Why and How to Teach Artificial Intelligence In K-12

David S. Touretzky
Carnegie Mellon University

Rutgers New Jersey Computer Science Summit
May 14, 2021

#AI4K12

Kids Are Growing Up Surrounded By AI

They converse with Alexa, Siri, Cortana, or Google Assistant...

Smartphones Are Full of AI

- Speech recognition and generation
- Face recognition
- Snapchat filters
- Google Lens
- Recommender systems
  - Facebook feed
  - Youtube, Netflix videos
  - Amazon product recommendations
  - Google ad network

Cars That Can (Almost) Drive Themselves

www.youtube.com › watch

Driver asleep at the wheel of his Tesla on busy freeway in Los ...

Driver **asleep** at the wheel of his **Tesla** on busy freeway in Los Angeles ... A California couple captured a man ...

Aug 24, 2019 · Uploaded by ABC News

www.nbcnews.com › nightly-news › video › tesla-driver-...

Tesla driver caught on camera apparently asleep at the wheel

A motorist on a Massachusetts highway captured a man **asleep** behind the wheel of his **Tesla**, presumably in ...

Sep 9, 2019

www.usatoday.com › story › money › cars › 2019/09/09

Tesla driver recorded asleep as car drives down ... - USA Today

A **Tesla** driver was filmed **asleep** at the wheel as the semi-autonomous vehicle cruised on its own down a ...

Sep 9, 2019

www.youtube.com › watch

Another Tesla Driver Seen Asleep at the Wheel, Tesla ...

Another **Tesla** driver was filmed **sleeping** behind the wheel — but now the company claims these are 'pranks ...

Sep 26, 2019 · Uploaded by NowThis News

www.businessinsider.com › Tech Insider › Transportation

Unsettling Videos of Tesla Autopilot Drivers Asleep at the Wheel

In 2019, a record number of videos surfaced of **Tesla** drivers seemingly **asleep** on the highway while ...

Dec 2, 2019 · Uploaded by ABC7

We Live With Autonomous Robots Now

Roombas and other robot vacuums now have computer vision (camera or lidar).

Amazon’s warehouses are full of Kiva robots.

Dominos has started offering robotic pizza delivery in Houston.

Why Should We Be Teaching Kids About AI?

1. AI is the new electricity: it is powering the **next industrial revolution**.
   It is bringing huge **economic** and **social changes**.
   We need **informed citizens** who can understand the issues AI is raising.

2. Children are growing up with AI. They should not regard it as **magic**.

3. In the future, many **jobs** will involve working with AI in some way, e.g., interacting with intelligent agents. Students needs to be prepared.

K-12 AI Education (Circa 2018)

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

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)

CSTA

NSF

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

Carnegie Mellon University
School of Computer Science

AI4K12.org 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 educators, researchers, and resource developers

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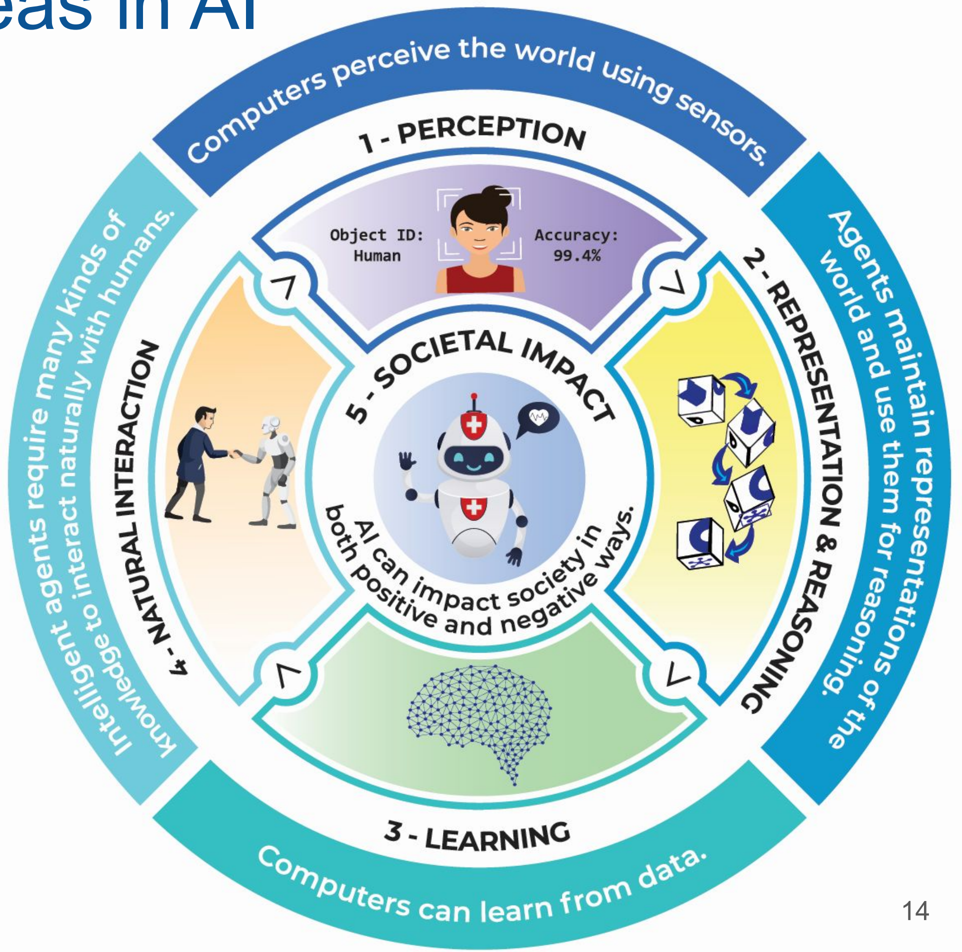
Five Big Ideas in AI

