

# K-12 Guidelines for Artificial Intelligence: What Students Should Know

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Fred Martin, and Deborah Seehorn



Supported by NSF DRL-1846073.

# Outline

1. Why is this the right time to begin teaching AI in K-12?
2. Overview of the AI4K12 Initiative
3. Exploring the “Big Ideas” in AI
  - What are the big ideas?
  - Grade band learning progression
4. Resources for teaching the big ideas in K-12
5. Discussion and Q&A

# Why is this the right time to be teaching AI in K-12?

1. AI is playing an increasingly prominent role in society:
  - Intelligent assistants
  - Self-driving cars
  - Autonomous robots in the workplace (and someday the home)
2. Informed citizens need to understand the basics of AI as our society faces important public policy decisions surrounding AI technologies.
3. AI technologies will cause job loss in some areas, and gains in other areas.
4. There is a growing need for AI-literate workers. Students should be encouraged from a young age to consider STEM careers.



# A basic understanding

In the near future, perhaps sooner than we think, **virtually everyone will need a basic understanding** of the technologies that underpin **machine learning and artificial intelligence.**

**When Computers Decide:**  
European Recommendations  
on Machine-Learned  
Automated Decision Making

Informatics Europe & EUACM  
2018



ACM Europe / Informatics Europe



# For some, or for all?

Children need to be adequately prepared for working with, and using, AI.

**For a proportion**, this will mean a **thorough education in AI-related subjects**, requiring adequate resourcing of the computing curriculum and support for teachers.

**For all children**, the **basic knowledge and understanding** necessary to navigate an AI driven world will be essential. In particular, we recommend that the ethical design and use of technology becomes an integral part of the curriculum.

The image shows the front cover of a report titled 'AI in the UK: ready, willing and able?'. The cover is white with a red vertical bar on the left side. At the top right, it says 'HOUSE OF LORDS' and 'Select Committee on Artificial Intelligence'. Below that is 'Report of Session 2017–19'. The title 'AI in the UK: ready, willing and able?' is centered in large, bold, black letters. At the bottom, there is a small line of text: 'Ordered to be printed 13 March 2018 and published 16 April 2018' and 'Published by the Authority of the House of Lords'. In the bottom right corner, it says 'HL Paper 100'.



## Mission

- Develop national guidelines for teaching AI in K-12
  - Modeled after the CSTA standards for computing education.
  - Four grade bands: K-2, 3-5, 6-8, and 9-12
  - What should students know?
  - What should students be able to do?
- Develop a curated AI resource directory for K-12 teachers
- Foster a community of K-12 AI resource developers

# The AI4K12 Initiative, a joint project of:

**AAAI** (Association for the Advancement  
of Artificial Intelligence)



Association for the  
Advancement of Artificial Intelligence

**CSTA** (Computer Science  
Teachers Association)



With funding from National Science  
Foundation ITEST Program (DRL-  
1846073)

**Carnegie Mellon University**  
School of Computer Science



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# K-12 Computing Education

Worldwide, we are making progress on integrating **computing** into K-12:

- **Israel** started working on National standards in 1995
- **United Kingdom:**
  - Computing At School
  - **First country in the European Union to mandate computer science classes for all children** between the ages of 5 and 16.
- **18 European Countries**

France, Spain, Switzerland, Slovakia, Finland, Poland, Portugal, Scandinavia, Italy, Estonia, Bulgaria, Cyprus, Czech Republic, Denmark, Greece, Ireland, Lithuania
- In progress: **US, India, China, Japan, Australia**
  - In the US: CSTA Computing Standards, CSForAll, Code.org

# K-12 AI Education

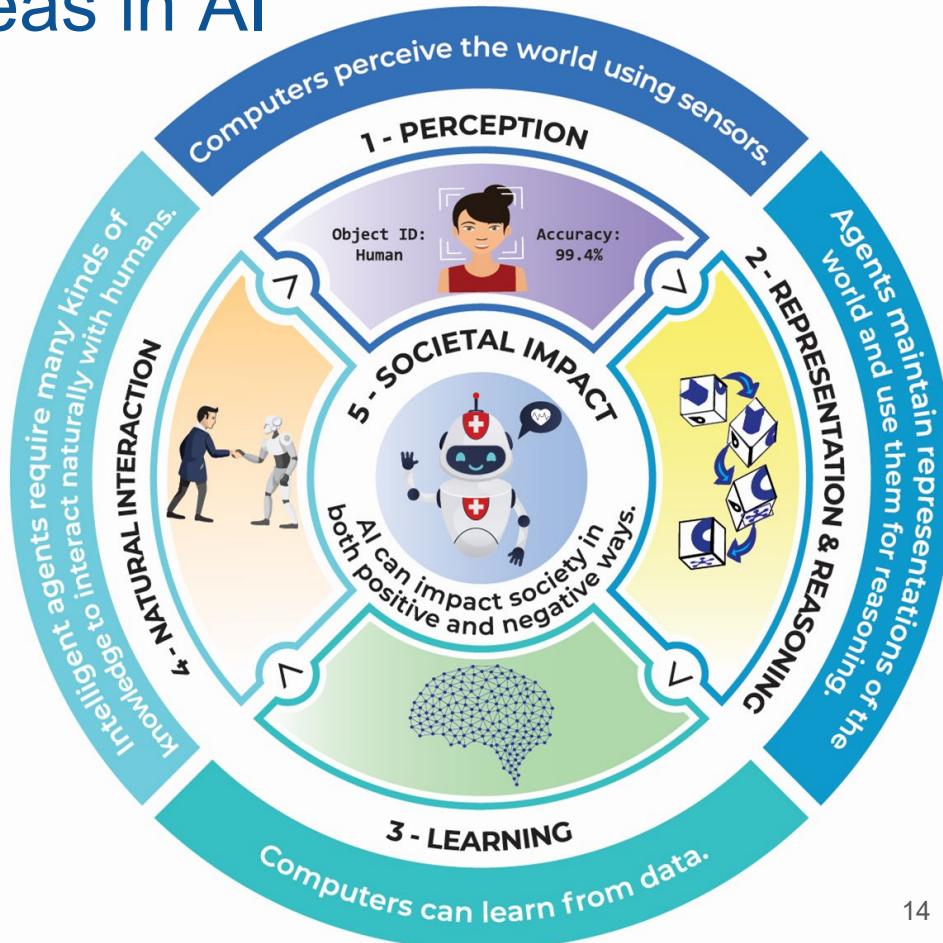
We are not as far along when it comes to AI

- Many countries are trying:  
China, UK, Thailand, Korea, and EU Countries
- The 2017 CSTA Computing Standards contain just two sentences about AI.
  - Both are for the 11-12 grade band. Nothing for younger students.

