Beyond Computational Thinking: AI Thinking in K-12

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Importance of K-12 Computing Education

Computer science is foundational

Just like they learn about photosynthesis, the digestive system, or electricity.

Every 21st century child should have a chance to learn about algorithms, how to make an app, or how the internet works.
Teaching Computational Thinking

“Computational thinking refers to the thought processes involved in expressing solutions as computational steps or algorithms that can be carried out by a computer.” – from k12cs.org
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

Image from Barefoot Computing, barefootcomputing.org
Importance of K-12 Computing Education

Computer science is fundamental for every student's success

Six different studies show: children who study computer science...

- perform better in other subjects
- excel at problem-solving
- are 17% more likely to attend college

Code.org
Promoting Computing Education in K-12

● CSTA Computer Science Standards released in 2011, revised in 2017
  ○ Officially adopted by some states; recognized by others
  ○ Only two sentences about AI

● NSF funding computing education research through programs such as CS10K, CSforAll, STEM+C, ITEST, etc.


● CSforALL.org: “make high-quality computer science an integral part of the educational experience for all K-12 students and teachers…”
But K-12 Computing Education Is Not Yet Universal

The majority of schools don’t teach computer science

90% of parents want their child to study computer science

47% of high schools teach computer science
Code.org’s 9 policy recommendations to make computer science fundamental to K-12 education

1. Create a state plan for K-12 computer science
2. Define computer science and establish rigorous K-12 computer science standards
3. Allocate funding for rigorous computer science teacher professional learning and course support
4. Implement clear certification pathways for computer science teachers
5. Create programs at institutions of higher education to offer computer science to preservice teachers
6. Establish dedicated computer science positions in state and local education agencies
7. Require that all secondary schools offer computer science with appropriate implementation timelines
8. Allow computer science to satisfy a core graduation requirement
9. Allow computer science to satisfy an admission requirement at institutions of higher education
No State Has Universal CS Education

Massachusetts

20,576
Open computing jobs
(2.1x the state average demand rate)
with an average salary of $105,459

75%
of public high schools teach a CS class

2,908
Computer science graduates

Policy Environment (rubric):

- ✔ Dedicated state funding for CS PD
- ✗ Does not require all high schools to offer CS
- ✔ K-12 CS curriculum standards
No State Has Universal CS Education

Pennsylvania

16,845
Open computing jobs
(2.6x the state average demand rate)
with an average salary of $89,590

59%
of public high schools teach a CS class

4,036
Computer science graduates

Policy Environment (rubric):
- Dedicated state funding for CS PD
- Does not require all high schools to offer CS
- K-12 CS curriculum standards

Code.org
No State Has Universal CS Education
No State Has Universal CS Education

California

79,368
Open computing jobs
(2.0x the state average demand rate)
with an average salary of $115,754

47%
of public high schools teach a CS class

7,311
Computer science graduates

Policy Environment (rubric):

- Dedicated state funding for CS PD
- Does not require all high schools to offer CS
- K-12 CS curriculum standards
No State Has Universal CS Education

Texas

58,981
Open computing jobs
(2.6x the state average demand rate)
with an average salary of $94,779

46%
of public high schools teach a CS class

4,160
Computer science graduates

Policy Environment (rubric):

- Provides funding for high school CS PD but no K-8 funding
- Requires all high schools to offer CS
- 9-12 CS standards exist, but no K-8 standards
No State Has Universal CS Education
Industrial Revolutions (Grossly Oversimplified)

1. Mechanical power
   - Automated manufacturing
   - Self-powered vehicles (trains, steamboats)

2. Electrical power
   - Electric lighting; telegraph, telephone, radio; electromechanical devices

3. Computer power
   - Digital information processing; computer networking; Internet and World Wide Web

4. AI power
   - Computer perception; autonomous robots; automated decision making
   - Machine learning on massive datasets
CS Is Hard Enough. Why Should We Teach AI in K-12?

- AI is the new electricity.

- **Our children are growing up with AI.** By time many children arrive in kindergarten, they’ve spent two years conversing with Alexa.

- We must prepare for the next round of revolutionary disruption:
  - Autonomous robots everywhere.
  - Changing nature of work.
  - Demand for an AI-literate workforce.
  - AI policy issues regarding fairness, privacy/surveillance, disparate impacts of technology, etc.
The AI4K12 Initiative, a joint project of:

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

**CSTA** (Computer Science Teachers Association)

With funding from National Science Foundation ITEST Program (DRL-1846073)
AI4K12 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
Five Big Ideas in AI

1. **Perception**: Computers perceive the world using sensors.

2. **Representation and reasoning**: Agents maintain representations of the world and use them for reasoning.

3. **Learning**: Computers can learn from data.

4. **Natural interaction**: Intelligent agents require many kinds of information to interact naturally with humans.

5. **Societal impact**: AI can impact society in both positive and negative ways.
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 Five Big Ideas**

- Now being referenced by multiple curriculum developers in the US and elsewhere.
- Big ideas poster is available in 16 languages.

