

Teaching Artificial Intelligence in K-12

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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



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Dr. April DeGennaro

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Dr. Phillip Eaglin

Brian Stamford

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Grades 9-12

Dianne O'Grady-Cunniff (Lead)

Jared Amalong

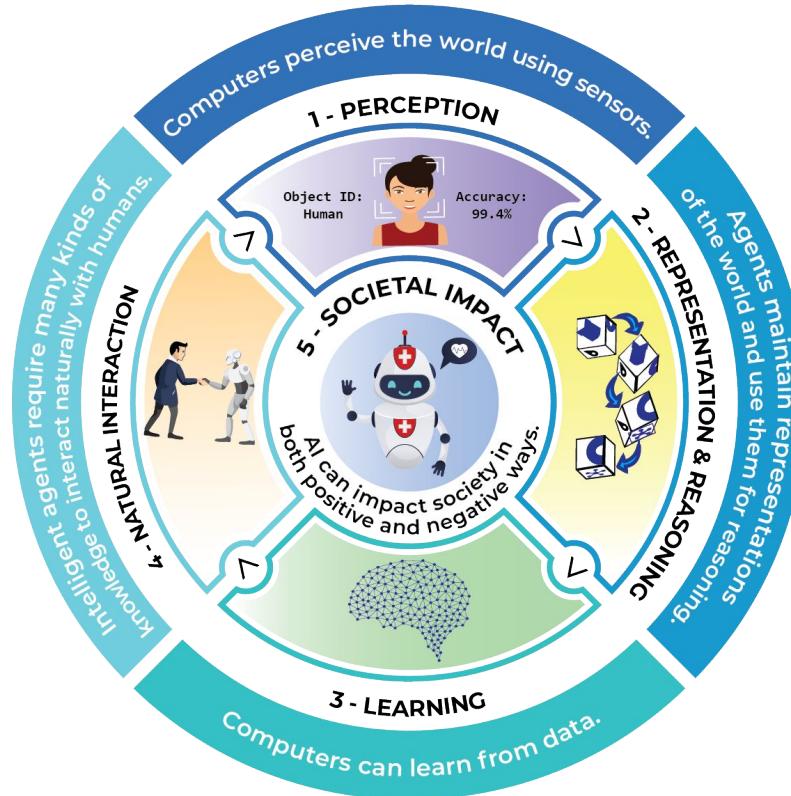
Dr. Smadar Bergman

Kate Lockwood

John Chapin

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.



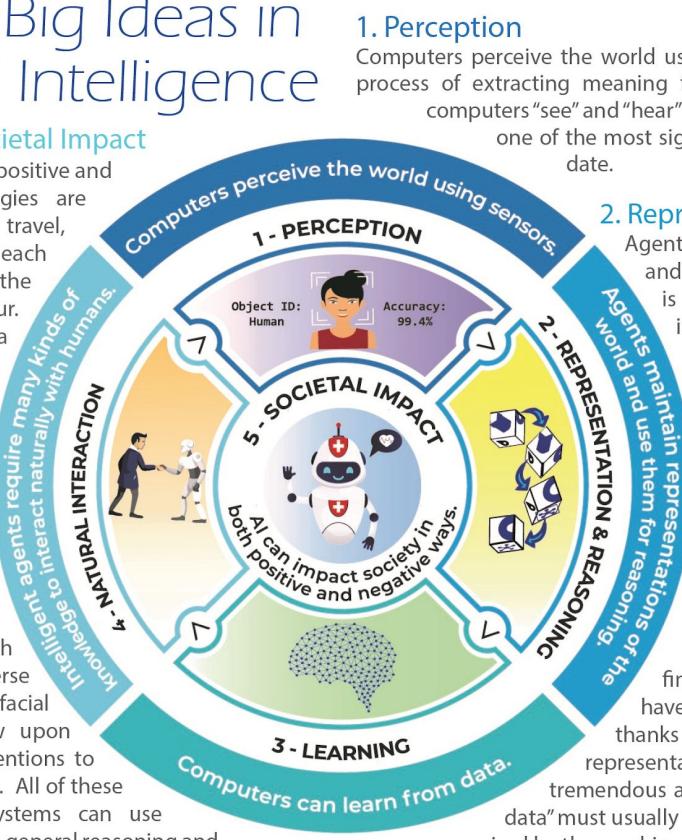
Five Big Ideas in Artificial Intelligence

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

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. 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.



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.



Widespread Adoption of the Five Big Ideas

- Now being referenced by multiple curriculum developers in the US and elsewhere.
- Big ideas poster is available in 17 languages.