3B-AP-08	11-12	Describe how artificial intelligence drives many software and physical systems.	>	Algorithms & Programming	Algorithms	Communicating
3B-AP-09	11-12	Implement an artificial intelligence algorithm to play a game against a human opponent or solve a problem.	>	Algorithms & Programming	Algorithms	Creating

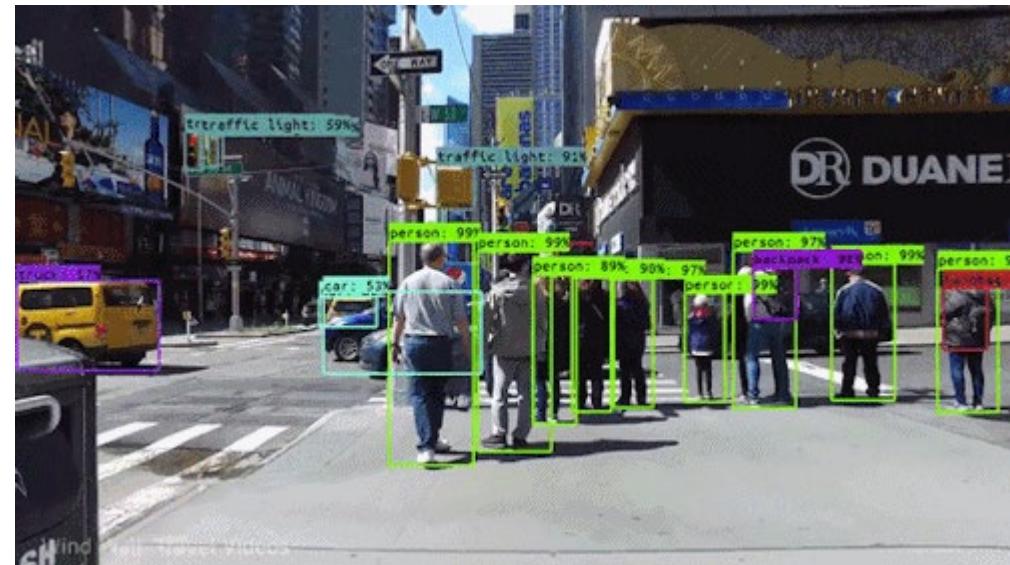
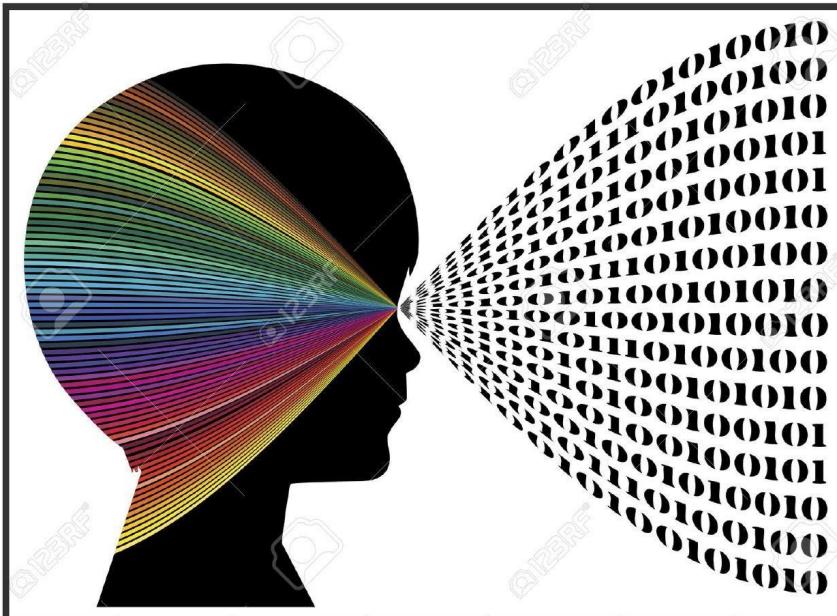
# Five Big Ideas in AI

- Organizing framework for the K-12 guidelines.
- 5 big ideas are enough to cover the richness of the field, but small enough to be manageable by teachers.
- CSTA experience shows 5 is a good number.
- Not necessarily the way AI practitioners view their field, but appropriate for the needs of the K-12 audience.



# Big Idea #1: Perception

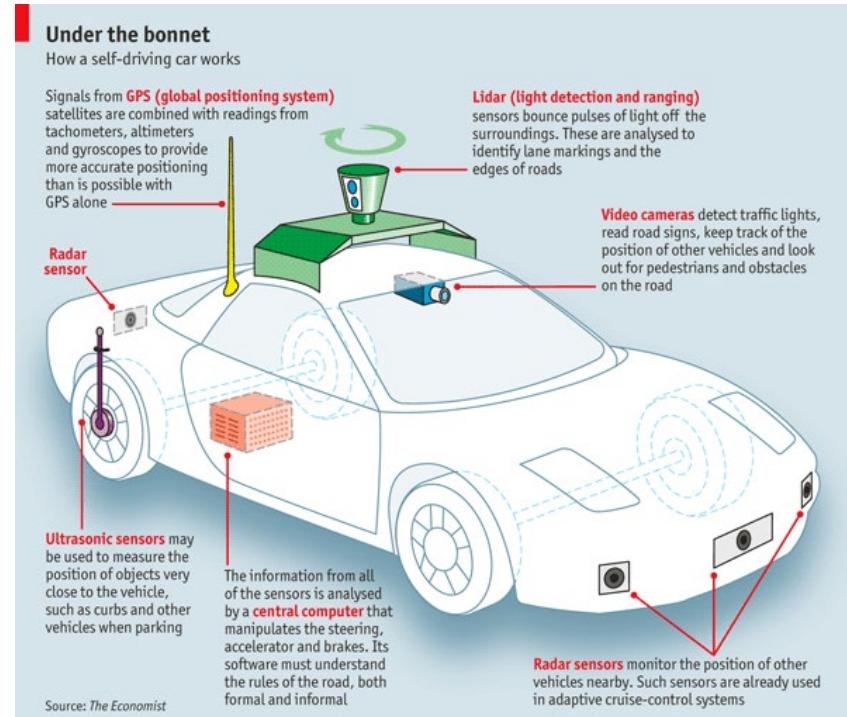
*Computers perceive the world using sensors.*



Perception is the extraction of *meaning* from sensory signals.

# Big Idea #1 – Examples of Perception

- Speech recognition
- Computer vision:
  - object recognition
  - face recognition
  - license plate readers
  - scene understanding
- Other forms of perception e.g., music recognition, or interpreting sonar, radar, or LIDAR data



# Big Idea #1 – Major Concepts

- Human senses vs. computer sensors
- Going from sensing to perception
- Types of perception: vision, speech recognition etc.
- How perception works: algorithms
- Limitations of computer perception
- Intelligent vs. non-intelligent machines

# Big Idea #1 – What should students be able to do?

## Grades K-2:

- Identify sensors on computers, robots, and intelligent appliances.
- Interact with intelligent agents such as Alexa or Siri.

