Introducing Children to AI and ML with Five Software Exhibits

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ABSTRACT

Artificial intelligence (AI) and machine learning (ML) have a deepening impact in our world. For empowered citizenship and career readiness, elementary and middle school students need to understand these technologies. To provide engaging introductory experiences, we created five original interactive software exhibits introducing children to hands-on activities in AI and ML. The exhibits were tested by 125 elementary and middle school students (aged 7 to 14). Four themes emerged: Students recognized that AI and ML systems can process data from cameras (perception); they saw that these systems responded to their training input (trust); they appreciated the practical import of AI/ML systems (affective and cognitive attitudes); and students were introduced to models and modes (specialization). This paper presents our goals in creating the exhibits and results from our initial testing with children. Our work contributes to the literature on formal and informal activities for introducing AI and ML to young learners.

CCS CONCEPTS

• **Social and professional topics → Computing education**; **K-12 education**; **Computing literacy**; • **Human-centered computing → Interactive systems and tools**.

KEYWORDS

Artificial Intelligence, Machine Learning, Models, K–8 Students, Software Tools

ACM Reference Format:
Saniya Vahedian Movahed, James Dimino, Andrew Farrell, Elyas Irankhah, Srija Ghosh, Garima Jain, Vaishali Mahipal, Pranathi Rayavaram, Ismaila Temitayo Sanusi, Erika Salas, Kelilah Wolkowicz, Sashank Narain, and Fred Martin. 2024. Introducing Children to AI and ML with Five Software Exhibits. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems (CHI EA '24), May 11–16, 2024, Honolulu, HI, USA.* ACM, New York, NY, USA, 6 pages. https://doi.org/10.1145/3613905.3650991

1 INTRODUCTION

In today's world, artificial intelligence (AI) is integrated into various domains such as education, entertainment, and communication, influencing and making decisions for both adults and children, often without their awareness [1, 5, 6, 29]. Sherry Turkle emphasizes that technology offers unique opportunities for exploration, self-expression, and relationship-building [24]; she highlights AI's role beyond being a mere tool and rather a technology that influences the way people learn and interact with the world [25]. However, the opacity of these systems can lead to misconceptions [14, 21] and challenge effective collaboration and critical evaluation. Issues such

CHI EA '24, May 11–16, 2024, Honolulu, HI, USA

ACM ISBN 979-8-4007-0331-7/24/05
https://doi.org/10.1145/3613905.3650991

as privacy breaches [20], biases [3], and discrimination [2] add to the complexity of their use. Research indicates that children often overestimate the capabilities of AI when they lack understanding of how these systems function [14]. Consequently, education about the benefits, risks, and ethical considerations of AI is crucial for people specially children to effectively navigate these challenges.

AI educational tools, lying at the intersection of Human-Computer Interaction (HCI), Explainable AI (XAI), and AI Literacy, aim to ensure accessibility, transparency, and effective use [11, 26]. These tools include visual programming languages, interactive games, and tangible interfaces designed to foster AI literacy, critical thinking, problem-solving, creativity, ethics, and social-emotional development in children.

The Artificial Intelligence for K-12 Initiative has outlined the "Five Big Ideas in AI": perception, representation and reasoning, learning, natural interaction, and societal impact [7, 23]. These concepts are further reinforced through exposure to knowledge-based systems, machine learning, and social robots [27], with attention to issues such as AI gender biases [17]. Many technologies for introducing children to AI have been developed, including Machine Learning for Kids [9], AI for Oceans by [19], PopBots [28], and Zhorai [12].

AI integration into learning environments offers an opportunity for hands-on exploration and experiential learning. Diverse and accessible AI education can help children better understand AI's potential benefits and risks and learn how to engage with AI systems critically [4, 8]. Informal education settings, like museum exhibits, play a vital role in promoting science literacy and enabling critical engagement with technology [22]. This study draws inspiration from museum exhibits introducing AI to children which combine interactive and engaging elements to create educational experiences [10, 13]. By engaging children in interactive AI and machine learning experiences, we gain insights into their interests, attitudes, and dispositions towards AI.