Chinese

人工智能的五大理念

5. 社会影响

AI的应用对社会既有正面影响也有负面影响。人工智能技术正在改变我们工作、出行、沟通、和相互照应的方式。但是我们必须注意其所能带来的危害。例如，若用于训练人工智能系统的数据存在偏见，可能会导致部分人受到的服务质量低于其他人。因此，讨论AI对我们社会的影响，并根据相关关系在道德层面的设计以及应用来制定标准是重要的。

4. 人机交互

智能代理需要多种知识才能与人类自然交互。为了与人类自然地交互，智能代理必须能够用人类语言交谈，识别面部表情和情感，并利用文化和社会习俗的知识推断所观察到的人类行为的意图。所有这些问题需要解决都不容易。今天的人工智能系统可以在有机器的程度上使用语言，但其综合推理和会话能力却不如一般的人类儿童。

1. 感知

计算机使用传感器来感知世界。感知是从传感器信号中提取意义的过程。AI领域迄今为止最重要的成就之一，就是使计算机能够足够好地去“看”和“听”，以投入实际应用。

2. 表示与推理

智能代理（能够）保持对现实世界的表示，并用他们进行推理。表示是自然智能和人工智能的基本问题之一。计算机使用数据结构来构建表示。这些表示辅助想算法，这些推算法可以从已知信息中推导出新的信息。虽然智能代理可以推理非常复杂的问题，但他们并不像人类一样思考问题。

3. 机器学习

计算机可以从数据中学习。机器学习是一种在数据中找到规律的统计推断。近年来，由于一些学习算法创造了新的表示，AI的许多领域都取得了显著进步。这种方法的成功需要大量的数据。这些“训练数据”通常必须由人们提供，但有时也可以由机器自身获取。



Arabic, Chinese, English, French, German, Hebrew, Hindi, Italian, Japanese, Korean, Portuguese, Spanish, Slovenian, Tamil, Thai, Turkish

Korean

인공지능에 관한 다섯 가지 빅 아이디어

1. 인식(Perception)

컴퓨터는 센서를 이용해 세상을 인식합니다.
인식은 서비스에서 감지된 신호로부터 의미를 추출하는 과정입니다. 실제적인 사용을 할 수 있도록 컴퓨터가 충분히 “보고”, “듣도록” 만드는 것은 지금까지 시의 가장 중요한 성과 중 하나입니다.

2. 표현 & 추론(Representation & Reasoning)

에이전트는 세상에 대한 표현을 만들고 이를 추론에 사용합니다.
보통은 인공지능과 같이 모든에서 구본적인 문제 중 하나입니다. 컴퓨터는 자료구조와 방식으로 표현을 구성하고, 이러한 표현은 이미 알고리즘을 것으로부터 새로운 정보를 얻은 후론 알고리즘을 생성하는데 이용됩니다. 인공지능 에이전트는 매우 복잡한 문제를 주론할 수 있지만 인간의 주론 방법과는 다르게 진행 됩니다.

3. 학습(Learning)

컴퓨터는 데이터를 통해 학습합니다.
마이너님은 데이터의 패턴을 찾는 일종의 통계적 추론입니다. 최근 몇 년 간 새로운 표현을 만들어내는 학습 알고리즘 덕분에 인공지능의 많은 영역이 크게 발전했습니다. 이러한 접근 방식이 성공하기 위해서는, 엄청난 양의 데이터가 필요합니다. 이러한 “운행 데이터(training data)”는 일반적으로 사람에 제공해야 하지만, 때로는 기계 스스로 수집해야 합니다.

4. 자연스러운 상호작용(Natural Interaction)

지능형 에이전트는 인간과 자연스럽게 상호작용하기 위해서는 많은 종류의 자식이 필요합니다.
에이전트는 관찰된 행동의 의도를 추론하기 위해서는 인간의 언어로 대화하고, 말과 표정의 설정을 인식하여 시체적 관습과 문화에 맞는 대화의 시스템을 활용할 수 있어야 합니다. 이 모든 것들은 매우 어려운 과정입니다. 오늘날의 인공지능 시스템은 세밀한 범위에서 언어를 이해할 수 있지만, 일반적인 주론이나 대화 능력은 아닙니다. 우리는입니다.

