# Envisioning AI for K-12: What should every child know about AI?

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**Abstract**

The ubiquity of AI in society means the time is ripe to consider what educated 21st century digital citizens should know about this subject. In May 2018, the Association for the Advancement of Artificial Intelligence (AAAI) and the Computer Science Teachers Association (CSTA) formed a joint working group to develop national guidelines for teaching AI to K-12 students. Inspired by CSTA's national standards for K-12 computing education, the AI for K-12 guidelines will define what students in each grade band should know about artificial intelligence, machine learning, and robotics. The AI for K-12 working group is also creating an online resource directory where teachers can find AI-related videos, demos, software, and activity descriptions they can incorporate into their lesson plans. This blue sky talk invites the AI research community to reflect on the big ideas in AI that every K-12 student should know, and how we should communicate with the public about advances in AI and their future impact on society. It is a call to action for more AI researchers to become AI educators, creating resources that help teachers and students understand our work.

## Introduction

Advances in AI have led to both beneficial and unintended negative effects, which have not escaped our research publications or mainstream media. For example: machine learning has greatly improved pattern recognition for medical diagnosis, but bias in a training set can lead to fairness issues in evaluating loan applications or problems with non-Caucasian facial recognition. These stories drive the imaginations and the fears of the general public. Despite the increased frequency of AI headlines in the media, there is a persistent lack of understanding of AI (West & Allen, 2018). We must consider the role we play as AI researchers and educators in helping people understand the science behind our research, its limits, and its potential societal impacts. On the graduate level, courses have been keeping pace with advances in the field. In undergraduate education, we've sought to provide fun and inspiring ways to engage students in various aspects of AI, such as robotics, modeling and simulation, game playing, and machine learning (Dodds, Hirsh, and Wagstaff, 2018). In addition, we've sought to write textbooks and design tools, nifty and model AI assignments, and curricula that help students learn and apply the fundamentals of AI. More recently, companies have been making AI API's such as IBM Watson, Google Web Speech, DialogFlow, and Azure Cognitive Services publicly available to educators and students.

Our hope for undergraduates is to prepare them for a bright future in the computing industry, or spur them on to graduate studies. But it is just as important now to think about what AI education should look like in K-12, not only to ensure a more informed populace that understands the technologies they interact with every day, but also to inspire the next generation of AI researchers and software developers. For many in this generation, AI will be an oft-overlooked, magical force that powers their lives much as electricity, the internal combustion engine, and networking technology power ours.

## Background

Over the past five years there has been a rapid expansion of CS education into formal K-12 curricula for all students, both nationally and internationally. In the United States this work has been undertaken by the National Science

Foundation, Code.org, Google, Microsoft, the Computer Science Teachers Association (CSTA), the Association for Computing Machinery's (ACM) Special Interest Group for Computer Science Education (SIGCSE), CS for All, and other organizations that aim to ensure that all students learn computer science and that it is taught regularly throughout their K-12 years. Standardization of what K-12 students should know about computer science has been supported by the development and implementation of the AP Computer Science Principles curriculum (College Board, 2017), the CS K-12 Framework (2016), the CSTA Standards for K-12 Computing Education (CSTA, 2017), and similar documents. Many software tools, resources, and curricula have been developed to make computing accessible for younger students. These tools allow students to focus on learning core programming concepts while designing personally meaningful artifacts. This process facilitates personal expression, creativity, and learning, allowing students to become producers of technology, not just consumers (Resnick, Bruckman, & Martin, 1996).

At the same time as investment in CS for K-12 has been increasing, AI has had an increasing impact on society, both in the U.S. and elsewhere. Internationally, China has mandated that all high school students learn about artificial intelligence (Jing, 2018). However, despite the increased media attention and ubiquity of AI technologies in our everyday lives, we are just beginning to think about how to introduce AI to K-12 students. In the new CSTA K-12 Computing Standards, there are only two sentences about AI. Both standards appear in the 11-12 grade band (CSTA, 2017). And unlike the general subject of computing, when it comes to AI, there is little guidance for teaching at the K-12 level.