## Grades 6-8:

- Explain how sensor limitations affect computer perception.
- Explain that perception systems may draw on multiple algorithms as well as multiple sensors.
- Build an application using multiple sensors and types of perception (possibly with Scratch plugins, or Calypso).

## Grades 3-5:

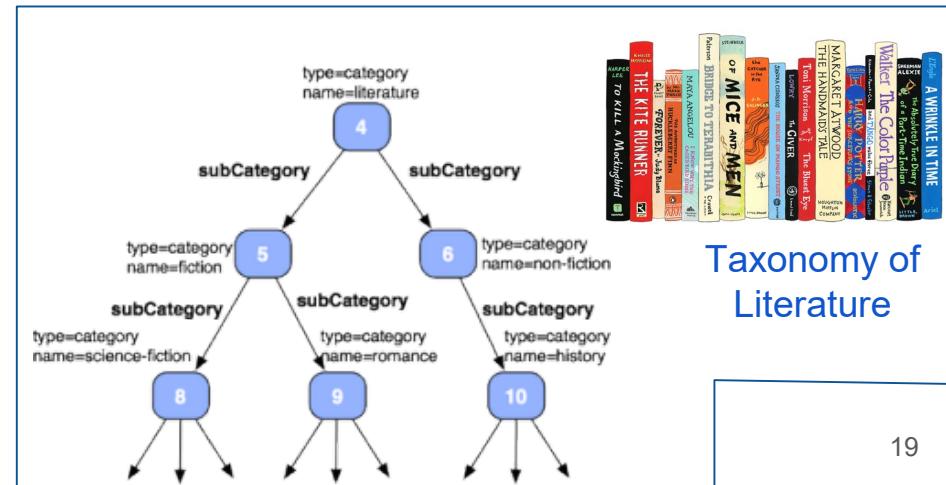
- Describe how sensor inputs are converted to analog or digital signals.
- Demonstrate a limitation of computer perception.
- Build an application using perception (possibly with Scratch plugins, or Calypso).

## Grades 9-12:

- Describe the domain knowledge underlying different forms of computer perception.
- Demonstrate speech recognition difficulty in handling homophones and other types of ambiguity.

## Big Idea #2: Representation and Reasoning

*Agents maintain representations of the world, and use them for reasoning.*



# Big Idea #2 – Examples of Representation & Reasoning

- Path planning for self-driving cars
  - Map of the city; description of the scene around car; goal: find best path to the destination
- Internet Search
  - Representations - content of web pages
  - Reasoning - choosing which pages to return in response to a query
- Playing chess, checkers, backgammon, go
  - Representations - board state
  - Reasoning - finding the best move
- Designing a school bus route
  - Representations - list of students and where they live; list of buses and seating capacities
  - Reasoning - assigning students to buses and deciding the order in which the stops are made

## Big Idea #2 – Major Concepts

- Types of representations
- Types of reasoning algorithms
- Representation supports reasoning: algorithms operate on representations
- Families of algorithms and the work they do
- Limitations of common reasoning algorithms

# Big Idea #2 – What should students be able to do?

## Grades K-2:

- Construct a model of something and compare it to the thing being modeled
- Use a decision tree to make a decision

## Grades 3-5:

- Create/design a representation of an (animal) classification system using a tree structure.
- Describe how AI representations support reasoning to answer questions

## Grades 6-8:

- Design a graph model of their home or locations in their community and apply reasoning to determine the shortest path to key locations on their map
- Create/design a representation of an (animal) classification system using a tree structure.

## Grades 9-12:

- Draw a search tree for tic-tac-toe
- Describe the differences between types of search algorithms

# Big Idea #3: Learning

*Computers can learn from data.*



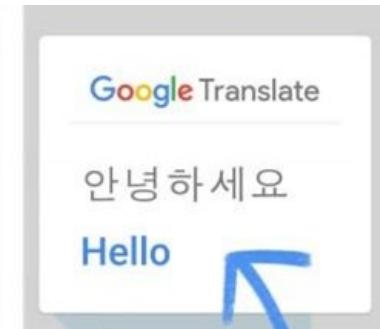
# Big Idea #3 – Examples of Machine Learning

Personal experience:

- Training your phone to recognize your face.
- Netflix learning what movies you like.

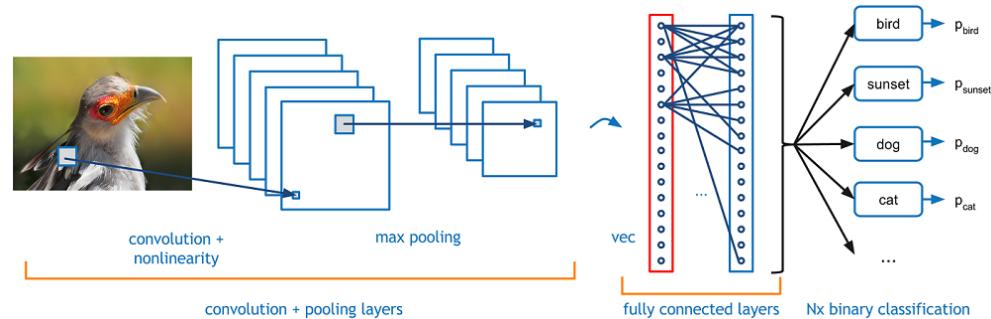
Industrial applications:

- Training a speech recognition system.
- Training a machine translation system: Google can translate between more than 100 different languages.
- Image search: training a classifier to recognize pictures of people, animals, vehicles, etc.



# Big Idea #3 – Major Concepts in Machine Learning

- What is learning?
- Approaches to machine learning
- Types of learning algorithms
- Fundamentals of neural networks
- Types of neural network architecture
- How training data influences learning
- Limitations of machine learning



# Big Idea #3 – What should students be able to do?

## Grades K-2:

- Learn from patterns in data with “unplugged” activities
- Use a classifier that recognizes drawings. Use Google Autodraw or Cognimates Train Doodle to investigate how training sets work to identify images and discuss how the program knows what they are drawing

## Grades 6-8:

- Identify bias in a training data set and extend the training set to address the bias
- Hand-simulate the training of a simple neural network

## Grades 3-5:

- Describe and compare the three different machine learning approaches: supervised, unsupervised and reinforcement learning.
- Modify an interactive machine learning project by training its model..
- Describe how algorithms and machine learning can exhibit biases.