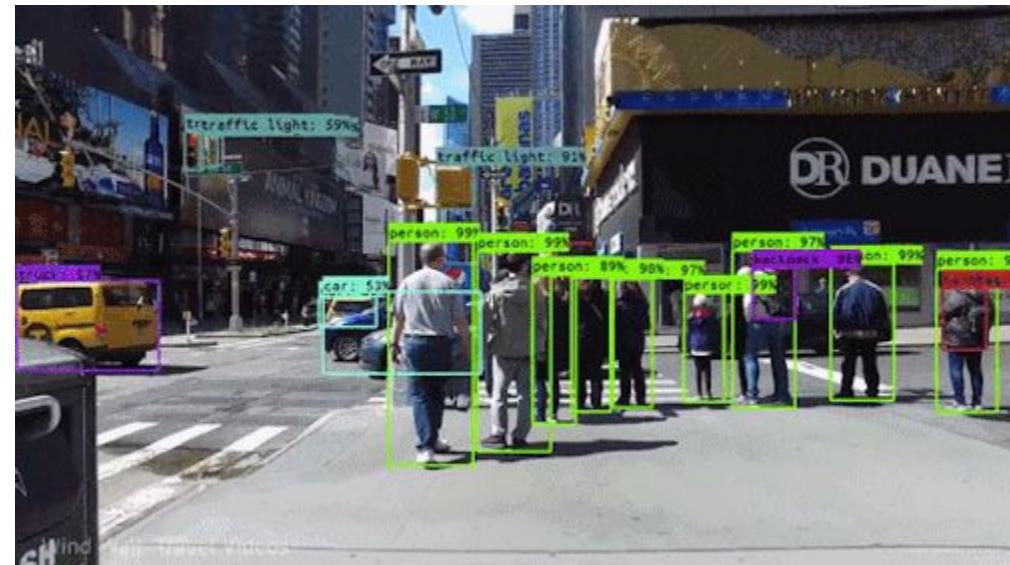
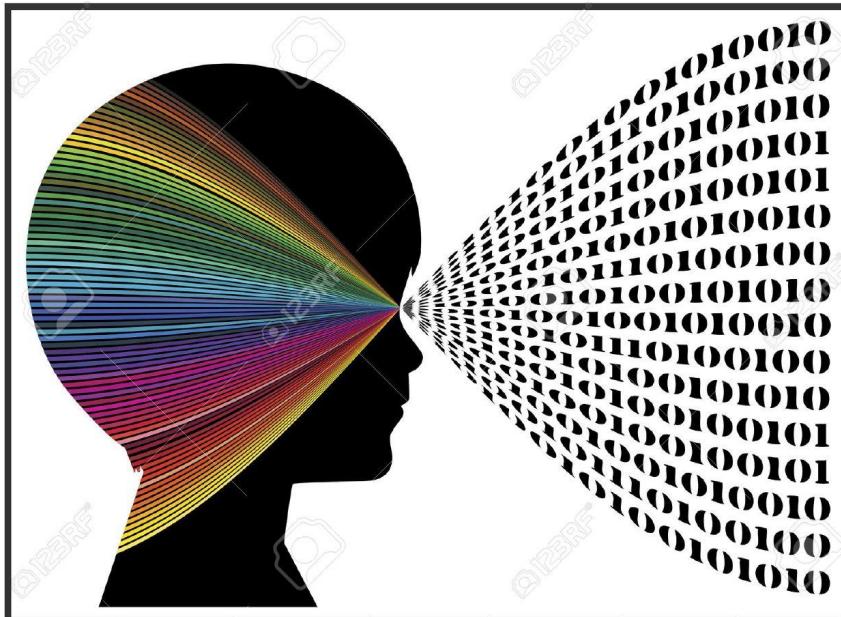
The AI for K-12 Initiative is a joint project of the Association for the Advancement of Artificial Intelligence (AAAI) and the Computer Science Teachers Association (CSTA), funded by National Science Foundation award DRL-184603.



Translated by Computational Thinking Teachers Research Group in Korea

Big Idea #1: Perception

Computers perceive the world using sensors.



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

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

Grades K–2 (5 to 8 years-old)

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

Grades 6–8 (12 to 14 yo)

- 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 (e.g., with Scratch plugins or Calypso).

Grades 3–5 (9 to 11 yo)

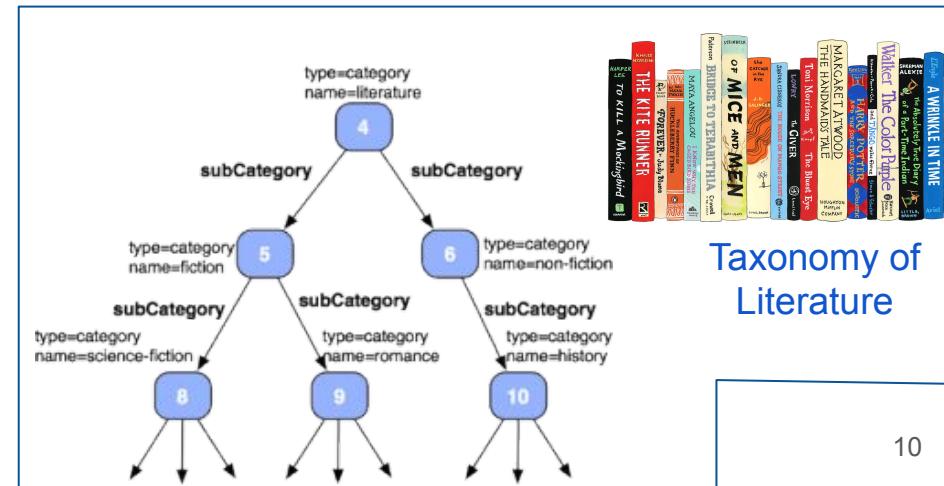
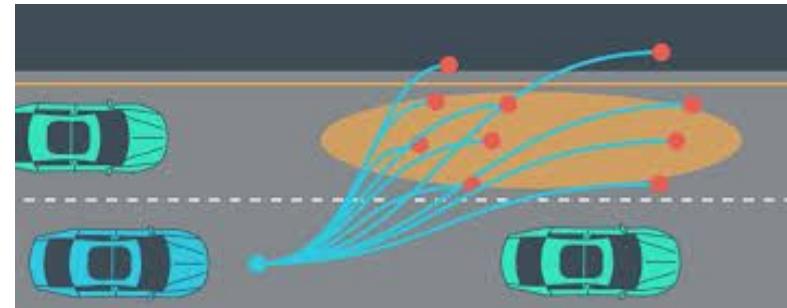
- Describe how sensor inputs are used in perception.
- Build an application using perception (e.g., with Scratch plugins or Calypso).

Grades 9–12 (15 to 18 yo)

- 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 – What should students be able to do?

Grades K–2 (5 to 8 years-old)

- Draw a map of the classroom or school and compare the map to the actual room or school building and grounds.
- Use a decision tree to make a decision

Grades 3–5 (9 to 11 yo)

- 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 (12 to 14 yo)

- 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

Grades 9–12 (15 to 18 yo)

- 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 – What should students be able to do?

