How Does AI Win At Tic–Tac–Toe?

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TEACHER

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SUBJECT/GRADE LEVEL

Subject
Middle / High School
Mathematics / Computer Science

Materials

- Internet Access
- Sticky Poster Paper

STANDARDS

Next Generation Science Standards

- HS-ETS1-2 Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
- HS-ETS1-4 Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Mathematics Standards | Common Core State Standards

- Find the conditional probability of A given B as the fraction of B's outcomes that also belong to A, and interpret the answer in terms of the model. (HSS.CP.B.6)
- Analyze decisions and strategies using probability concepts (e.g., product testing, medical testing, pulling a hockey goalie at the end of a game). (HSS.MD.B.7)

English Language Arts Standards | Common Core State

- Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. (RST.6-8.3 / RST.9-10.3 /RST.11-12.3)
- Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 6-8 / 9-10 / 11-12* texts and topics. (RST.6-8.4, RST.9-10.4, RST.11-12.4)

LESSON OBJECTIVE(S)

Students articulate the underlying principles of how AI (artificial intelligence) works by writing the pseudocode that accurately represents how AI would learn to win Tic-Tac-Toe and demonstrating that the AI involved in Tic-Tac-Toe can be adapted to play Connect 4.

CAREER CONNECTION(S)

Mentor Background: Erin Zaroukian, Ph.D., works as a cognitive scientist for the Army Research Laboratory. Her research involves using machine learning techniques to design artificial intelligence agents that can optimally collaborate with human teammates (e.g. unmanned vehicles, artificial intelligence that records the interactions of human teammates, and applications that can promptly translate text from a foreign language to English).

STEM Careers: This article from *Best Colleges* gives an overview of the huge, ever-increasing demand for people qualified to work artificial intelligence jobs in fields such as machine learning engineering, robotics engineering, and data science. The article also explains what kind of coursework a person interested in an AI-related career should expect to go through.

ENGAGEMENT

Teacher Actions:
1. Begin demonstration by asking students, "Does anyone think they can beat a sheet of paper in a game of Tic-Tac-Toe?" Choose one student to play Tic-Tac-Toe on the board with a 3x3 grid set up on it, and hand another student a set of rules on a sheet of paper for him / her to use to mark moves against the other player.

2. After the demonstration stimulate a quick discussion about AI by asking if the paper had any intelligence, and then quickly use this teachable moment to introduce AI. (It might be a good idea to have students brainstorm on sticky notes or a poster what they think AI is, and maybe even what they think it is not, before telling them the formal definition of AI)

Student Actions:
1. Participate or view demonstrations. 2. Participate in discussion

EXPLORATION

Teacher Actions:
1. Ask students to pair up and play Tic-Tac-Toe.

2. Students should identify strategies that win and place those strategies on Flipgrid for all to view. If Flipgrid is not available strategies can be placed on sticky poster paper and viewed as a gallery walk.

Additionally, students may view this video titled "The Math behind Winning at Tic Tac Toe/ Naughts and Crosses"to highlight the best Tic-Tac-Toe moves from a mathematical standpoint.

Student Actions:
1. Students should play Tic-Tac-Toe to identify the winning strategies.

2. Students should compile a list of strategies on Flipgrid or poster paper, and then compare newly found strategies with other groups. (A template such as this one, which can be used to list the pros and cons of each strategy, might prove useful)

3. After comparing a comprehensive class list of best strategies, the strategies will be compiled and used later in the lesson to write pseudocode.

EXPLANATION

Teacher Actions:
Direct instruction involving a discussion of AI these Google Slides. The slides included explanations of key concepts such as "If… then…" statements and reinforcement learning. Check for understanding with this Quizizz.

Student Actions:
1. Actively complete guided notes
2. Actively complete AI Quizizz

ELABORATION

Teacher Actions:
1. Tell students, "You will now write pseudocode that captures the key elements of real code that would be used to create a Tic-Tac-Toe game. Make a Google document that you can easily find, share with me, and edit at any time."
   - Describe the assignment like how an English would describe how to make an outline for an essay; what is important is that students can make an "outline" for code that accurately captures the logical "flow" needed to ensure the AI can play Tic-Tac-Toe well.
   - Tell students to use "If… then…" as well as "Else" statements in their pseudocode (e.g. if the first X is placed in a corner and the first O is placed in locations B, D, F, or H then place the second X in location A, C, G, or I to maximize chances of winning).
   - For struggling students, it might be a good idea to give them a printout of sample authentic code like from this website, then instruct them to explain in their own words what every five or so lines of code does to contribute to making the program run properly.

Student Actions:
As alluded to above, students either write their own pseudocode for Tic-Tac-Toe, or they are given actual code and must explain in their own words why the code works. The assignment is submitted for a grade.

EVALUATION

Teacher Actions:
Review the key concepts involved with programming artificial intelligence to play Tic - Tac - Toe (reinforcement learning, If… then… statements, etc.) using materials used earlier in the lesson (Google Slides, Quizizz, etc.) or your own self-made materials.

As a summative assessment of their learning, task students with writing pseudocode for Connect 4 on a Google Document.

- This should make for an excellent extension because Connect 4 is essentially a more complicated version of Tic-Tac-Toe.

Differentiated Learning: If students do not yet feel comfortable with writing pseudocode for Connect 4, guide students into the assignment by having them engage in a strategy comparison activity (e.g. gallery walk) like what they did in the Exploration Stage. They can also be shown a video such as this one.

Student Actions:
Students participate in the review of the underlying concepts.

Students complete the Connect 4 pseudocode assignment for a grade.

REFERENCES

Agrawal, R. (2018, December 15). *Playing Games with Python-Part 1: Tic Tac Toe*. Retrieved from https://towardsdatascience.com/lets-beat-games-using-a-bunch-of-code-part-1-tic-tac-toe-1543e981fec1

Eric Buffington. (2017, April 28). *The Math behind Winning at Tic Tac Toe/ Naughts and Crosses* [Video file]. Retrieved from https://www.youtube.com/watch?v=g0kasQaqgro

Keith Galli. (2016, December 27). *How to win at Connect 4 almost every time!* [Video file]. Retrieved from https://www.youtube.com/watch?v=3R1Cx6uGjMw