## Grades 9-12:

- Train a neural net (1-3 layers)  
*TensorFlow Playground*
- Trace and experiment with a simple ML algorithm

# Big Idea #4: Natural Interaction

*Intelligent agents require many types of knowledge to interact naturally with humans.*



Humans are among the hardest things for AI agents to understand.

# Big Idea #4 – Examples of Natural Interaction

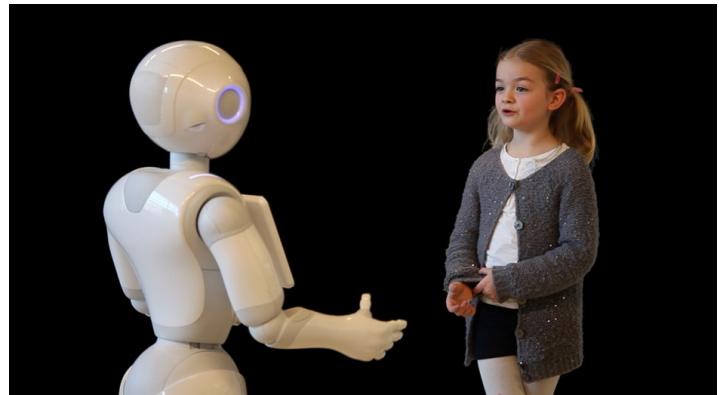
- Intelligent assistants such as Alexa and Siri
- Conversational agents (chatbots)
- Intelligent tutoring systems that provide for adaptive education
- Gesture and facial expression recognition

Pressing questions about the capabilities of AI for natural interaction:

- Can computers exhibit common sense reasoning comparable to people?
- Can a computer ever be conscious or self-aware?

# Big Idea #4 – Major Concepts in Natural Interaction

- Natural language understanding
- Affective computing
- Common sense reasoning
- Consciousness and philosophy of mind
- Natural interaction applications
- Human-robot interaction
- Limitations of AI for natural interaction



# Big Idea #4 – What should students be able to do?

## Grades K-2:

- Identify words in stories that have positive and negative connotations.
- Recognize and label facial expressions into appropriate emotions (happiness, sadness, anger) and explain why they are labeled the way they are
- Experiment with software that recognizes emotions in facial expressions

## Grades 6-8:

- Construct a simple chatbot
- Explain and give examples of how language can be ambiguous
- Reason about the nature of intelligence, and identify approaches to determining whether an agent is or is not intelligent.

## Grades 3-5:

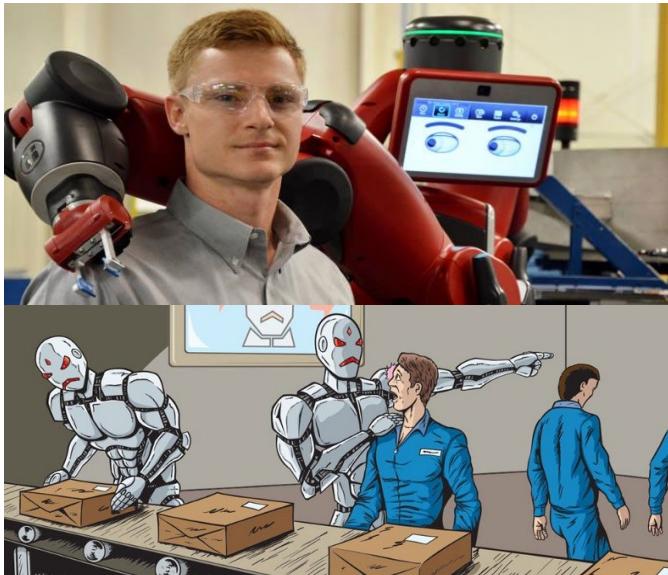
- Identify how humans combine multiple inputs (tone, facial expressions, posture, etc) in order to understand communication.
- Describe some tasks where AI outperforms humans, and tasks where it does not

## Grades 9-12:

- Demonstrate how sentence parsers handle ambiguity
- Explore the Google Knowledge Graph
- Identify and debate the issues of AI and consciousness

# Big Idea #5: Societal Impact

*“Artificial Intelligence can impact society in both positive and negative ways.”*



# Big Idea #5 – Examples of Societal Impact of AI

- Ethics: What sorts of applications are desirable/permissible?
  - Transparency and accountability of AI systems
  - Competing definitions of “fairness”
  - Values tradeoffs, e.g., privacy vs. security; who should own your data?
- Effects: What are the likely impacts of AI technology on society?
  - Robot servants, rescuers, and companions
  - Economic disruption; changes in the nature of work
  - Effects of unintended biases

## Big Idea #5 – Major Concepts around Societal Impact

- AI technologies are changing business, healthcare, education, and government
- Use of AI is an economic driver that makes new services possible and businesses more efficient
- Humans make numerous technical and ethical decisions when developing AI applications
- AI technologies impact communities and people in different ways
- Ethical standards are needed for AI systems that make decisions about people
- AI and robotics will change the way people work, create new jobs, and eliminate some jobs

# Big Idea #5 – What should students be able to do?

## Grades K-2:

- Identify common AI applications encountered in their daily lives
- Discuss whether common uses of AI technology are a good or bad thing

## Grades 3-5:

- Explore how behavior is influenced by bias and how it affects decision making
- Describe ways that AI systems can be designed for inclusivity

## Grades 6-8:

- Explain potential sources of bias in AI decision making
- Understand tradeoffs in the design of AI systems and how decisions can have unintended consequences in the function of a system

## Grades 9-12:

- Critically explore the positive and negative impacts of an AI system
- Design an AI system to address social issues (or explain how AI could be used to address a social issue)

# Five Big Ideas in Artificial Intelligence

## 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. For example, biases in the data used to train an AI system could lead to some people being less well served than others. Thus, it is important to discuss the impacts that AI is having on our society and develop criteria for the ethical design and deployment of AI-based systems.

## 4. Natural Interaction

Humans are among the hardest things for AI agents to understand. Intelligent agents require many kinds of knowledge to interact naturally with humans. Agents must be able to converse in human languages, recognize facial expressions and emotions, and draw upon knowledge of culture and social conventions to infer intentions from observed behavior. Today's AI systems can use language to a limited extent, but lack the general reasoning and conversational capabilities of even a child.

## 1. Perception

Computers perceive the world using sensors. Perception is the process of extracting meaning from sensory signals. Making computers "see" and "hear" well enough for practical use is one of the most significant achievements of AI to date.