In response to these needs, the Association for the Advancement of Artificial Intelligence (AAAI) and the Computer Science Teachers Association (CSTA) announced a joint initiative in May 2018 to develop national guidelines for teaching K-12 students about artificial intelligence (AAAI, 2018). Inspired by CSTA's national standards for K-12 computing education (CSTA, 2017), the AI for K-12 Working Group will define for artificial intelligence what students should know and be able to do. Other organizations including AI4All (http://ai-4-all.org/) and the International Society for Technology in Education (ISTE) have also recognized these needs and are beginning to address them (ISTE, 2018; Baloch, Crompton, Gerl, Harrison, Law, McGirt, Ramos, and South, 2018). These initiatives are laying the groundwork for AI education in K-12, but there is much more we as a community need to do to support this work.

To frame the guidelines we're developing, we have defined what we think are the "big ideas" (Wiggins and McTighe, 2005) in AI that every student should know. Before laying out these ideas, we discuss the environment in which students will learn them.

## Tools & Resources for AI in K-12

In order for K-12 students and teachers to appreciate the big ideas of AI, they need to be able to tinker with AI. There has recently been an explosion of products and tools that make AI accessible to younger students. Most cellphones today include a voice assistant (Google Assistant, Apple's Siri, Microsoft's Cortana), and there are a number of home appliances with similar functionality (Google Home, Amazon Echo, Apple HomePod). Computer vision is also present "under the hood" of some consumer products, such as Snapchat filters, or the popular Osmo app that uses vision to recognize game pieces and children's drawings. These help to familiarize children with AI technologies.

Going a step further, a variety of new software and hardware tools are providing AI components to young programmers who can incorporate them into their own creations. For example:

- Cognimates (Druga, Vu, Likhith, Oh, Ocejo, Qui, & Breazeal, 2018) offers a set of Scratch extensions that provide access to speech generation, speech recognition, text categorization, object recognition, and robot control APIs. https://cognimates.me
- eCraft2Learn (Kahn and Winters, 2017) offers similar extensions for the Snap! language, a Scratch variant. https://ecraft2learn.github.io/ai/
- Machine Learning for Kids is another site that provides online demos where students train classifiers using web applications or Scratch extensions. https://machinelearningforkids.co.uk/
- The Cozmo robot by Anki is an inexpensive mobile manipulation platform with built-in computer vision including object and custom marker detection, face recognition, object manipulation, path planning, and speech generation.
- Calypso for Cozmo (Touretzky, 2017) is a rule-based visual programming language for Cozmo that adds speech recognition (using the Google Speech API), landmark-based navigation, a visible world map, and support for state machine programming. https://Calypso.software
- Google has released a series of online "AI experiments" such as "Teachable Machine" (training a visual classifier) and "QuickDraw" (a neural net tries to guess what you're drawing). https://experiments.withgoogle.com/collection/ai
- Google's AIY ("AI and You") vision and voice kits offer Raspberry Pi Zero-based image and speech recognition at affordable prices. The vision kit uses a neural network

classifier, while the voice kit connects with the cloud-based Google Assistant.

- TensorFlow Playground is an interactive graphical tool that allows high school students and undergraduates to explore neural networks and backpropagation learning (Thomas, 2018). https://playground.tensorflow.org

## What are the "Big Ideas" in AI?

We are at the beginning stages of developing the guidelines for AI for K-12 via a collaboration between AI experts and K-12 teachers. The guidelines we will unpack AI's "Big Ideas" along five thematic strands, and organize them by four grade bands: K-2, 3-5. 6-8, and 9-12. The current draft of the big ideas is set out below. We recognize that others might frame the field differently. Some may prefer a more traditional division into application areas (speech, vision, planning, game playing, natural language, robotics, etc.), but we think the current formulation better meets the needs of K-12 students and teachers. We welcome feedback from the AI community as part of this initiative.