- 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.



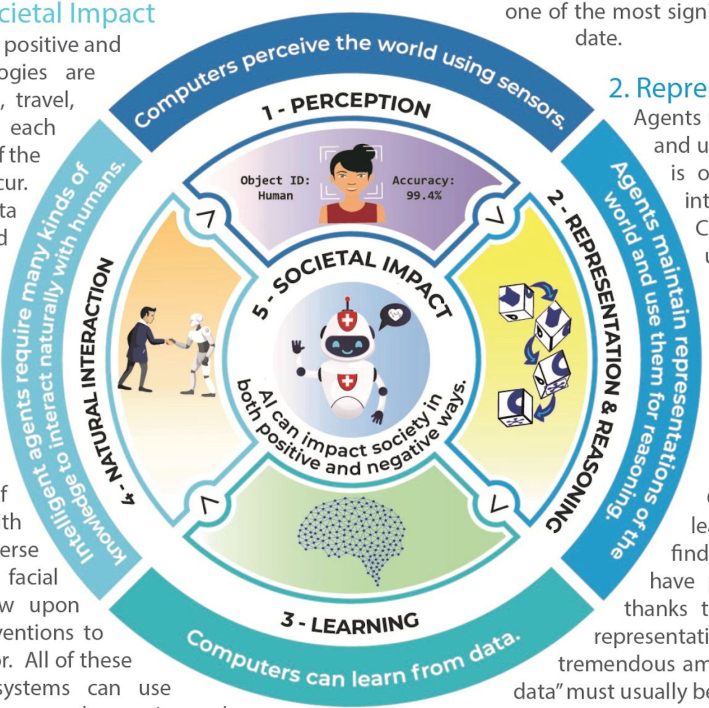
Five Big Ideas in Artificial Intelligence

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.

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.



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.

4. Natural Interaction

Intelligent agents require many kinds of knowlege 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. All of these are difficult problems. Today's AI systems can use language to a limited extent, but lack the general reasoning and conversational capabilities of even a child.

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.

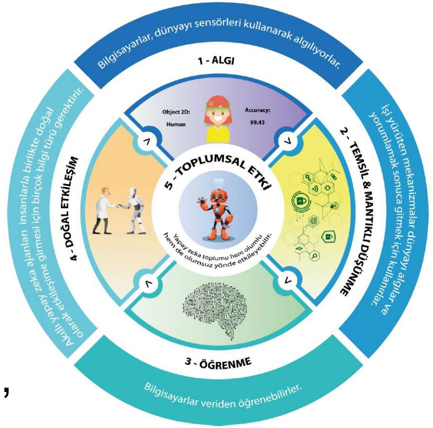
The AI for K-12 Initiative is a joint project of the Association for the Advancement of Artificial Intelligence (AAAI) and the Computer Science Teachers Association (CSTA), funded by National Science Foundation award DRL-1846073