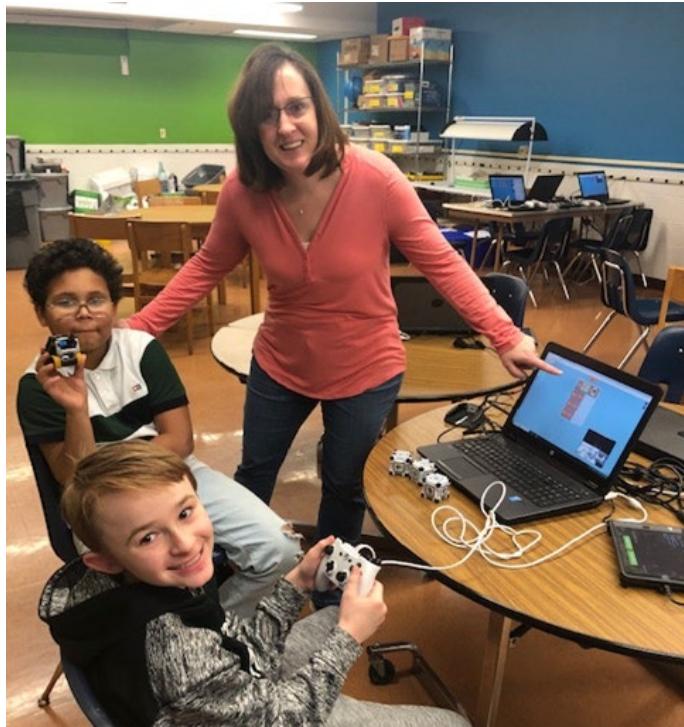
## 2. Representation & Reasoning

Agents maintain representations of the world and use them for reasoning. Representation is one of the fundamental problems of intelligence, both natural and artificial. Computers construct representations using data structures, and these representations support 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.

## 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. For the approach to succeed, tremendous amounts of data are required. This "training data" must usually be supplied by people, but is sometimes acquired by the machine itself.

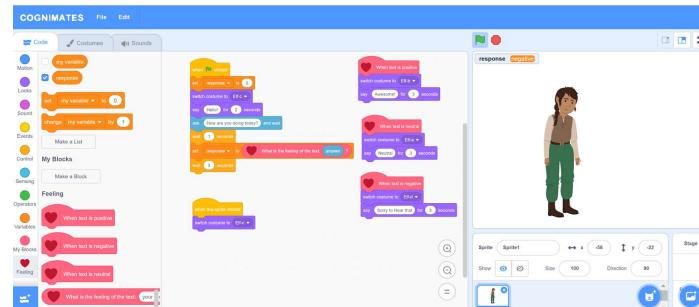
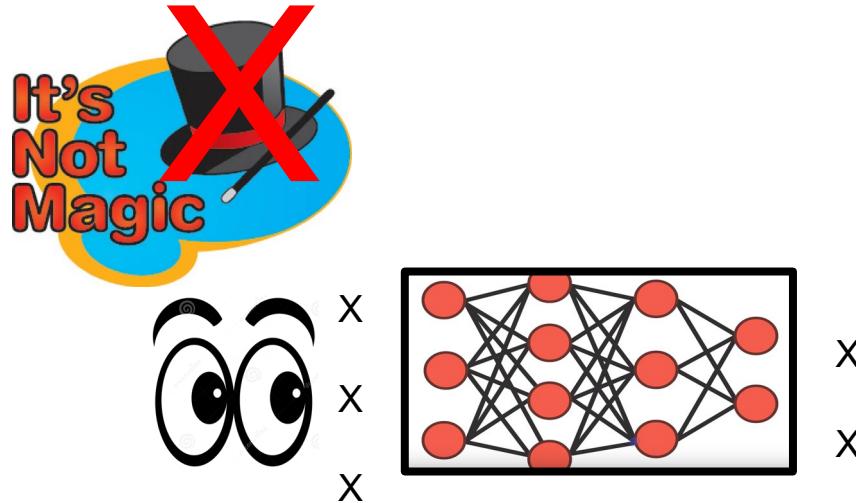




## Teaching AI in K-12 Classrooms

# Guidelines for supporting K-12 students

1. Use transparent AI demonstrations that help students see what is going on inside the black box: it's not magic!
2. Help students build mental models of what is happening under the hood in AI applications.
3. Encourage students to develop AI applications using AI services.

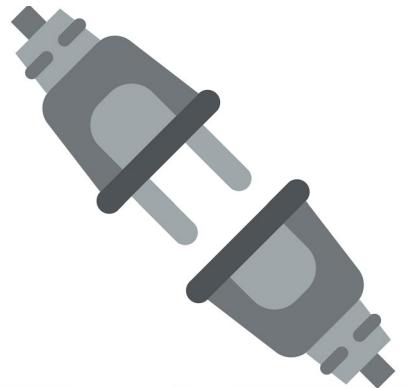


# Student Activity Considerations

- **Experiment with AI agents** to investigate their behavior
- **Hand simulate** AI algorithms
- Encourage students to **build their own AI applications**
- **Explore case studies of AI-related societal issues** from multiple perspectives

These activities promote understanding of:

- How AI works
- Limitations of AI
- Systems thinking (AI systems are built from smaller components)
- Sources of bias in AI
- Societal impacts of AI systems

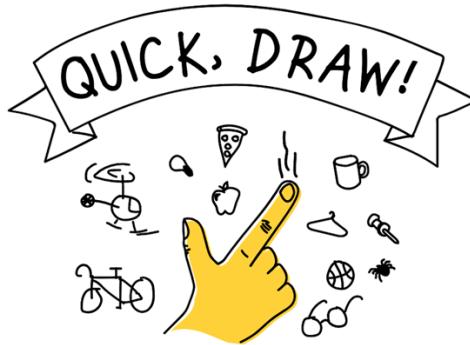


# Overview of the Resource Library: AI Tools & Resources for K-12



# Google's Quick, Draw!

<https://quickdraw.withgoogle.com/>



Can a neural network learn to recognize doodling?

Help teach it by adding your drawings to the [world's largest doodling data set](#), shared publicly to help with machine learning research.

Let's Draw!

You were asked to draw snake

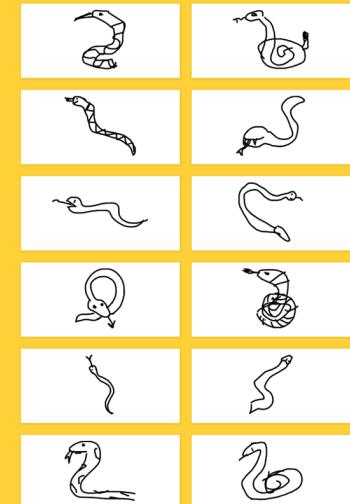
You drew this, and the neural net recognized it.