Grades K–2 (5 to 8 years-old)

- 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 (12 to 14 yo)

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

Grades 3–5 (9 to 11 yo)

- Modify an interactive machine learning project by training its model.
- Describe how algorithms and machine learning can exhibit biases.

Grades 9–12 (15 to 18 yo)

- 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 – What should students be able to do?

Grades K–2 (5 to 8 years-old)

- 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.**

Grades 3–5 (9 to 11 yo)

- **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 6–8 (12 to 14 yo)

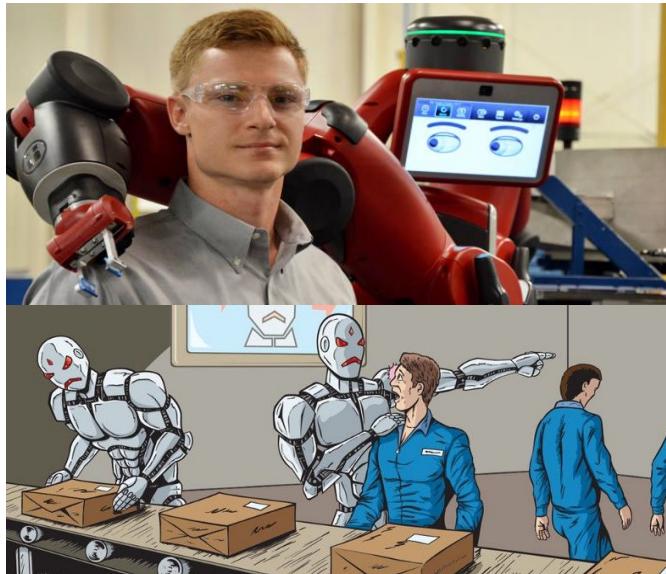
- **Construct a simple chatbot.**
- Explain and give examples of how language can be ambiguous.
- Reason about the nature of intelligence, and identify approaches to determining whether an agent is or is not intelligent.

Grades 9–12 (15 to 18 yo)

- 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 – What should students be able to do?

Grades K–2 (5 to 8 yo)

- 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 (9 to 11 yo)

- 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 (12 to 14 yo)

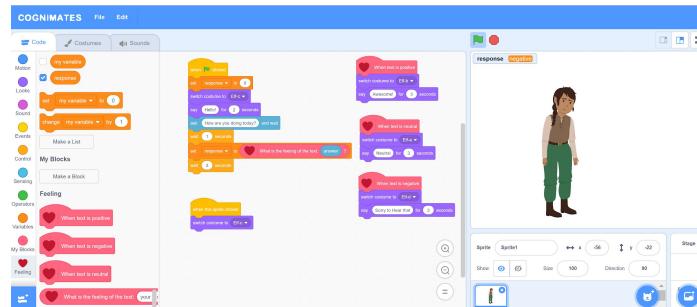
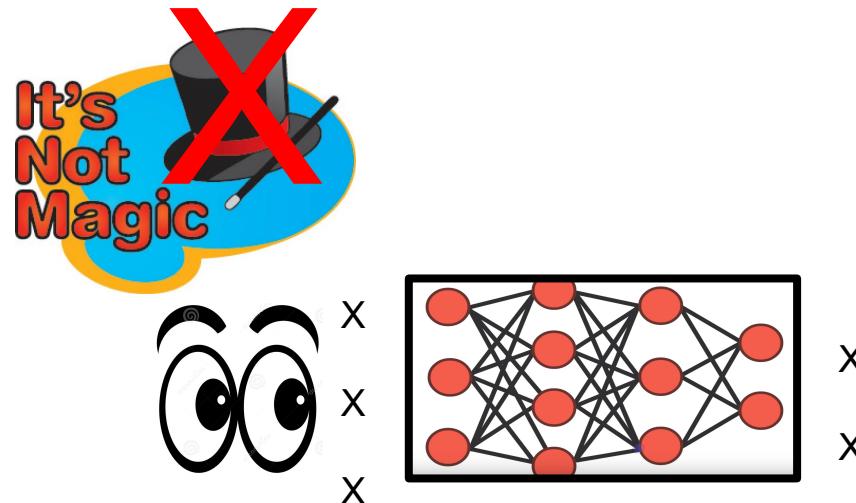
- Explain potential sources of bias in AI decision making
- Understand tradeoffs in the design of AI systems and how decisions can have unintended consequences in the function of a system

Grades 9–12 (15 to 18 yo)

- 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)

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
- 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

What Does AI Thinking Look like in K-12?



The Computational Thinkers

concepts



Logic

Predicting & analysing



Evaluation

Making judgements



Algorithms

Making steps & rules



Patterns

Spotting & using similarities



Decomposition

Breaking down into parts



Abstraction

Removing unnecessary detail



approaches



Tinkering

Changing things to see what happens



Creating

Designing & making



Debugging

Finding & fixing errors



Persevering

Keeping going



Collaborating

Working together

Computational Thinking

- Logic
- Evaluation
- Problem Decomposition
- Pattern Recognition
- Abstraction
- Algorithms

AI Thinking

- Perception (not just sensing!)
- Reasoning
- Representation
- Machine Learning
- Language Understanding
- Autonomous Robots

How AI Thinking Extends Computational Thinking

AI is built on representation and reasoning.

- Representations are data structures (**abstractions**)
- Reasoners are **algorithms**

So AI draws on the concepts and dispositions of computational thinking.