AI4K12.org

11x14 Poster available for free download at AI4K12.org

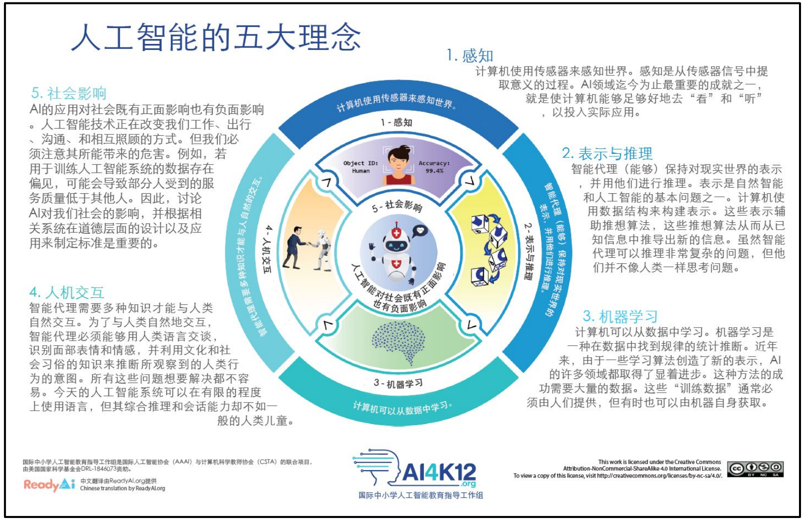
Adoption of the Big Ideas

Turkish

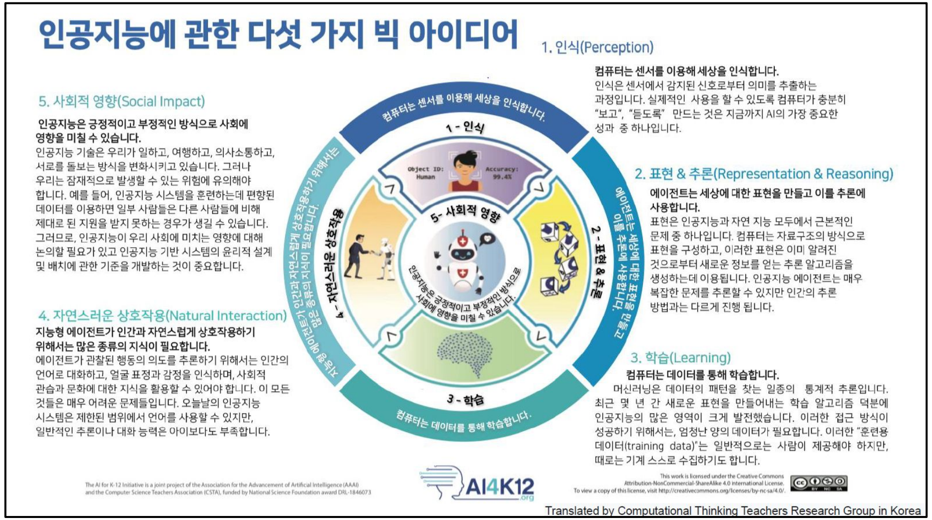


- Now being adopted by curriculum developers in the US and elsewhere.
- Translations available in 14 languages including Chinese, Korean, Japanese, Spanish, Portugese, Hebrew, Arabic, Hindi, and Thai.

Chinese



Korean

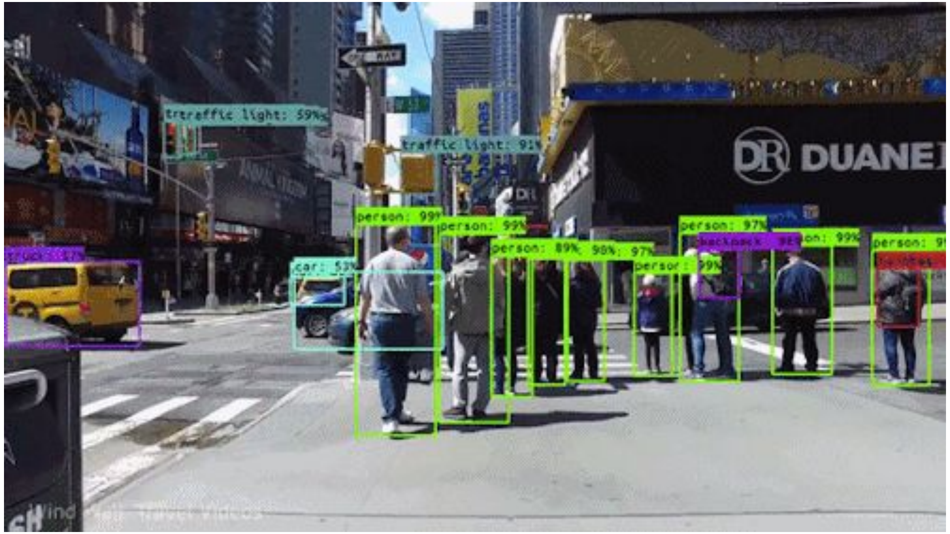


Big Idea #1: Perception

Computers perceive the world using sensors.

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

- Human senses vs. computer sensors
- Types of perception: vision, speech recognition etc.
- How perception works: algorithms



Example Guidelines

- Identify sensors on computers, robots, and intelligent appliances.
- 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).