Our study aims to engage children in a K-8 school setting with interactive, introductory experiences in AI and machine learning (ML). Our objectives are to:

- Investigate the impact of interactive, introductory AI and ML experiences on children's perceptions and understanding of AI and ML.
- Introduce children to the idea of models in machine learning.
- Highlight the practical significance and applications of AI/ML systems.

It is crucial to understand how children interpret, understand, and interact with AI in order to design AI interfaces, educational programs, and policy that will impact how children use AI. For ethical considerations about privacy, security, and the impact of AI on children's development and well being, it is also important to consider children's views and experiences with AI.

In the following section, we discuss the AI exhibits, including the purpose, description, and experiences associated with each tool. Interpretations come from both qualitative and quantitative data, depending on the tool. This is followed by a discussion and conclusion.

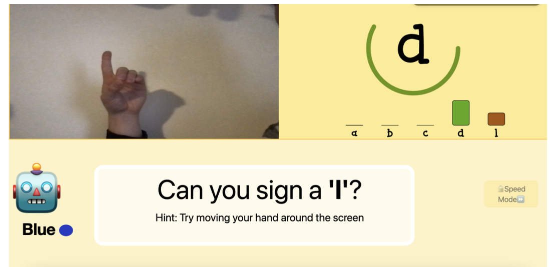

Figure 1: AI for American Sign Language

2 AI EXHIBITS

The last author offered a special topics course in Spring 2023 entitled "Developing AI Tools for Children." Ten students of mixed levels and and two other faculty members participated in the course (the co-authors). The group met weekly to conceive and implement five original interactive software experiences introducing ideas in AI and ML [16]. They reviewed foundational literature in teaching AI to children, including Long and Magerko's "competencies and design considerations" for AI literacy [14].

The class engaged in a brainstorming and iterative refinement process and produced five interactive software "exhibits" designed for short engagements. The exhibits were tested over two school days at a public K–8 school located in a gateway city in the Northeast United States. IRB permission to conduct the study was obtained and district permission was granted. Parental consent and student assent was obtained.

A total of 125 children aged from 7 to 14 years old used the software products. Five 45-minute class sessions were conducted over two days. Each exhibit had two stations for student use and had one or two university students dedicated to helping the children interact with the tool. During each session, a class of 25 students rotated through the exhibits in small groups. Assistance was provided by school teachers and staff. Usage data were collected via screen-recording with audio recording of conversations; instrumentation of click data from the tools themselves; and post-surveys.

As connected with AI4K12.org's Five Big Ideas, the exhibits were: (1–Perception) AI for American Sign Language, in which students' hand gestures were recognized by pre-trained models as individual letters of the ASL alphabet; (2–Representation & Reasoning) Tic-Tac-Toe, where students play against any of three computer opponents, each with a different algorithm/skill-level; (3–Learning) Chemistry Safety Lab, where students provided training examples of safe and unsafe items and saw the results of their training as applied to other examples; (4–Natural Interaction) Ask Me Anything, a child-safe chatbot to have conversations on three topics of interest to children; and (5–Societal Impact) AI for Self-Driving Cars, a simulation of how autonomous cars perform when trained on different obstacles they will encounter in driving. See Table 1 above for key details on each.

2.1 AI for American Sign Language

The AI for American Sign Language (ASL) exhibit was designed to show students that AI is capable of recognizing video images of

Table 1: Overview of the Five Exhibits

Exhibit	Introduction	AI4K12 Big Idea	Student Outcomes
AI for American Sign Language	Have computer recognize video hand gestures for letters of the ASL alphabet	1–Perception	How sample quality affect model performance
Tic-Tac-Toe	Play Tic-Tac-Toe against your choice of three different opponents	2–Representation & Reasoning	Recognizing AI has different capabilities; trying to beat the computer
Chemistry Safety Lab (ChemAIstry)	Specify to computer which objects are lab-safe and see results of training	3–Learning	Understand the significance of the training model
Ask Me Anything	Interact with chatbot with questions on dinosaurs, shoes, and astronomy	4–Natural Interaction	Insights into students' trust of AI
AI for Self-Driving Cars	See behavior of on-screen self-driving car using three different training models	5–Societal Impact	Understanding the potential impacts of inadequate training data.