It also thought your drawing looked like these:



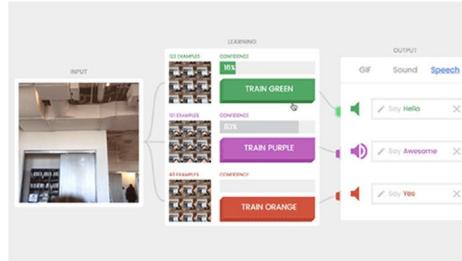
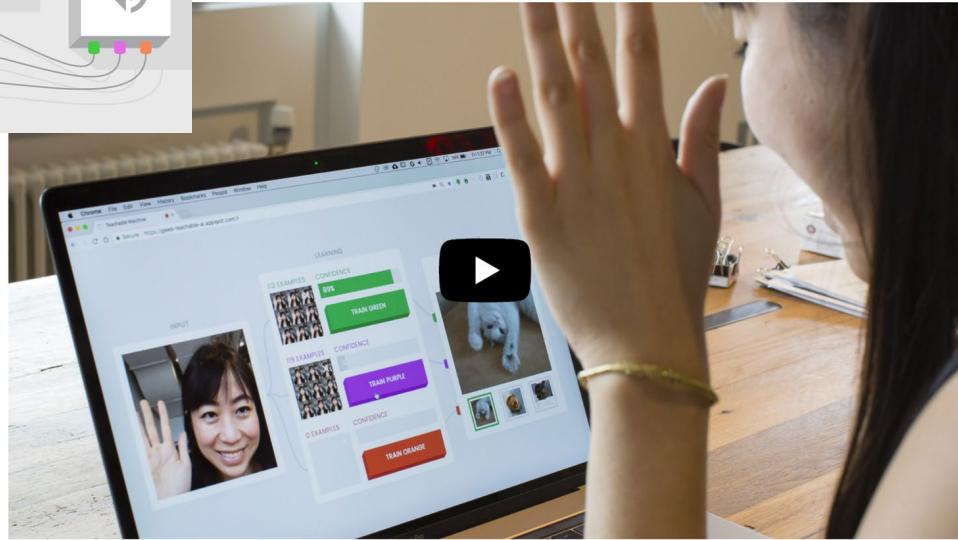
How does it know what snake looks like?  
It learned by looking at these examples drawn by other people.





Built with TensorFlow

- Teach a machine using your camera.
- Live, in the browser.
- No coding required.



<https://experiments.withgoogle.com/teachable-machine>



# Machine Learning for Kids

<https://machinelearningforkids.co.uk>

- 1 Collect examples of things you want to be able to recognise
- 2 Use the examples to train a computer to be able to recognise them
- 3 Make a game in Scratch that uses the computer's ability to recognise them

**School Library**

Create a school librarian in Scratch that suggests who a reading book might be suitable for.

Teach a computer to make recommendations

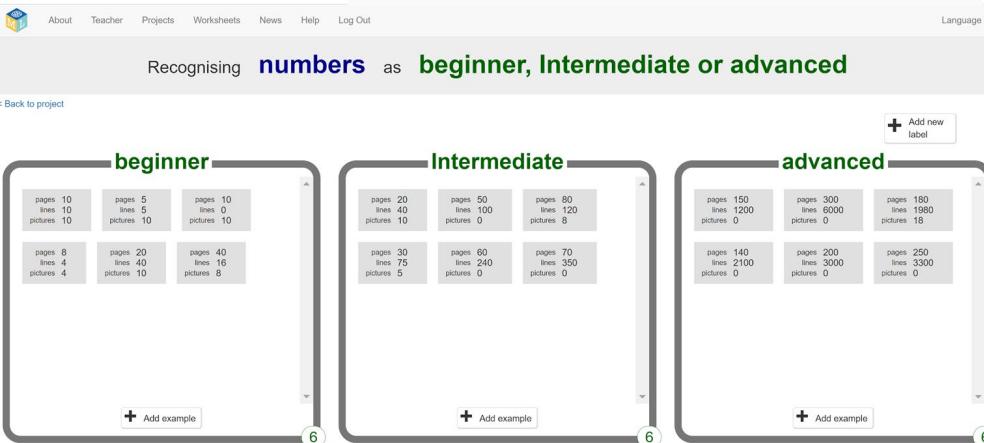
Difficulty: Intermediate

Recognising: **numbers**



Tags: predictive model, recommendations, supervised learning

[Download](#)



Category	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6
beginner	pages 10 lines 10 pictures 10	pages 5 lines 5 pictures 10	pages 10 lines 0 pictures 10	pages 8 lines 4 pictures 4	pages 20 lines 40 pictures 10	pages 40 lines 16 pictures 8
Intermediate	pages 20 lines 40 pictures 10	pages 50 lines 100 pictures 0	pages 80 lines 120 pictures 8	pages 30 lines 75 pictures 5	pages 60 lines 240 pictures 0	pages 70 lines 350 pictures 0
advanced	pages 150 lines 1200 pictures 0	pages 300 lines 6000 pictures 0	pages 180 lines 1980 pictures 18	pages 140 lines 2100 pictures 0	pages 200 lines 3000 pictures 0	pages 250 lines 3300 pictures 0

It is being built by Dale Lane using APIs from IBM Watson Developer Cloud.

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# TensorFlow Playground

<https://playground.tensorflow.org>

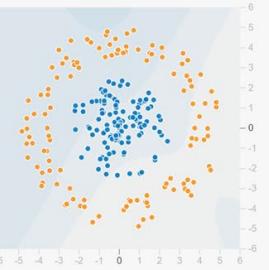
Tinker With a **Neural Network** Right Here in Your Browser.  
Don't Worry, You Can't Break It. We Promise.

Epoch 000,000      Learning rate 0.03      Activation Tanh      Regularization None      Regularization rate 0      Problem type Classification

**DATA**  
Which dataset do you want to use?  
  
Ratio of training to test data: 50%  
Noise: 0  
Batch size: 10  
**REGENERATE**

**FEATURES**  
Which properties do you want to feed in?  
 $x_1$     $x_2$     $x_1^2$     $x_2^2$     $x_1 x_2$     $\sin(x_1)$     $\sin(x_2)$

**HIDDEN LAYERS**  
+ - 2 HIDDEN LAYERS  
4 neurons      2 neurons  
This is the output from one neuron. Hover to see it larger.  
The outputs are mixed with varying weights, shown by the thickness of the lines.