Big Idea #2: Representation and Reasoning

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

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

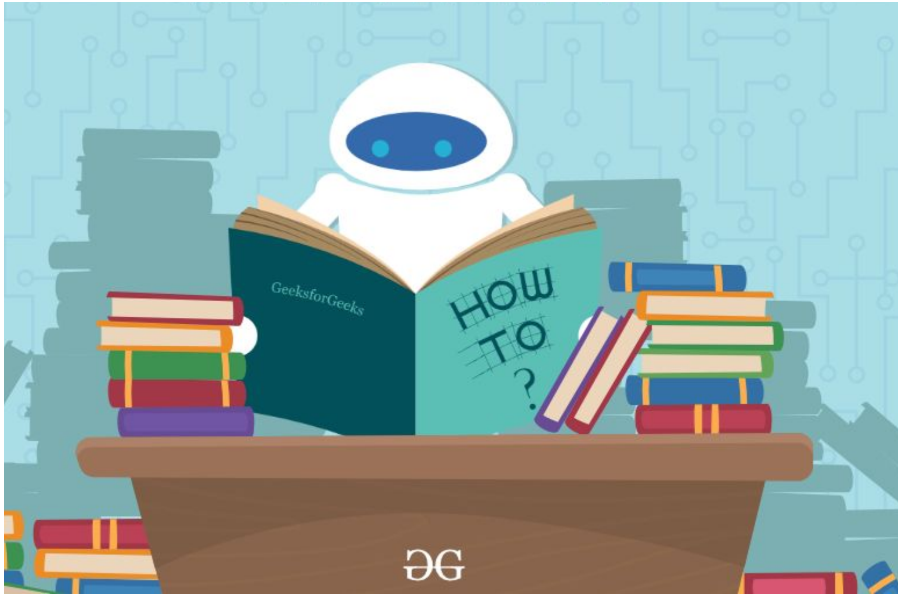
Example Guidelines

- Create/design a representation of an (animal) classification system using a tree structure.
- Draw a search tree for tic-tac-toe
- Describe how AI representations support reasoning to answer questions
- Describe the differences between types of search algorithms

Big Idea #3: Learning

Computers can learn from data.

- Nature of learning
- Fundamentals of neural networks
- Data sets



Example Guidelines

- Modify an interactive machine learning project by training its model..
- Describe how algorithms and machine learning can exhibit biases.
- Identify bias in a training data set and extend the training set to address the bias
- Train a neural net (1-3 layers) using *TensorFlow Playground*
- Trace and experiment with a simple ML algorithm

Big Idea #4: Natural Interaction

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

- Natural language understanding
- Common sense reasoning
- Affective computing & interaction (e.g. with robots, or speech agents)
- Consciousness and philosophy of mind

Example Guidelines

- 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
- Construct a simple chatbot
- Describe some tasks where AI outperforms humans, and tasks where it does not
- 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.

Big Idea #5: Societal Impact (1 of 3)

"Artificial Intelligence can impact society in both positive and negative ways."

- **Ethics of AI making decisions about people**
  - Fairness and bias
  - Transparency and explainability
  - Accountability

Example Guidelines

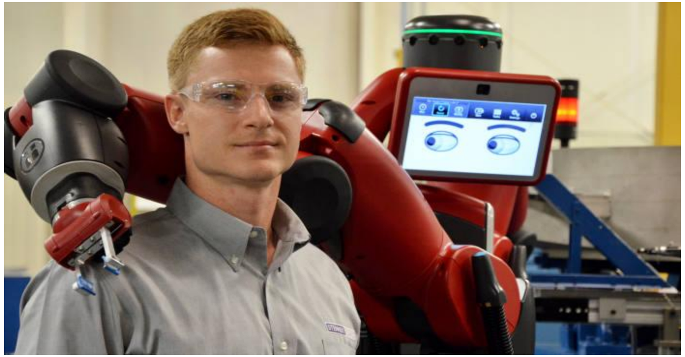
- Critically explore the positive and negative impacts of an AI system.

- Describe ways that AI systems can be designed for inclusivity.

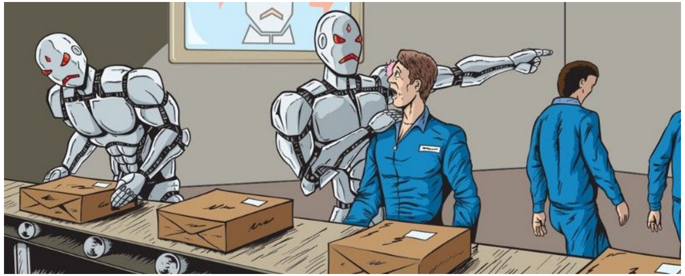
Machine Bias: ProPublica.org

Big Idea #5: Societal Impact (2 of 3)

"Artificial Intelligence can impact society in both positive and negative ways."



- **Economic impacts of AI**
    - Increased productivity
    - New types of services
    - Reduction in of some types of jobs
    - New career opportunities



Example Guidelines

- Design and explain how an AI system can be used to address a social issue.