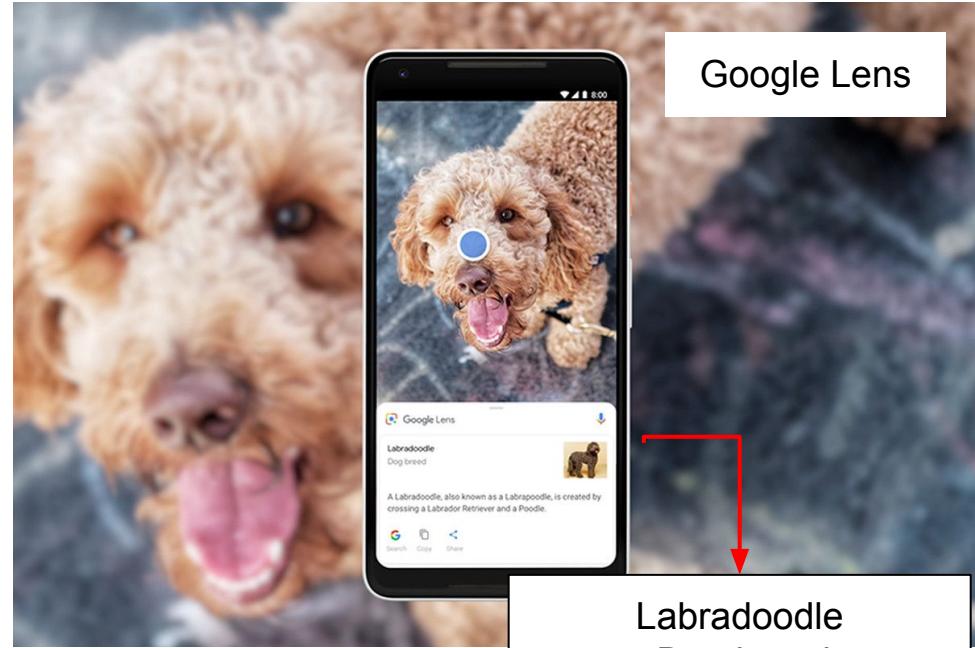
But AI asks students to consider that **computation can actually be thinking**.

Computational thinking is exactly what humans need when they try to understand how machines can think.

Visual Perception

Computers can see:

- Faces
- Household objects
- Road scenes



Google Lens

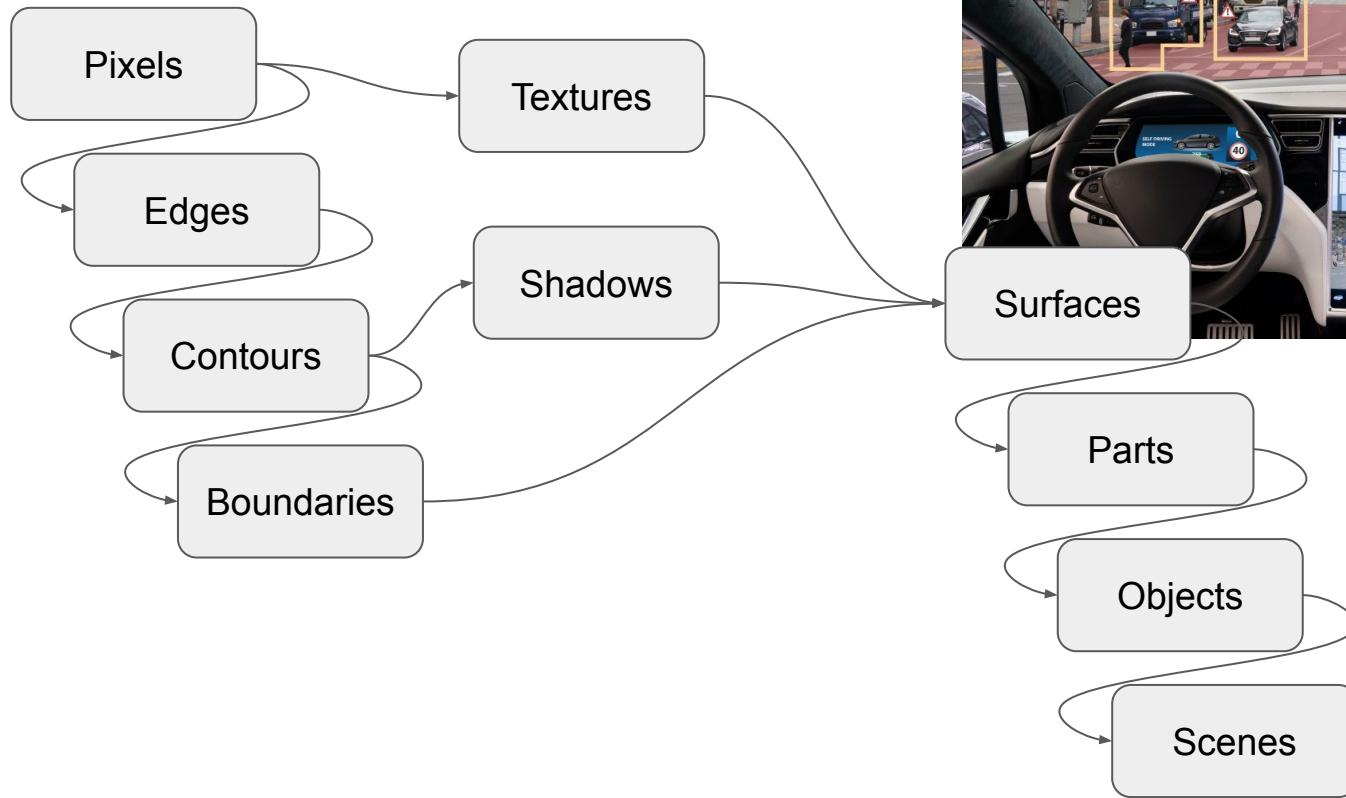
I can teach a computer to recognize what I want it to see.