**Big Idea #1: Computers perceive the world using sensors.**

Perception is the process of extracting information from sensory signals. The ability of computers to "see" and "hear" well enough to be practically useful is one of the most significant achievements of AI. Students should understand that machine perception of spoken language or visual imagery requires extensive domain knowledge, e.g., for speech one must know not just the sounds of the language but also its vocabulary, grammar, and usage patterns. In the absence of such knowledge, speech recognition by machine cannot approach human-level accuracy.

Students in K-2 should know how to interact with voice-based agents, and have some experience with machine vision (e.g., face or object recognition using a webcam and a web-based app, or Google's QuickDraw demo). In grades 3-5 students should be able to modify simple perception-based applications written in children's programming frameworks that include AI primitives. For example, they can create applications that respond to spoken phrases, or the presence of visual markers or specific faces. In grades 6-8, students should be able to create more complex applications on their own. By grades 9-12, students should be able identify and demonstrate the limitations of machine perception systems and use machine learning tools (see Big Idea #3) to train perceptual classifiers.

**Big Idea #2: Agents maintain models/representations of the world and use them for reasoning.**

AI systems are commonly described as intelligent agents that perceive and represent the world, deliberate, and produce outputs that affect the world. Representation is one of the fundamental problems of intelligence, both natural and artificial. Students should understand the concept of a representation, e.g., the way a map represents a territory, or a diagram represents the state of a board game. Students should further understand that computers construct representations using data, and these representations can be manipulated by applying reasoning algorithms that derive new information from what is already known. While AI agents can reason about very complex problems, they do not think the way a human does. Many types of reasoning that are easy for humans are still beyond the abilities of today's AI systems.

In grades K-2 we expect students to be able to examine representations created by intelligent agents (e.g., the world map created by Calypso for Cozmo), and create simple representations using paper and pencil. In grades 3-5 we expect students to be able to work with representations in simple computer programs, e.g., in Scratch a sprite can treat the canvas and sprites as a representation of the world and use the Touching block to query it. Students at this level can also investigate inference algorithms through exercises such as constructing a decision tree to determine which animal a person is thinking of based on a series of yes/no questions, such as "does it have wings?". In grades 6-8 students should be able to examine representations such as the Google knowledge graph and simulate simple graph search algorithms. In grades 9-12 students should be able to make use of elementary data structures (lists and dictionaries) to program simple inference algorithms.

**Big Idea #3: Computers can learn from data.**

Machine learning algorithms allow computers to create their own representations using training data that is either supplied by people or acquired by the machine itself. Many areas of AI have made significant progress in recent years thanks to machine learning technology, but for the approach to succeed, tremendous amounts of data are needed. For example, the Open Image Dataset V4 contains 9 million training images and 30 million labels. Processing data at this scale requires computing power that was unavailable a few years ago. Care must be taken in the collection of this data to avoid introducing biases into the training set.

Students should understand that machine learning is a kind of statistical inference that finds patterns in data. In K-2 they can experience this by having a computer learn to recognize their face or simple gestures. In grades 3-5 students should be able to modify object recognition applications, e.g., write a Scratch program that responds to a specific object in the camera image. In grades 6-8 students should be able to measure how well a trained system generalizes to novel inputs, and they should understand how biases in the training data can affect performance. In grades 9-12 students should be able to train a network using an interactive tool like Tensorflow Playground, and advanced students should be able to code simple machine learning applications using Python tools like scikit-learn.

**Big Idea #4: Making agents interact comfortably with humans is a substantial challenge for AI developers.** Understanding people is one of the hardest problems faced by intelligent agents. This includes tasks such as conversing in natural language, recognizing emotional states, and inferring intentions from observed behavior. Students should understand that while computers can understand natural language to a limited extent, at present they lack the general reasoning and conversational capabilities of even a child.