- Understand tradeoffs in the design of AI systems and how decisions can have unintended consequences in the function of a system.

Big Idea #5: Societal Impact (3 of 3)

"Artificial Intelligence can impact society in both positive and negative ways."

- **AI & Culture**
  - Living with intelligent assistants and robot companions.
  - Would you let your child travel unaccompanied in a self-driving car?
  - New YouTube genre: self-driving car mishaps.

Example Guidelines

- Critically explore the positive and negative impacts of an AI system.
- Describe the debate about whether people should be polite to agents and robots.

What Do The Guidelines Look Like?

Big Idea #1: Perception - Progression Chart

FEEDBACK WELCOMED!!!

Draft Big Idea 1 - Progression Chart

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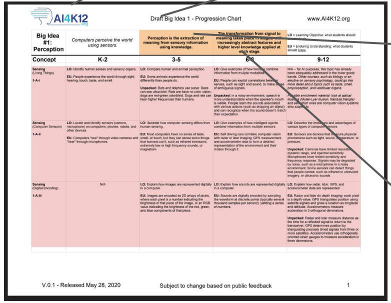
Big Idea #1: Perception	*Computers perceive the world using sensors.*	**Perception is the extraction of meaning from sensory information using knowledge.**	**The transformation from signal to meaning takes place in stages, with increasingly abstract features and higher level knowledge applied at each stage.**	**LO** = Learning Objective: what students should be able to do. **EU** = Enduring Understanding: what students should know.
Concept	**K-2**	**3-5**	**6-8**	**9-12**
Sensing (Living Things) **1-A-i**	**LO:** Identify human senses and sensory organs. **EU:** People experience the world through sight, hearing, touch, taste, and smell.	**LO:** Compare human and animal perception. **EU:** Some animals experience the world differently than people do. **Unpacked:** Bats and dolphins use sonar. Bees can see ultraviolet. Rats are have no color vision; dogs are red-green colorblind. Dogs and rats can hear higher frequences than humans.	**LO:** Give examples of how humans combine information from muliple modalities. **EU:** People can exploit correlations between senses, such as sight and sound, to make sense of ambiguous signals. **Unpacked:** In a noisy environment, speech is more understandable when the speaker's mouth is visible. People learn the sounds associated with various actions (such as dropping an object) and can recognize when the sound doesn't match their expectation.	N/A – for AI purposes, this topic has already been adequately addressed in the lower grade bands. *Other courses, such as biology or an elective on sensory psychology, could go into more detail about topics such as taste, smell, proprioception, and vestibular organs.* *Possible enrichment material: look at optical illusions (Muller-Lyer illusion, Kanizsa triangle) and ask which ones are computer vision systems also subject to.*
Sensing (Computer Sensors) **1-A-ii**	**LO:** Locate and identify sensors (camera, microphone) on computers, phones, robots, and other devices. **EU:** Computers "see" through video cameras and "hear" through microphones.	**LO:** Illustrate how computer sensing differs from human sensing. **EU:** Most computers have no sense of taste, smell, or touch, but they can sense some things that humans can't, such as infrared emissions, extremely low or high frequency sounds, or magnetism.	**LO:** Give examples of how intelligent agents combine information from multiple sensors. **EU:** Self driving cars combine computer vision with radar or lidar imaging. GPS measurement, and accelerometer data to form a detailed representation of the environment and their motion through it.	**LO:** Describe the limitations and advantages of various types of computer sensors. **EU:** Sensors are devices that measure physical phenomena such as light, sound, temperature, or pressure. **Unpacked:** Cameras have limited resolution, dynamic range, and spectral sensitivity. Microphones have limited sensitivity and frequency response. Signals may be degraded by noise, such as a microphone in a noisy environment. Some sensors can detect things that people cannot, such as infrared or ultraviolet imagery, or ultrasonic sounds.
Sensing (Digital Encoding) **1-A-iii**	N/A	**LO:** Explain how images are represented digitally in a computer. **EU:** Images are encoded as 2D arrays of pixels, where each pixel is a number indicating the brightness of that piece of the image, or an RGB value indicating the brightness of the red, green, and blue components of that piece.	**LO:** Explain how sounds are represented digitally in a computer. **EU:** Sounds are digitally encoded by sampling the waveform at discrete points (typically several thousand samples per second), yielding a series of numbers.	**LO:** Explain how radar, lidar, GPS, and accelerometer data are represented. **EU:** Radar and lidar do depth imaging: each pixel is a depth value. GPS triangulates position using satellite signals and gives a location as longitude and latitude. Accelerometers measure accleration in 3 orthogonal dimensions. **Unpacked:** Radar and lidar measure distance as the time for a reflected signal to return to the transceiver. GPS determines position by triangulating precisely timed signals from three or more satellites. Accelerometers use orthogonally oriented strain gauges to measure acceleration in three dimensions.