I can make artifacts (programs, devices) that use computer vision.

Labradoodle
Dog breed

A Labradoodle, also known as a Labrapoodle, is created by crossing a Labrador Retriever and a Poodle.

Levels of visual structure



Speech Perception

Computers can understand spoken language.

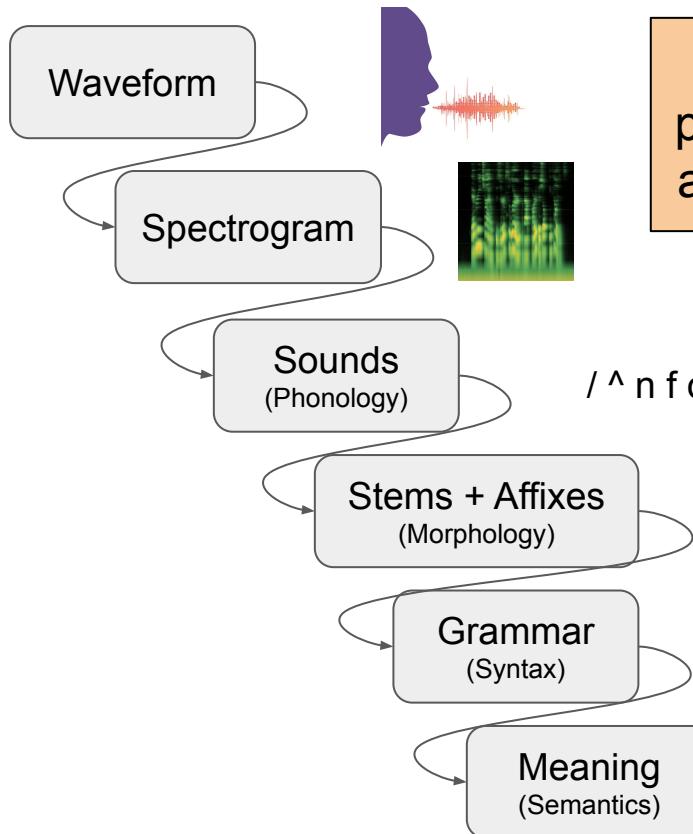
Lots of knowledge is required to accurately decode the speech signal:

- “They’re building their new house over there.”



I can make artifacts that understand voice commands.

