How Should K-12 Students Experience AI?

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I. Introduction

AI education in K-12 has become a national priority for both China and the United States. The AI4K12 Initiative, a joint project of the Association for the Advancement of Artificial Intelligence (AAAI) and the Computer Science Teachers Association (CSTA), with funding from the U.S. National Science Foundation, is developing guidelines for what students in each of four grade bands should know about AI, and what they should be able to do. The initiative is also compiling a curated online resource directory of age-appropriate demos, videos, activity descriptions and similar materials for K-12 teachers, and working to foster the development of a community of AI resource developers. Further information is available at http://AI4K12.org.

II. Chidren's Early Exposure to AI

Today's children are growing up in an AI-powered world whether they realize it or not. Machines that speak and listen are now commonplace, from GPS units in our cars to intelligent assistants in our phones or home appliances. Computer vision has found many niche applications, such as Snapchat filters, face recognition in social media, face-based phone unlocking, vision-based toys such as Osmo and Cozmo, lane departure warnings and self-parking systems in automobiles, license plate readers, check reading in ATM machines, and more. For those applications that children don't interact with directly, they observe their parents doing so.

Intelligent assistants such as Alexa or Siri are particularly interesting because young children are drawn to them. By the time these children enter kindergarten they will have spent many hours observing or interacting with AI-powered technologies. Thus, it's not necessary to ask whether we should be introducing children to AI. Rather, we should be thinking about how to help them understand how AI works.

III. Organiztion of the Initiative

The AI4K12 Initiative is led by a Steering Committee consisting of the four authors of this extended abstract. The bulk of the work of formulating the guidelines is done in conjunction with the Working Group, which is composed of a mix of current and former K-12 teachers and AI and computer science subject matter experts. The teachers are organized into four grade bands: K-2, 3-5, 6-8, and 9-12. Each is responsible for determining what children in that age range should be able to understand about AI, and what skills they should be able to demonstrate.

The AI4K12 Initiative also benefits from a diverse Advisory Board including people from industry, government, and nonprofits, and people involved in AI education in other countries. Finally, the AI4K12 Initiative operates an "interest group" mailing list open to anyone with an interest in this topic (see AI4K12.org).

IV. Structure of the Guidelines

The AI for K-12 guidelines will be modelled after the 2017 CSTA Computer Science Standards, which are organized around five "big ideas" in computing. The AI4K12 Working Group has selected the following five big ideas for AI:

1. **Perception.** *Computers perceive the world using sensors.* Perception is the process of extracting meaning from sensory signals.
2. **Representation and Reasoning.** *Agents maintain models/representations of the world and use them for reasoning.* Representations are implemented as data structures, such as trees or graphs in discrete symbolic AI, or feature vectors in statistical models or neural networks. Representations support reasoning algorithms.
3. **Learning.** *Computers can learn from data.* Machine learning is a kind of statistical inference that finds patterns in data. Many areas of AI have progressed significantly in recent years thanks to learning algorithms that create new representations.
4. **Natural Interaction.** *AI developers strive to create agents that interact naturally with humans.* This includes conversing in our language, recognizing facial expressions and emotions, and drawing upon knowledge of culture and social conventions to infer our intentions from observed behavior.
5. **Societal Impact.** *AI can impact society in both positive and negative ways.* AI technologies are changing the ways we work, travel, communicate, and care for each other. But we must be mindful of the harms that can potentially occur.

Each big idea will be unpacked for each of the four grade bands. For each grade band, we will consider both the essential understandings that students should have and the skills they should be able to demonstrate.

V. AI Teaching Resources for K-12

There are already a variety of age-appropriate resources for teaching K-12 students about AI. We can organize these into several categories:

a. **Black box demos** provide hands-on experience with AI applications but don't reveal what's going on under the hood. An example is Google's Teachable Machine, which runs in the browser and allows students to quickly train an image classifier to recognize three different gestures made in front of a webcam. The web site indicates that this is done using a neural net, but provides no way to examine its activations or weights. Similarly, the MachineLearningForKids web site lets students train a variety of decision tree classifiers but does not reveal the decision trees that are learned.

b. **Glass box demos** expose the workings of an AI algorithm and invite the user to play with its parameters. An excellent online example is Google's TensorFlow Playground, in which users train a multilayer neural net using backpropagation learning. The architecture of the network is graphically displayed, as are the individual weights. Users can vary the number of layers, units per layer, activation function, and learning rate parameters, and they can watch the network's behavior change as learning progresses. Glass box demos are best suited for low-dimensional problems where the algorithm's representations are visualizable and interpretable.

c. **AI Programming frameworks** allow students to develop their own applications by extending a familiar programming language with new AI primitives. Several developers have produced plugins for Scratch (e.g., Cognimates) or Snap! (eCraft2Learn) that access cloud-based AI services such as IBM's Watson, Microsoft's cognitive services, or Google Speech. Calypso for Cozmo is a robot programming framework for the Cozmo robot by Anki, inspired by Microsoft's Kodu Game Lab. Calypso includes primitives for computer vision, face recognition, landmark-based navigation, and speech recognition and generation.

d. **Unplugged activities** guide students to explore AI by hand-simulating learning or reasoning algorithms. An example would be a "guess the animal" game where the goal is to use a decision tree to determine which animal a person is thinking of. Students learn how to incrementally grow the decision tree by adding new animals with appropriate questions. Another example of an unplugged activity would be learning to draw a search tree, either for a game or for a graph search problem.

e. **Videos** that combine verbal explanations with visualizations of AI algorithms can be very effective teaching tools. An example is the YouTube video "How Snapchat's filters work", which explains facial recognition technology.

f. **Hardware** resources include vision-based mobile robots such as Anki's Cozmo or Amazon's forthcoming DeepRacer, neural net processing boards like NVIDIA's Jetson Nano, and Google's "AI and You" kits for vision and voice recognition.

g. **Formal curricula** for AI in K-12 are beginning to appear online. Examples include ReadyAI's "AI + Me" micro-course, and AI-4-All's Open Learning platform, currently in beta test.

The AI4K12.org web site includes a Resources Directory with links to all the above resources except for hardware.

VI. The Need for Additional ResourceS

Developing the AI for K-12 guidelines and resource directory has made us acutely aware of how much more remains to be done in the area of resource development. We aim to build a community of developers to address these needs. Some specific areas that deserve attention are:

- **Activities** that help students **build mental models** of AI computations such as search or learning algorithms.
- **Browser-based demos of computational primitives** used in AI. For example, it would be very helpful to be able to capture speech input from a laptop's microphone and display a spectrogram. Similarly, a real-time display of a webcam image side by side with the results of an edge detector would help students understand how computer vision begins with local feature detection.
- Glass box **demos** of **natural language processing** functions such as parsing a sentence, or deriving a semantic representation of a query.
- **Videos** that illustrate complex concepts such as how convolutional neural nets analyze an image.
- Better scaffolding for students to **build their own AI applications,** e.g., help them write grammars that can be used by a chatbot to parse input sentences.

VII. Summary

Today's students will spend their entire lives interacting with intelligent machines of one sort or another. As AI technologies continue to transform society, it is important that we include the big ideas in AI in every child's education. Students with an interest in STEM careers will find many opportunities in AI and machine learning application development, data science, and robotics. But society will also experience disruption due to loss of some types of jobs and changes to the nature of work. (In the future it will be common for people to work alongside robots.) Ethical issues arising from new technologies, such as the risks associated with self-driving cars, will also have to be dealt with. Educating our children about AI will help make them informed citizens prepared to grapple with these issues.

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