hand gestures. It uses Google's Teachable Machine, trained with two different ML models—*Blue* and *Red*—for recognizing the ASL alphabet. The Blue model had the letters **a b c d l** and the Red model had the letters **d e f g i**. In the case of letter **d**, students could select either model to have it recognized, but in the case of the other letters, students had to select the correct model. AI for ASL introduced the very idea of a model: that two models were provided with differing capabilities. The project also introduced students to the ASL alphabet. See Figure 1.

Purpose. AI for ASL exhibit highlights Big Idea 1, Perception: that AI can interpret and understand sensor data. In ASL, the emphasis is on understanding and managing the input data as the accuracy, performance, and predictive capabilities of machine learning models are greatly affected by this factor. This exhibit aimed to teach students not just how machines recognize patterns, but how their input data influences their predictions (their hand gestures).

Description. For privacy reasons, we designed a setup to eliminate participants' faces on camera. Students started interacting with the program by practicing Blue and then Red model letters in Free mode. When finished, they switched to a "Speed mode," where they attempt to sign as many letters as possible within a time limit of two minutes. Students were prompted to choose the proper model for recognizing each specified letter. They earned points for correct responses by demonstrating the hand signs for each letter, promoting engagement. We supported them in positioning their hands closer to or farther from the camera; they realized that distance affected the model output prediction. Comparing the Blue and Red AI models' prediction accuracy stimulated discussions about possible data set biases.

Experiences and Observations. A total of 20 students interacted with AI for ASL. They observed the ML models' predictions and guesses based on their hand signs in real-time. They recognized that specific letters correlated with certain models in both free and speed mode play. The majority of students enjoyed the speed mode challenge game. Students recognized that their hand signs—the input data—is the foundation of the model performance. To test this, we asked them how your hand's distance from the screen affects the model's recognition? Per one student, "the model may be used to a larger hand, so you would want to bring your hand closer to it." Another student responded "It may be unfocused and may have trouble identifying the letter."

Figure 2: Tic-Tac-Toe

2.2 Tic-Tac-Toe

This educational tool implemented the well-known game of Tic-Tac-Toe to engage students in thinking about how artificial intelligence can have algorithms with different performances. It facilitated this understanding through three "personified" AI opponents: Olivia (easy), Emma (medium), and Chris (advanced), each exhibiting varying levels of strategic depth in the game-play. See Figure 2.

Purpose. The three AI opponents implicitly presented students with a variety of AI decision-making models. Olivia, the easiest AI, made moves randomly. Chris, the advanced AI, employed the mini-max algorithm and plays perfectly. Emma, the medium-level AI, randomly selected from Olivia's game play or Chris's game play.

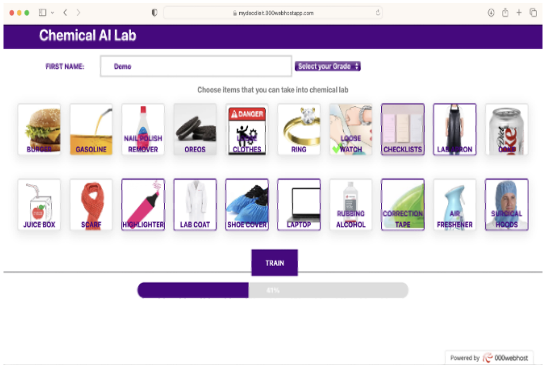

Figure 3: Chemistry Safety Lab (ChemAIstry)