Levels of representation and linguistic knowledge



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

Representation

Maps are representations of the world

Robots maintain maps of their environment

Computers build representations to aid their reasoning

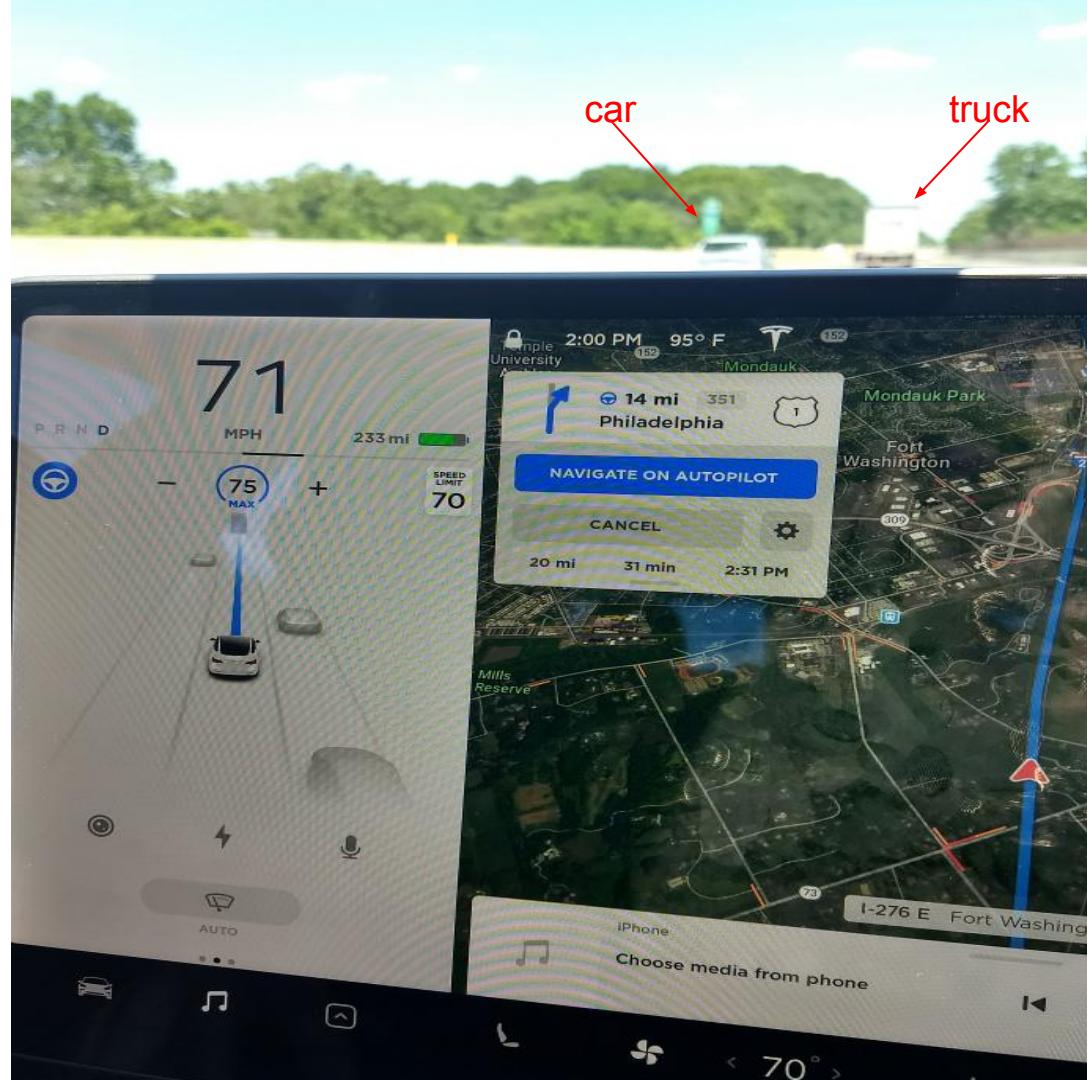
Representations are data structures

- Trees
- Graphs
- Feature vectors

I can make representations and manipulate them.

Tesla's World Map

At right is an image from a real self-driving car, a Tesla, showing the road and other nearby vehicles on its world map.



Calypso 0.9.04 - Google Chrome

15-294-A3 Rapid Prototype | 15-494/694 (5 unread) | WAICY 2019 Rubric - Read | Calypso 0.9.04 | +

127.0.0.1:43125/Calypso/index.html

Apps West Mifflin, PA Browse K-12 STE Seniors For Safe CMU Oracle Web S3 Admin Console Home - Workday The Best of the F 15-294-A3 Rapid Cognitive Robot

Stop program

Ctrl ↑ State machine view

Ctrl ← → Switch characters

Ctrl ↓ Map editor view

Esc Stop program

Scroll up/down

1

hello cozmo

speech recognition

rules

perception

world map

LightCube 3 id=1

LightCube 2 id=2

LightCube 1 id=44

LightCube 2 id=45

Cozmo's battery 3.9 volts Cube3 batt 1.24V (48%)

0

30

The screenshot displays the Calypso 0.9.04 software interface. On the left, a programming workspace shows three scripts:

- Script 1: WHEN see cube 1 DO move toward it
- Script 2: WHEN bumped DO grab it
- Script 3: WHEN + DO switch to page 2

A pink callout box labeled "rules" points to the top section of the workspace. A pink callout box labeled "perception" points to a camera feed at the bottom left showing three LightCubes labeled "LightCube 1 id=44", "LightCube 2 id=45", and "LightCube 3 id=1". A pink callout box labeled "speech recognition" points to the text "hello cozmo" in the upper right. A pink callout box labeled "world map" points to a small robot icon in the lower right. The status bar at the bottom shows "Cozmo's battery 3.9 volts" and "Cube3 batt 1.24V (48%)".



Calypso for Cozmo



- A robot intelligence framework that combines multiple types of AI:
 - Computer vision
 - Speech recognition
 - Landmark-based navigation
 - Path planning
 - Object manipulation
- Rule-based language inspired by Microsoft's Kodu Game Lab
- Teaches AI thinking
- Web sites:
 - <https://Calypso.software> (Cozmo robot version)
 - <https://calypso-robotics.com> (free simulator version runs in the browser)

Learning: Computers Can Learn From Data

Computers don't learn the way people do.

Machine learning constructs a reasoner.

The learning algorithm uses training data to **adjust the reasoner's internal representations** so that it produces the right answers.

What are the internal representations?

- For a decision tree, the representations are the nodes of the tree.
- For a neural network, the representations are the weights.

I can use machine learning to train a reasoner.

Is this test true?