<table>
<thead>
<tr>
<th>Language</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Chinese</td>
<td>人工智能的五大理念</td>
</tr>
<tr>
<td>Korean</td>
<td>인공지능에 관한 다양한 가지 빅 아이디어</td>
</tr>
</tbody>
</table>

**Chinese**

### 人工智能的五大理念

#### 1. 感知

计算机的使用渗透日常生活。感知是从物质世界中提取知识的关键。AI技术正在改变我们的工作和生活。

#### 2. 表示与推理

表示语言（符号）是计算机处理的基础。表示方法帮助计算机理解人类智慧的基本组成部分。计算机的表示和推理能力是其智慧的体现。

#### 3. 机器学习

计算机可以从数据中学习。机器学习是一种在计算机中执行模式识别的技术。在这一过程中，机器学习程序会通过反馈和调整来优化其性能。

#### 4. 智能代理

智能代理可以管理各种知识，与人类交互。智能代理必须具备模型和人类交互的基础，识别人类的情感和意图，为人类执行任务。

#### 5. 人际交互

人际交互是人工智能的重要组成部分。人际交互的目的是理解人类行为。

**Korean**

### 인공지능에 관한 다양한 가지 빅 아이디어

#### 1. 인식 (Perception)

인공지능은 실질적이고 신뢰할 수 있는 방식으로 사회에 영향을 끼치고 있습니다. 인공지능 기술이 우리의 일상 생활을 바꾸고 있습니다. 인공지능을 사용하여 사회의 다양한 분야를 활용할 수 있습니다.

#### 2. 표현 & 주도 (Representation & Reasoning)

계산성이 적절한 정보에 적절하게 표현하고 주도할 수 있는 기술을 핵심입니다. 컴퓨터는 정보를 적절하게 표현하고 주도할 수 있습니다.

#### 3. 학습 (Learning)

학습은 인공지능의 핵심 구성요소입니다. 학습은 인공지능의 복잡성을 높이고, 인공지능의 능력을 향상시킵니다.
# 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.

<table>
<thead>
<tr>
<th>Concept</th>
<th>K-2</th>
<th>3-5</th>
<th>6-8</th>
<th>9-12</th>
</tr>
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<tbody>
<tr>
<td>Sensing (Living Things)</td>
<td>LO: Identify human senses and sensory organs.</td>
<td>EU: People experience the world through sight, hearing, touch, taste, and smell.</td>
<td>LO: Use examples of how humans combine information from multiple modalities.</td>
<td>NA - no assessment.</td>
</tr>
<tr>
<td>1-A-1</td>
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</tr>
<tr>
<td>Sensing (Computer Senses)</td>
<td>LO: Locate and identify sensors (cameras, microphones) on computers, phones, robots, and other devices.</td>
<td>EU: Computers &quot;feel&quot; through video cameras and &quot;hear&quot; through microphones.</td>
<td>LO: Give examples of how intelligent agents combine information from many sensors.</td>
<td>NA - no assessment.</td>
</tr>
<tr>
<td>1-A-2</td>
<td></td>
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</tr>
<tr>
<td>Sensing (Digital Encoding)</td>
<td>LO: Explain how images are represented digitally in a computer.</td>
<td>EU: Images are encoded as 2D arrays of pixels, where each pixel is a number indicating the brightness of that point of the image.</td>
<td>LO: Explain how sounds are represented digitally in a computer.</td>
<td>NA - no assessment.</td>
</tr>
<tr>
<td>1-A-3</td>
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**V.0.1 - Released May 28, 2020**

**Subject to change based on public feedback**
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.
What Does AI Thinking Look like in K-12?
Computational Thinking

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

AI Thinking

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

Computers can see:

- Faces
- Household objects
- Road scenes

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

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

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

- Pixels
- Edges
- Contours
- Boundaries
- Textures
- Shadows
- Surfaces
- Parts
- Objects
- Scenes
Neural Net Edge and Face Detection Demo

Real-time face detection by a deep neural network (TinyYoloV2)

https://www.cs.cmu.edu/~dst/FaceDemo
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.

Waveform

Spectrogram

Sounds (Phonology)

Stems + Affixes (Morphology)

Grammar (Syntax)

Meaning (Semantics)

/ʌnfərɡətəbl/  
un + forget + able

site/sight

(NP (ADJ “unforgettable”) (N “site”/“sight”))

“unforgettable sight”
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.
rules

perception

speech recognition

world map
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)
Reasoning

Types of reasoning problems:

- Classification: cat or dog?

- Search: find a path to a goal state.

- Many other types, including regression, optimization, sequential decision making, logical deduction, Bayesian inference, etc.

I can build a classifier.

I can build a reasoner.
Reasoning Algorithms

There are algorithms for each type of reasoning problem.

- **Classifiers**
  - Decision trees
  - Neural networks
  - Nearest neighbor

- **Search algorithms**
  - Breadth-first, depth-first, best-first, heuristic search, etc.
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
The Importance of Training Data

- Goal: generalize correctly to new instances
- The dataset needs to be representative
- Effects of biased training data

Language Understanding

- Question answering: “How much does an alligator weigh?”
- Machine translation
- Chatbots and intelligent agents
  - Intent recognition
  - Slot filling

I can build a simple chatbot.

Work by Jessica Van Brummelen and Hal Abelson
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.
Moving Forward
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 State & Territories Completed Plans
NM, VA
Puerto Rico, Virgin Islands

- 16 States are currently advancing their K-12 AI Implementation Plan
- 5 States developed CTE AI Course frameworks
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 Us in Developing the Guidelines, or Help Grow the Community of AI Resource Developers

Visit us:
https://AI4K12.org

Join the mailing list:
https://aaai.org/Organization/mailing-lists.php
Thank You!

Questions?