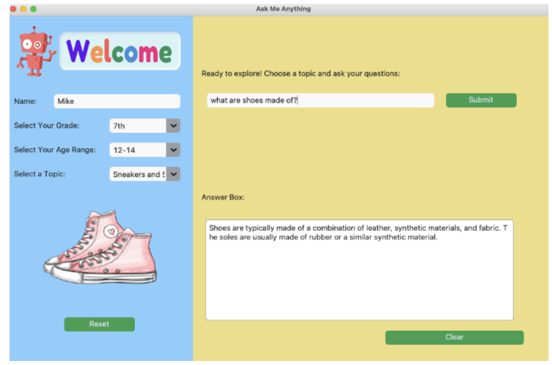

Figure 4: Ask Me Anything

This exhibit highlighted AI4K12.org's Big Idea 2, Representation and Reasoning.

Description. To play the game, students choose their opponent and then go first, playing the "X" move. The AI responds and then it's the student's turn. At the end of the game, the system tells them the result along with congratulations if they win or encouragement to play again if they lose or tie.

Experiences and Observations A total of 56 students used the Tic-Tac-Toe exhibit. They demonstrated varying strategies to outmaneuver the AI opponents. Some students began by making random moves, but as they continued playing and started discerning the different decision-making styles of the AI opponents, they began to modify and improve their strategies. For example, against Olivia, they quickly learned to capitalize on her random moves. Against Emma, they took advantage of her reactive strategy, and against Chris, they had to think several moves ahead owing to his anticipatory play style.

Students recognized that Chris was the most challenging opponent. They took particular joy in trying (unsuccessfully) to beat Chris. They deliberately chose to play some games against the other two players to have the satisfaction of winning. In a post-trial survey, students were able to accurately identify the relative skill levels of the three personified opponents. The students' responses indicated an overall positive reception, with appreciation for the game's challenge and insights into AI's decision-making processes they gained from playing against the three AI opponents.

2.3 Chemistry Safety Lab (ChemAIstry)

ChemAIstry is an interactive software tool that allowed students to train a machine learning (ML) about the safety procedures in a chemistry lab [15]. See Figure 3.

Purpose. This exhibit highlighted AI4K12.org's Big Idea 3, Learning. It demonstrated the foundational premise of machine learning; namely, that the computer develops a model from training data. It also highlighted that an ML system classifies objects into different categories. In this case, the categories are of items that are either "safe" or "unsafe" to bring into a chemistry lab.

Description. The tool displays a set of twenty objects on the screen. The student selects the items that are safe to take in a chemistry lab and then clicks a button to train its ML model. Based on the items selected by the student, the trained model then classifies a new set of similar items as safe or unsafe. Each initial set of twenty items consists of eight safe items and twelve unsafe items which are randomly selected from a set of 100 items that consist of 40 safe items and 60 unsafe items. These items belonged to five categories: Flammable Items, Personal Protective Equipment (PPE), Food, Research Instruments, and Unsafe Wearables. Only the items belonging to the PPE and Research Instruments categories were coded as safe.

Experiences and observation. ChemAIstry was particularly intended for middle school students. When used by younger students, we described it as simply a "science lab." A total of 40 students used the tool, performing 95 train-and-review cycles.

The software itself gathered usage data, including the items students chose and the items they did not during training. With the help of this information, we were able to determine a "Correspondence Score," which measured a student's performance on the task in range from zero to 20, where 20 is a perfect score. Additionally, we performed a Monte Carlo simulation that indicated a 95% confidence for scores between $[0, 6]$ and $[15, 20]$. 49 out of 95 trials lied within this range and showed that the students' selection were intentional. We also recorded the screen activity and the audio for the exhibits' conversations. Students trained the model using the objects they determined to be safe. A few students also did a "reverse training," deliberately training with unsafe items. They analyzed the results after training and made some remarks like "Well, in my opinion this is pretty cool" and "That makes sense." These data suggest that the trained model is made decisions based on the items they chose and that students were able to understand the activity.

2.4 Ask Me Anything

Ask Me Anything (AMA) is a chatbot powered by ChatGPT [18]. To spark student interest, it was deliberately limited to respond to students' questions about three specific child-friendly topics: Astronomy, Sneakers & Shoes, and Dinosaurs. See Figure 4.

