midst of the COVID-19 pandemic, we evaluated an abbreviated version of the curriculum by conducting a virtual workshop.

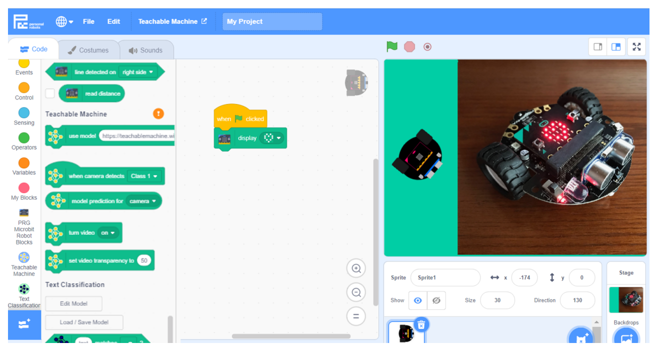

Figure 1: The block-based programming interface and micro:bit robot used in some curriculum activities.

2 BACKGROUND AND RELATED WORK

Over the past three years, there has been increased attention on developing educational interventions that teach children about AI. Our curriculum focuses on helping students define AI and recognize it in their everyday lives (Competencies 1 and 2 [9]), understand that AI learn from data (Big Idea #3 [16]), realize that AI can impact society in both positive and negative ways (Big Idea #5 [16]). Furthermore, we seek to have students develop the skills to appropriately scope, plan, and develop machine learning projects of their own (Skills 1, 2, and 3 [7]) so that they can develop confidence in their ability to contribute to the field of AI (Attitude 3 [7]).

2.1 Machine Learning in AI Education

Powerful platforms, such as Machine Learning for Kids [6] and Teachable Machine [2], use child-friendly interfaces to enable middle school students to learn about AI by constructing their own models. One limitation of these interventions is that they are primarily designed for informal learning experiences. We designed *How to Train Your Robot* to reach students who may not have previous interest or experience in technology. Our curriculum builds on

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top of Teachable Machine and Scratch Blocks' open-source repository [8] so that students' learning can revolve around hands-on experiences.

2.2 Ethics in AI Education

Ethics is an extremely important, yet often overlooked, topic in many Computer Science and AI classes [4, 12]. In the MIT AI and Ethics Middle School Curriculum developed by Payne, technical concepts are taught alongside ethical ones [11]. Our curriculum leverages some of the activities and approaches developed by Payne to help students grasp the importance of having ethics in mid when designing new AI systems.

3 APPROACH AND UNIQUENESS

Toward the goal of an AI literate society, we strive to have students become conscientious consumers and ethical engineers of AI [12]. Students should be able to knowledgeably engage with AI artifacts and navigate making design choices to maximize positive benefits reducing harm. To be inclusive of a range of middle school classrooms, we designed the activities and tools to be low-cost, effective on low-power computers, and related to middle school common core, science, and digital literacy standards [1].

3.1 Activities

Everyday, students explored different ethical and technical concepts in machine learning and AI. In the ethics modules, they learned about the positive and negative impacts of AI, product design tradeoffs, and how to conduct stakeholder analysis. In the technical modules, students learned about text and image classification, algorithmic bias, and how to build their own models. Activities generally followed the structure of an introduction to the topic, a demonstration of a hands-on exploration activity, scaffolded guidance as students completed the activity, and then discussion and reflection. At the end of the week, students completed final projects to share what they had learned to an audience of their family and friends. Curriculum materials are available at https://httyr.media.mit.edu.

3.2 Programming Platform

Students program using a custom version of Scratch Blocks [8] we built to integrate machine learning extensions into the typical Scratch experience (see Figure 1). Using Teachable Machine, students can train custom image recognition models and then export the model for use in their block-based programs where the model classifies images from the webcam. For text classification, we built an interface directly into Scratch that leverages Google's Universal Sentence Encoder [3, 15] and TensorflowJS K Nearest Neighbors library [14]. All extensions run in the Chrome browser without the need for any installations or user accounts; this makes setup easy and keeps student data off external servers. The platform can be accessed at https://mitmedialab.github.io/prg-extension-boilerplate/robotafe.

3.3 Robot Platform

Although robotics education is not our focus, we integrated a physical robot into the course to promote student engagement through embodied interaction [5, 13]. Students used a $30, commercial micro:bit robot that include peripherals like push buttons, a 25-LED array, two RGB LED headlights, a piezo buzzer, a distance sensor, two line sensors, and two motors[1]. We developed firmware that made it possible for students to connect robots directly to Chrome browsers using bluetooth.

3.4 Participants

We conducted a study as an online class, where students engaged in activities for three hours every day over five days. Five teachers and 29 students from Title 1 schools around the United States attended, with 25 students consenting to our use of their work in the research study. Participants ranged in age from 11 to 16 (average 12.7 years-old), 17 identified as female, 6 identified as male, and 2 did not specify a gender.

4 RESULTS

To evaluate the usability of the tools and their ability to stimulate students' creativity, we examined the kinds of projects that students created. We had 24 project designs since one pair of siblings collaborated on a project. Fourteen out of 24 projects used machine learning algorithms, eight projects used robotics but no machine learning, and one built on a non-AI, decision-making algorithm students learned on the second day. Applications of student projects included entertainment (7 projects), helping people (7 projects), healthcare (5), science (3), and education (2). The primary beneficiaries of students' projects were children and teens (5 projects), their families (2), and their communities (2).

To evaluate the effectiveness of the activities and our project-based learning approach, we used a rubric to evaluate projects on their implementation and application of technical and ethical knowledge. Two researchers independently rated projects final projects as satisfactory, marginal, or unsatisfactory on each of the aforementioned points.

Students performed well in selecting problems, programming, and constructing machine learning models. The only example of an issue of problem selection occurred in a project to use the K Nearest Neighbors algorithm to distinguish the symptoms of a cold, a flu, and COVID-19. There were too many overlaps in the symptoms for the algorithm to work well. In model construction, only two text classification projects had issues with their model construction: one had an unbalanced dataset with too many training examples in one class and the other had fewer than five training examples in their classes. Overall, students' ability to successfully design and build projects with machine learning demonstrates their AI capabilities.

Students struggled the most with identifying a plan to test and improve their applications after they were deployed, sometimes neglecting to design an appropriate mechanism for evaluation and feedback of their systems. For example, in a math robot tutor project, the student design mentioned surveying users on how much they liked the robot tutor, but did not include an evaluation based on whether users' mathematics scores improved with tutoring. We discussed the importance of feedback loops in class, however applying

[1] Yahboom Tinybit, https://category.yahboom.net/products/tinybit

these ideas to projects might require more time for reflection, perhaps by engaging with peers or directly with stakeholders during the design process.

From this evaluation, we identified common applications and oversights in students projects. This information will help us better support students as we use this curriculum in more classrooms.

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