Graceful interaction with humans is especially important for robotic agents that will share our living and working spaces. We may want a robot assistant to stay close so it's always ready to help, but it shouldn't stick to us so closely that it's constantly in the way. Inferring a person's future intentions by observing their actions is challenging even for humans. Robots will need to acquire some of this skill if they are to be welcome in our lives.

Students in K-2 should be able to describe the types of requests an intelligent assistant understands, and use a web app to demonstrate facial expression recognition. In grades 3-5 students should be able to distinguish a chatbot from a human, and analyze natural language examples to determine which ones would be difficult for a computer to understand, and why. In grades 6-8 students should be able to use parser demos to demonstrate syntactic parsing of sentences, and construct sentences that purely syntactic parsers will mis-handle due to problems such as erroneous prepositional phrase attachment (e.g., "I pour syrup for pancakes from a bottle"). They should also be able to show how parsers that take semantic information into account do a better job resolving attachment problems.

In grades 9-12 students should be able to construct context-free grammars to parse simple languages, and use language processing tools to construct a chatbot. They should also be able to use sentiment analysis tools to extract emotional tone from text.

**Big Idea #5 - AI applications can impact society in both positive and negative ways.**

Students should be able to identify ways that AI is contributing to their lives. The societal impacts of AI involve two kinds of questions: what applications should AI be used for (there is growing interest in "AI for social good"), and what ethical criteria should AI systems be required to meet? In the near future many people will work alongside intelligent assistants or autonomous robots, but in the long term, the automation of many jobs may lead to massive unemployment or a shift in the kinds of work people pursue. Technologies that allow intelligent agents to better understand humans could give us the robotic servants we've long been dreaming of, or home health aides for the elderly, but they could also enable massive government surveillance and complete loss of privacy.

Students should understand that the ethical construction of AI systems that make decisions affecting people's lives requires attention to the issues of transparency and fairness. Transparent systems provide justifications for their conclusions so their reasoning can be checked and wrong assumptions identified. Fairness is tricky because when some level of error is unavoidable in a decision system, the best one can hope for is to distribute those errors equitably, avoiding socially undesirable biases.

Students in grades K-2 should be able to identify how AI contributes to their daily lives, and how it may contribute more in the future (e.g., robot servants). Students in grades 3-5 should exhibit critical thinking about the impacts of new AI applications, e.g., self-driving cars will be a boon to people who cannot drive themselves, but may also put taxi drivers out of work. Students in grades 6-8 should be able to draw parallels between earlier industrial revolutions and what some AI futurists are calling the fourth industrial revolution. In grades 9-12 students should be able to evaluate new AI technologies and describe the ethical or societal impact questions raised by them.

## Curriculum Development

There are already significant efforts to address the need for curriculum resources. Australian AI researchers collaborated with K-6 teachers through the Scientist-in-Schools program to deliver a three year curriculum covering basic AI concepts, AI vocabulary, and the history of AI (Heinze, Haase, & Higgins, 2010). Another recent example is IRobot: an AI curriculum for high school students (Burgsteiner, Kandlhofer, & Steinbauer, 2016). ISTE has announced a partnership with GM to develop an AI curriculum for high school students (ISTE, 2018), and AI4All recently received a $1 million grant from Google to develop an open, online AI curriculum to launch in 2019 (AI4ALL, 2018)

The joint AAAI/CSTA AI for K-12 initiative will not be developing a curriculum of its own. Rather, it will establish guidelines that future curricula should meet, and curate an online resources directory that will help educators locate tools and curricula like those described above. We welcome feedback and resource suggestions for K-12 educators as we continue to develop the AI for K-12 guidelines.

## Conclusion

We conclude with a call to action for the AI community. K-12 students will be searching the internet trying to understand how AI works and how it will shape their future. Think about how your research can be made into an easily available demo, resource, or activity that students and teachers can use and share.

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