Purpose. The goal of the project was to elicit and understand students' attitudes towards AI chatbots. Ask Me Anything highlighted AI4K12.org's Big Idea 4, Natural Interaction. The project provided students with an experience with the contemporary capabilities of chatbots and their ability to focus conversation on a specific topic.

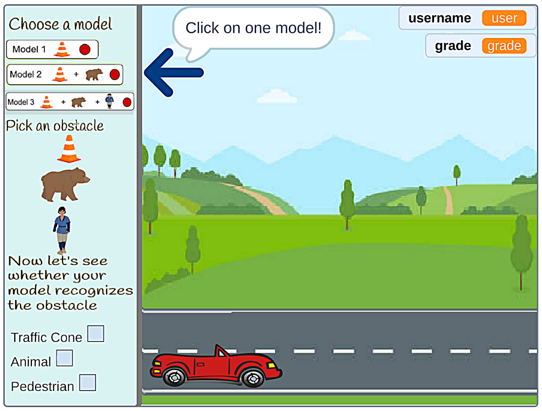

Figure 5: AI for Self-Driving Cars

Description To interact with AMA, students first entered their name and navigated to a drop-down menu where they select their grade. They indicated their age, which caused the chatbot to respond with corresponding simplicity or complexity. Children then selected the conversation topic, and a displayed image changed as a visual cue. Students typed their questions into a designated text box on the right side. Upon clicking on the submit button, the chatbot quickly responded.

Experiences and observation A total of 63 students interacted with Ask Me Anything. Interactions with AMA were engaging, curious, trusting, and sometimes surprising for students. Dinosaurs and Sneakers & Shoes were the more popular topics. Students expressed surprise at AMA's perceived intelligence during their interactions with it. Some students used a "trust test" strategy by posing questions for which they already knew the answers to verify the AMA's accuracy; when the chatbot provided accurate information, this confirmed its reliability. For example, one 8th grader expressed trust in the chatbot's responses, "I can trust the chatbot answer because it sounds real and I can compare it to what I already know about dinosaurs." A 7th grader conveyed a curious attitude toward the chatbot's knowledge of astronomy, indicating an eagerness to learn more about its capabilities, "It knows so much about astronomy, I wonder if it can learn about other things." Some students anthropomorphized the chatbot, asking relational questions like "Can I wear sandals to the beach?"—a sign of their deep, human-like engagement with the chatbot.

2.5 AI for Self-Driving Cars

AI for Self-driving Cars introduced an interactive simulation designed to help students grasp the practical application of AI in enabling self-driving cars to identify obstacles on roads and navigate safely. See Figure 5.

Purpose. The exhibit addressed AI4K12.org's Big Idea 5, Societal Impact. This interactive simulation fostered awareness among young learners about the profound societal implications of AI systems, using self-driving cars as an example. By engaging in role-playing scenarios as developers and end-users, children explored the vital role of diverse training data in constructing ethically sound AI models.

Description. We created three models using images of obstacles a self-driving car could encounter on the road, including traffic cones, animals, and pedestrians. The first model, Model 1, was exclusively trained on recognizing traffic cones. Model 2 was trained to identify traffic cones and animals, and Model 3 was trained on all three types of obstacles: traffic cones, animals, and pedestrians. The rationale behind developing these models was to underline the significance of diverse labeled training data in robust ML models. These models were then employed in the self-driving simulation.

The simulation had two main options: Model Selection and Obstacle Selection. Users chose a model (e.g., Model 1) to determine the car's behavior based on its capabilities. They picked obstacles like traffic cones, pedestrians, or animals to simulate encounters while the car moved. The simulations had scenarios showing positive and negative obstacle detection outcomes. In positive detection, Model 1 (trained exclusively on traffic cones) recognized obstacles like traffic cones, and the car took appropriate actions such as switching to another lane to account for lane closure. If an untrained obstacle like an animal is chosen, Model 1 treated it as a traffic cone and risked collision with the animal.