**OUTPUT**  
Test loss 0.508      Training loss 0.504  
  
Colors show data, neuron and weight values.  
 Show test data       Discretize output

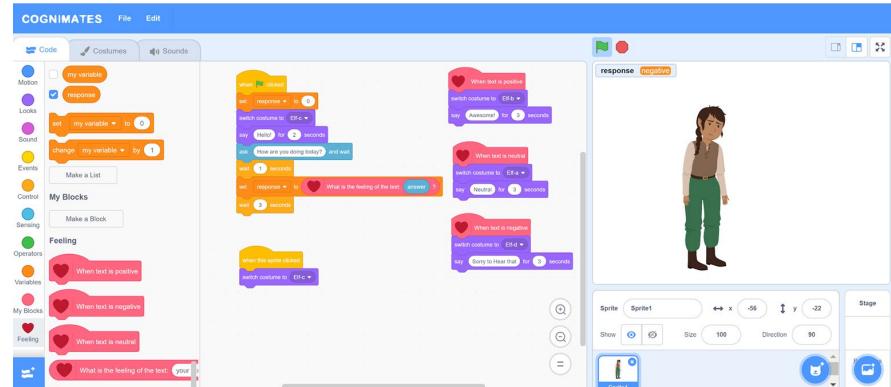
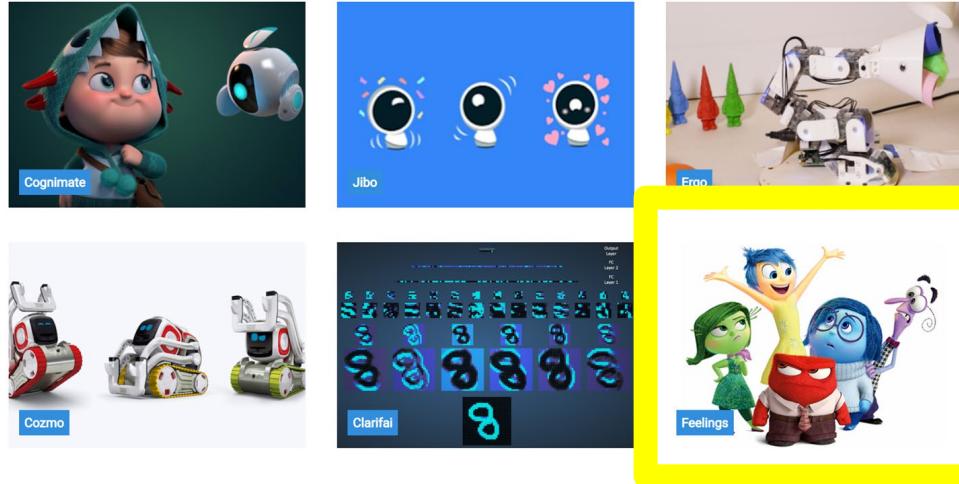
Tutorial: <https://cloud.google.com/blog/products/gcp/understanding-neural-networks-with-tensorflow-playground>



<http://cognimates.me>

Cognimates offers AI extensions for Scratch, such as:

- speech recognition
- sentiment analysis
- visual pattern detection
- robot control

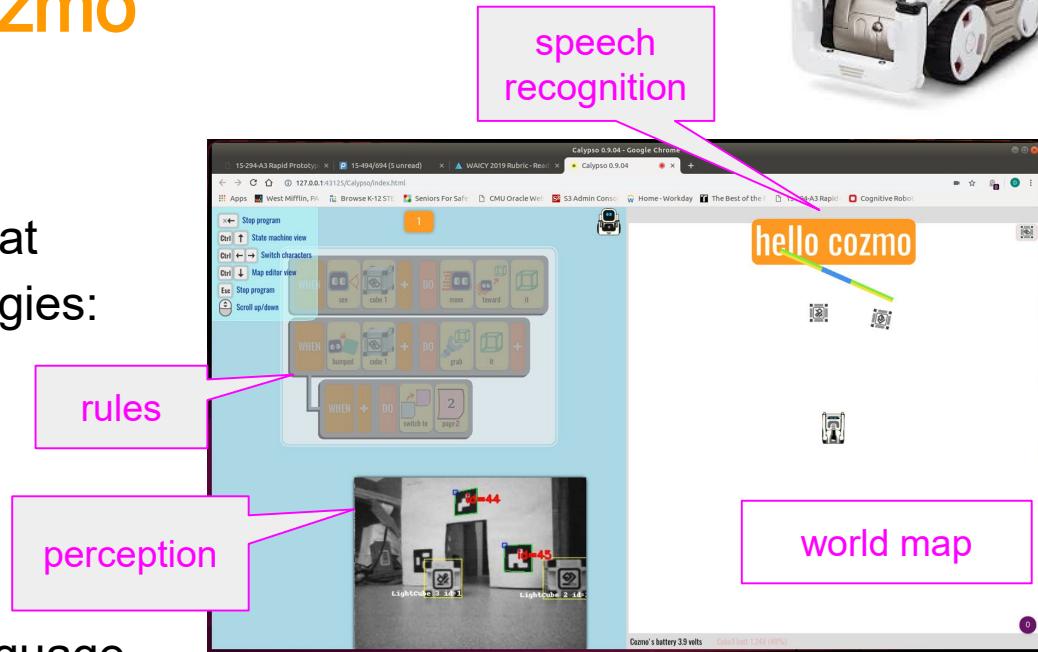




# Calypso for Cozmo



- A robot intelligence framework that Incorporates multiple AI technologies:
  - Computer vision; face recognition
  - Speech recognition and generation
  - Landmark-based navigation
  - Path planning
  - Object manipulation
- Rule-based pattern matching language inspired by Microsoft's Kodu Game Lab
- Teaches computational thinking: “Laws of Calypso”, idioms, etc.
- Web site: <https://Calypso.software>

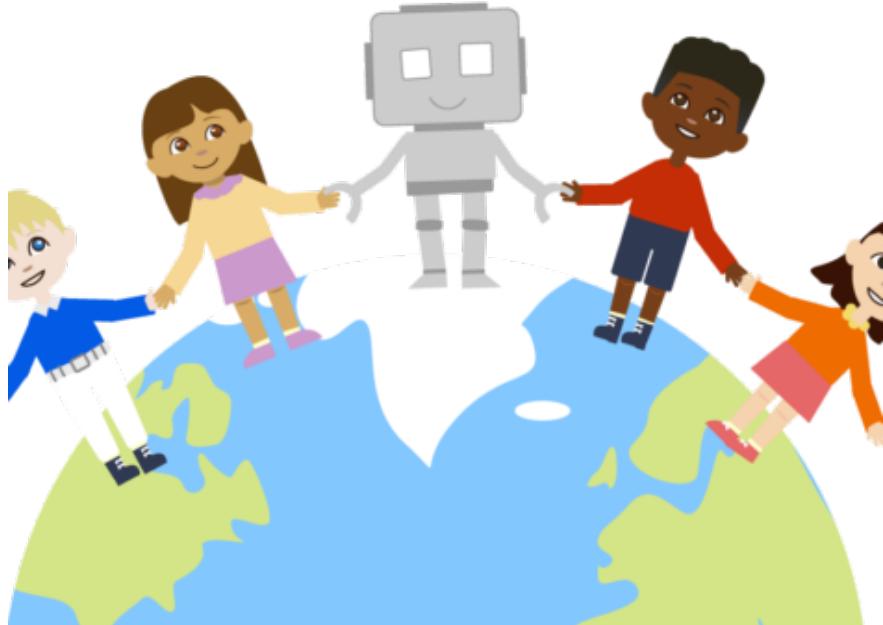


# AI + ME (AI and Me)

[edu.readyai.org/courses/aime/](http://edu.readyai.org/courses/aime/)

“AI+ME” is an online experience intended to provide young learners with the basics of AI. The lesson takes about one hour to complete. This is the first publicly available course introducing students to the “Five Big Ideas in AI” as defined by the AI4K12 Initiative.