V.0.1 - Released May 28, 2020 Subject to change based on public feedback 1

bit.ly/36InJgi

Big Idea #1: Perception

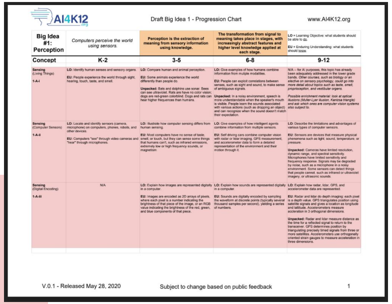
Computers perceive the world using sensors.



Perception is the extraction of meaning from sensory information using knowledge.

The transformation from signal to meaning takes place in stages, with increasingly abstract features and higher level knowledge applied at each stage.

Big Idea #1 Concept List



AI4K12 Draft Big Idea 1 - Progression Chart www.AI4K12.org

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1-A: Sensing

- 1-A-i: Living Things
- 1-A-ii: Computer Sensors
- 1-A-iii: Digital Encoding

1-B: Processing

- 1-B-i: Sensing vs. Perception
- 1-B-ii: Feature Extraction
- 1-B-iii: Abstraction Pipeline: Language
- 1-B-iv: Abstraction Pipeline: Vision

1-C: Domain Knowledge

- 1-C-i: Types of Domain Knowledge
- 1-C-ii: Inclusivity

1-A-i: Sensing in Living Things

K-2	3-5
LO: Identify human senses and sensory organs.	**LO:** Compare human and animal perception.
EU: People experience the world through sight, hearing, touch, taste, and smell.	**EU:** Some animals experience the world differently than people do.
	Unpacked: Bats and dolphins use sonar. Bees can see ultraviolet. Rats have no color vision...

LO (Learning Objective): What students should be able to do.
EU (Enduring Understanding): What students should know.

Big Idea #3: Learning - Progression Chart

3 - LEARNING
Computers can learn from data.

AI4K12.org

Draft Big Idea 3 - Progression Chart

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Big Idea #3: Learning	*Computers can learn from data.*	LO = Learning Objective: What students should be able to do.	EU = Enduring Understanding: What students should know.	Unpacked descriptions are included when necessary to illustrate the LO or EU
Concept	**K-2**	**3-5**	**6-8**	**9-12**
Nature of Learning *(Humans vs. machines)* **3-A-i**	**LO:** Describe and provide examples of how people learn and how computers learn. **EU:** Computers learn differently than people. **Unpacked:** People learn by observation, by being told, by asking questions, by experimentation, by practice, and by making connections to past experience. Computers learn by finding patterns in data, or by trial and error. **Activities:** Describe a time when you learned something by being told, by watching another person, or by asking questions. A demo such as Teachable Machine can be used to illustrate a computer learning something from positive and negative examples.	**LO:** Differentiate between how people learn and how computers learn. **EU:** Both people and computers can learn by finding patterns in data, or by trial and error. But people are flexible learners who can adapt to unfamiliar situations and learn in other ways, such as by observing others, by asking questions, or by making connections to prior learning. **Unpacked:** People are natural learners, while computers have to be programmed to learn. Presently there are two ways that computers can be programmed to learn: they can learn by finding patterns in human-supplied examples, or they can learn by trial and error.	**LO:** Contrast the unique characteristics of human learning with the ways machine learning systems operate. **EU:** People learn by observation, by being told, by asking questions, by experimentation, by practice, and by making connections to past experience. Computers learn by applying specialized algorithms to large amounts of training data, or by thousands or even millions of trial and error experiences, to solve narrowly defined problems. **Unpacked:** People are flexible learners who employ multiple strategies. Computers use specialized algorithms that require large amounts of data or many trials, and only solve narrowly defined problems. While humans can construct reasoners by explicitly programming them, for complex problems it is often more convenient to let the machine learning algorithm do the work.	