Experiences and Observations. Our exhibit engaged 26 students across grades 6, 7, and 8. In a post-survey, we asked students whether incorporating a broader range of data was essential for training strong models or if a more limited dataset would suffice. Nearly all, 96.2% (25 out of 26), clearly understood this concept. A second theme explored students' recognition of limitations tied to training models with limited data, focusing on whether models trained solely on images of traffic cones would accurately identify other obstacles like animals. 84.6% (22 out of 26) displayed a solid understanding. Our third theme prompted students to share their thoughts on how self-driving cars should behave when encountering pedestrians. A majority, 88.4% (23 out of 26), emphasized that cars should replicate human behaviors like stopping for pedestrians. One student's response encapsulated the prevailing sentiment: "A positive impact of AI in these scenarios is its potential to reduce accidents through proper training, while a negative impact could arise from inadequate training leading to accidents." This viewpoint echoed the consensus among most students.

3 FINDINGS AND DISCUSSION

Four key themes emerged from students' interactions:

1. Students recognized that AI and ML systems can receive and process data from cameras (perception). Examples were the AI for ASL exhibit (with webcams) and the AI for Self-Driving Cars exhibit (with simulated vision of obstacles on the car's roadway).

2. Students recognized that these systems provided useful information and responded to students' training input (trust). All exhibits responded directly to student input in predictable and trust-building ways. In AI for ASL, students held their hands in front of the camera so that the exhibit would properly recognize their gestures. In Tic-Tac-Toe, the system responded to students' game moves. In ChemAIstry, students saw their training data used to make subsequent classifications. In AMA, students confirmed that the chat agent responded to their questions with pertinent information. In AI for Self-Driving Cars, students saw how the selected model responded to obstacles.

3. Students recognized the practical import of AI/ML systems (affective and cognitive attitudes). Students appreciated the practical value of the AI technologies. With the AI for ASL exhibit, students suggested that they could use it to communicate with friends who were hard of hearing. From an affective standpoint, students liked to challenge themselves; e.g. only playing against the most-competent "Chris" opponent in the Tic-Tac-Toe exhibit. With the AMA chatbot, students considered that it could be helpful in completing their homeworks.

4. The concept of models and modes in AI and ML systems was highlighted. AI for ASL had two models and students chose between them when performing letter gestures. In Tic-Tac-Toe, students selected among three different players (modes). In ChemAIstry, students performed explicit training of a classifier. In AMA, students selected the topic they wished converse about with the chatbot. In AI for Self-Driving Cars, three different models could be selected.

Our exhibits illustrated that it is possible to engage students in discovering key themes in artificial intelligence and machine learning via short interactions. Students gained first-hand experience of how AI can perform various tasks, from basic to complex decision-making. They were introduced to the concept of machine learning and AI models.

AI education can be improved when children interact and engage with various AI tools like those we demonstrated. **Improving AI understanding:** Through a breadth of AI applications, students may begin to understand that AI refers to a range of technologies that have diverse applications rather than being a single thing. **Learning about capabilities and limitations of AI:** By interacting with these tools, students saw how AI can excel in certain areas (such as pattern recognition in the ASL tool) as well as fail in other areas (such as when presented with new, untrained scenarios in the simulation of a self-driving vehicle). **Safety and Ethics in AI:** The use of self-driving vehicle image recognition tools helped children gain an understanding of AI safety and ethics. As they consider the importance of training AI systems effectively, they can also consider the potential consequences if it's not done correctly.

These findings show how AI tools can enrich children's learning and entertainment experiences and highlight the importance of tool-specific design and application considerations. Children's ability to interact and perceive AI tools differently suggests a promising future for integrating diverse AI tools into their daily lives.

ACKNOWLEDGMENTS

We thank the teachers and administrators who facilitated our work and the children who participated in this study. This material is based upon work supported in part by the National Science Foundation under Grant IIS-2112633.

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