samples = how many training examples got here

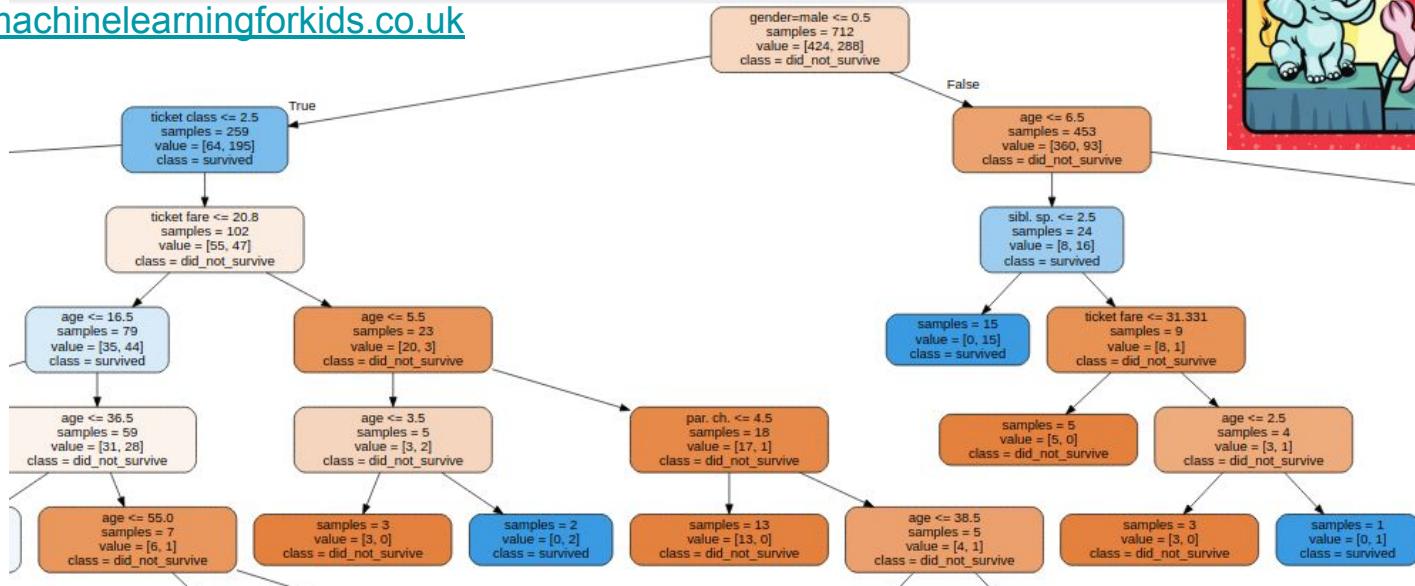
class = prediction so far

Go this way if
the test is true

Go this way if
the test is false



<https://machinelearningforkids.co.uk>



MACHINE
LEARNING
FOR KIDS

A PROJECT-BASED INTRODUCTION
TO ARTIFICIAL INTELLIGENCE

DALE LANE



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

David Touretzky, CMU & Christina Gardner-McCune, UF

<https://ai4k12.org/news/the-state-of-k-12-ai-education-in-your-state-a-planning-workshop/>

January 28-29, 2021

141 Participants

- 27 States
- 3 Territories

15 State Completed Plans (Jan)

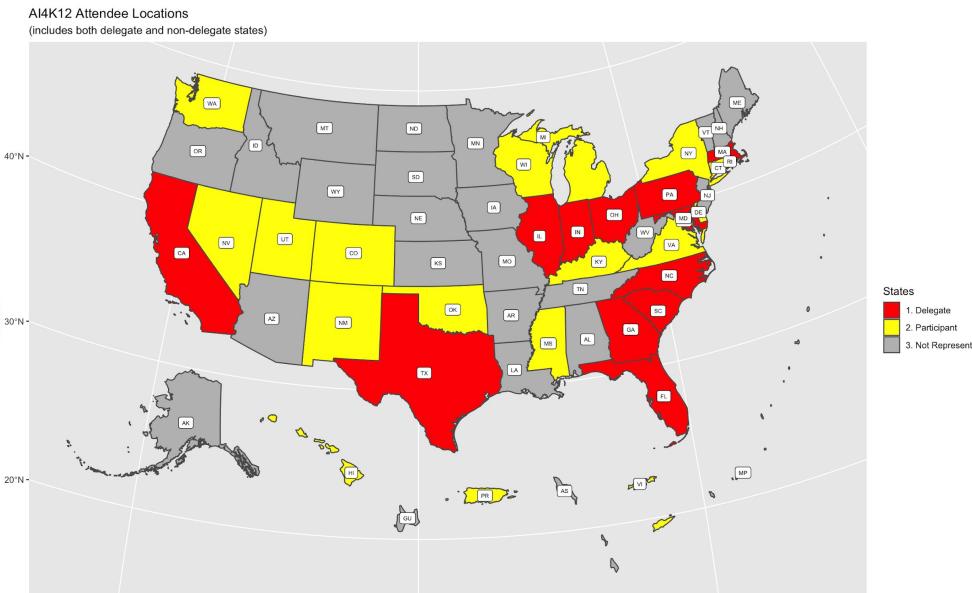
CA, CT, FL, GA, HI, IL, IN, MD, MA, MS, NC, OH, PA, SC, TX,

2 New States & 2 Territories

Completed Plans

NM, VA

Puerto Rico, US Virgin Islands



- 16 States are currently advancing their K-12 AI Implementation Plan
- 5 States developed CTE AI Course frameworks



AI4K12.org

K-12 AI Education Efforts World Wide

- United States: AI4K12.org, MIT RAISE, AI4ALL, ISTE, Code.org, many NSF projects (including our own AI4GA)
- China: government mandate that all students will learn about AI. No national standards yet. Many experiments with curriculum; multiple textbooks.
- South Korea: 2022 revised national curriculum includes AI in all grades K-12.
- United Kingdom: ComputingAtSchool advocating for AI education; teacher PD.
- European Union
 - Erasmus+ funding development of an AI curriculum adapted to European high schools
 - Many small experiments taking place in Germany, Italy, Portugal, Spain, etc.

Join the AI4K12 Community and Help Bring AI Education to K-12!

Visit us:
AI4K12.org

Join the mailing list:
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Acknowledgments

AAAI (Association for the Advancement of Artificial Intelligence)



CSTA (Computer Science Teachers Association)



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