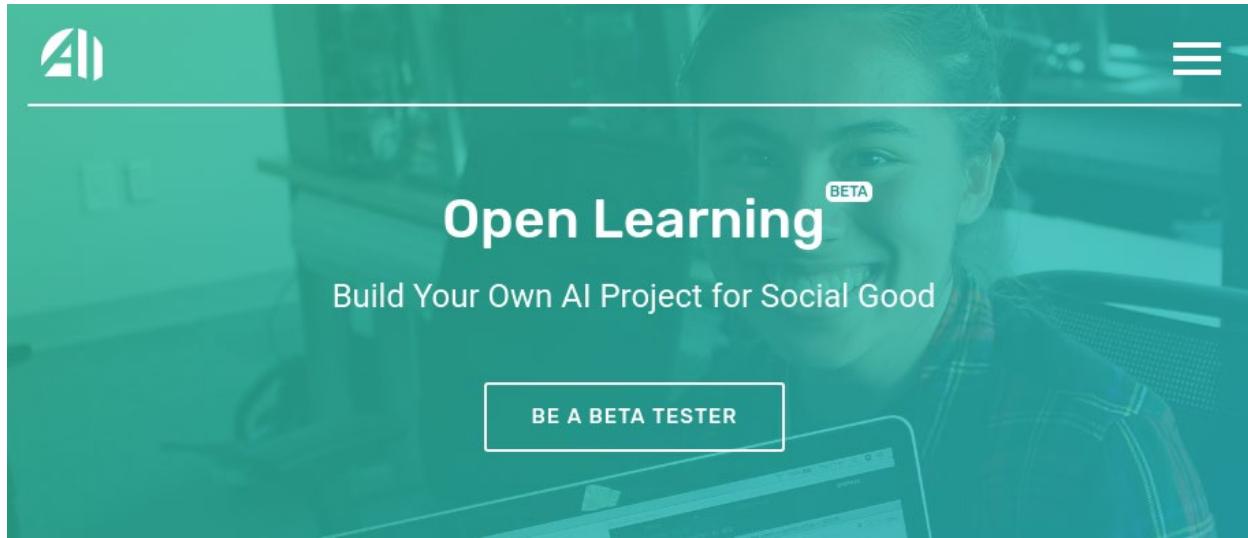
*Target Audience: Elementary School*



# AI4All: Online Student Portal

<http://ai-4-all.org/open-learning>

The AI4All Open Learning platform will offer a series of online AI courses for high school students. As of summer 2019, the first course is in beta test. This course focuses on the basics of machine learning.





# WAICY: World Artificial Intelligence Competition for Youth

2018 WAICY Stats:

**5+** Time zones

**200+** Students

**50** Teams

(**20+** remote participation)

"S.T.E.A.M.-Powered A.I."

- 50/50 Rubric
- Winning Project



**East to West**  
Energy Transportation  
Median Age: 8



**AI Ninja**  
Home Assistant  
Median Age: 7



**Earthquake**  
Search and Rescue  
Median Age: 12



# Professional Development Course

## Artificial Intelligence Explorations and Their Practical Use in Schools

[www.iste.org/learn/iste-u/artificial-intelligence](http://www.iste.org/learn/iste-u/artificial-intelligence)

### Course Dates:

Summer 2019 Session: June 3 - September 13

*Enrollment period: Now until July 12\**

[ENROLL NOW](#)

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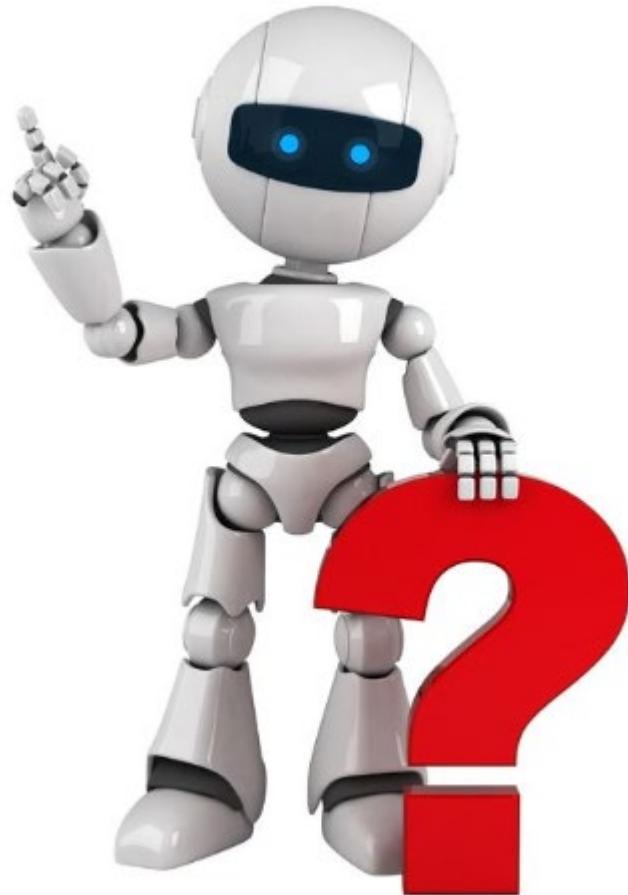
Fall 2019 Session: October 14, 2019 - January 27, 2020

*Enrollment period: Now until October 28\**

### Course Details:

- Grade Level: 6-12
- Course Length: 30 hours
- Cost: \$224 Member / \$299 Non-member
- Course Style: asynchronous with instructor

# Questions?





invites you to join us at the

## 2nd Annual AI for K-12 Symposium:

### Teaching AI in K-12

**November 8-9th, 2019**  
**Westin Arlington Gateway**  
**Arlington, VA**

*Part of the AAAI 2019 Fall Symposium Series*

# **It's time for all of us to think about AI in K-12.**

**Visit us:**

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# Session Evaluation

Please take a moment to evaluate this session. Your valuable feedback helps make the overall program stronger and ensures we're meeting your learning needs. Evaluations are also used by the conference program committee to provide feedback to presenters and inform future presentations.

To provide feedback and rate the quality of this session, please use the ISTE19 app or locate the session online using the program search at [isteconference.org](http://isteconference.org).

Thank you!