**LO:** Define supervised, unsupervised, and reinforcement learning algorithms, and give examples of human learning that are similar to each algorithm. **EU:** Both supervised and unsupervised learning algorithms find patterns in data. Supervised learning uses features to predict the class label supplied by a teacher; unsupervised learning groups similar instances together, creating its own classes. Reinforcement learning uses trial and error to find a policy for choosing actions that maximizes the reinforcement signal. **Unpacked:** Supervised learning is like being corrected by a coach. Unsupervised learning is like noticing that your store has three kinds of customers based on their distinctive purchasing patterns. Reinforcement learning is like trying different moves in a video game and seeing which yields the most points (greatest reward).
Nature of Learning (Finding patterns in data) **3-A-ii**	**LO:** Identify patterns in labeled data and determine the features that predict labels. **EU:** Classes can be defined in terms of feature values. The relevant features can be inferred by examining labeled examples. **Unpacked:** To give students a feel for the problem of learning to classify we must ask them to learn a class that's not intuitively obvious, e.g., learn "poisonous fish" by examining cartoon fish images labeled "poisonous" or "not poisonous". They can then be asked to describe which features indicate a fish is poisonous, e.g., red fish with square heads. Using images as input simplifies the task because the features are intuitive, even though the classification rule should not be.	**LO:** Model how supervised learning identifies patterns in labeled data. **EU:** When learning to classify labeled data, the patterns (or rules) that are discovered can be expressed as weights in a neural network or nodes in a decision tree. **Unpacked:** This extends the K-2 version by having students draw a decision tree instead of merely verbalizing their proposed rule. In addition, the task can be made richer in 3-5 by increasing the number of classes or by making the class definitions more complex. For example, a fish could be poisonous if it is either red with a square head or blue with a round head or purple with pointy spines and any shape head. Each node of the decision tree can test one feature value, e.g., color, so complex features require deeper trees.	**LO:** Model how unsupervised learning finds patterns in unlabeled data. **EU:** Unsupervised learning is useful when we don't know in advance what classes exist. It discovers patterns (or classes) in data by grouping nearby points into clusters. Once a set of clusters has been found, new points can be classified based on distance from the cluster boundaries. **Unpacked:** This can be done graphically using points in the plane and visually constructing cluster boundaries by outlining (e.g., drawing an ellipse around) each cluster.	**LO:** Model how machine learning constructs a reasoner for classifcation or prediction by adjusting the reasoner's parameters (its internal representations). **EU:** Supervised learning adjusts the parameters of a mathematical model (selected in advance by a human) to generate correct classifications or predictions. This model could be a simple linear equation, a high-degree polynomial, or an even more complex nonlinear equation such as a deep neural network. The internal representations that encode the relationship between inputs and outputs express the "patterns" found in the data. **Unpacked:** In regression, we pick a mathematical model such as a linear equation $y=mx+b$ and then adjust its parameters to fit a set of data points as best we can. The model can then be used to predict a y value for any x value. Linear regression can be done with a ruler by eyeballing the distance between the line and the points. Students can model polynomial or logistic regression by giving them a graphical display with sliders to control the parameter values. They can manually adjust the sliders to reach what they perceive as a best fit to the data. More advanced students can be shown how quality of fit can be measured mathematically using mean squared error. For classification problems the Y value is either 1 for "in class" or 0 for "not in class" and the decision boundary is the line or surface $y=0.5$.

FEEDBACK WELCOMED!!!

bit.ly/3oT0xE9

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- Curriculum Materials
- Demos
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- Online Courses for K-12 Students
- Reference Sources & Tutorials
- Resource Directories
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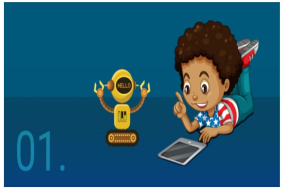
Featuring:

AI for Teachers

https://aiforteachers.org/teaching-resources



AI Literacy in K-12

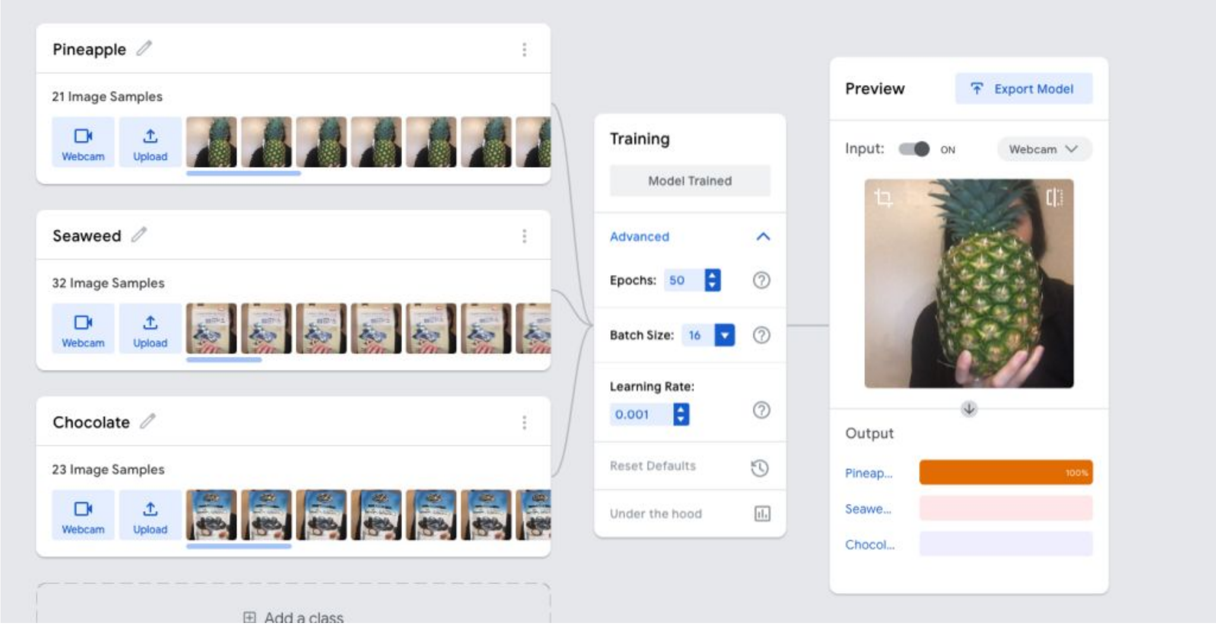
MIT AI Education Website

https://aieducation.mit.edu/

Online Demos

- Teachable Machine: https://teachablemachine.withgoogle.com/
  Train a visual classifier using your webcam.

- Runs in the browser: nothing to install



Programming Tools

- AI extensions to: Scratch, Snap!, App Inventor
- MachineLearningForKids: train a classifier and export it for use in your Scratch or App Inventor program
- AI programming framework for kids: Cloud Calypso
- Python toolkits: scikit-learn, Pytorch, TensorFlow

The State of K-12 AI Education in Your State: A Planning Workshop

David Touretzky, CMU & Christina Gardner-McCune, UF

January 28-29, 2021

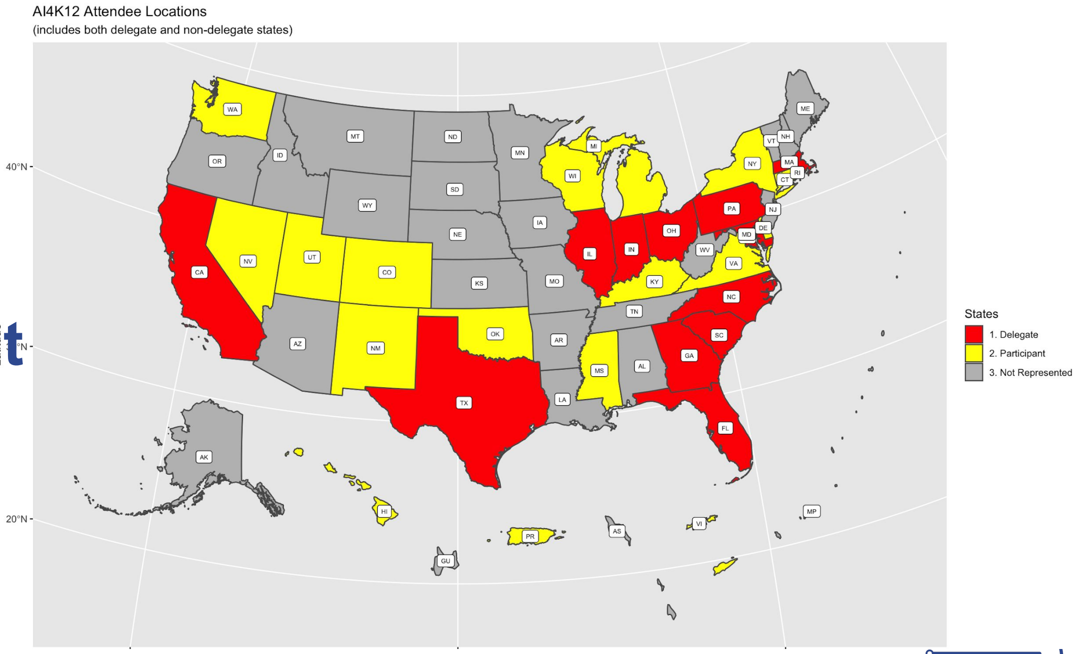
Funded by National Science Foundation award DRL-1846073.

141 Participants

27 States
3 Territories

Focused Breakout Groups (15):

CA, CT, FL, GA, HI, IL, IN, MD, MA, MS, NC, OH, PA, SC, TX, Puerto Rico, Virgin Islands (no docs)



K-12 AI Education Community (US Focused)

Includes

- AI4K12 - Mailing List
- AI4K12 State Teams (Slack)
- AI4ALL - Teachers & Students (PDs & Camps)
- WAICY Competition - Students & teacher teams over past 4 years
- ISTE Teacher Community on Facebook
- AI for Teachers - https://aiforteachers.org/
- Teachers working with NSF Grants focused on K-12 AI Education Curriculum & Professional Development

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

Email us:

info@ai4k12.org

Visit us:

http://AI4K12.org

Follow Us &
Join the Twitter Chats

#AI4K12

Join the mailing list:

https://aaai.org/Organization/mailing-lists.php

AI4K12.org