Teacher Guide

Engineering Tomorrow

Algorithms & AI: Applied Machine Learning with Catapults

SUGGESTED LESSON PLAN - 50 minute periods	
Total Time ~90-120 minutes • 35 minutes to watch the lab introduction video • 30-45 minutes for students to design, build and test their catapult. • 15-20 minutes for students to analyze their data and apply their predictions to the problems in their workbook or worksheet. • 10-20 minutes for a closing activity or discussion Optional Extension Activities • 0-10 minutes Google Teachable Machine (Optional Activity #1) • 0-20 minutes TensorFlow (Optional Activity #2) *(Note: An optional 30-45 minutes can be scheduled to do a Wrap-Up and QA with an Engineer and College Mentor at Teacher's discretion).*	
Hook/Essential Question	How do machine learning models like ChatGPT learn from their users?
Supplies to Have in Class	ET Algorithms & AI Kit materials can be found at the end of this file. Standard household/classroom materials should work for catapult construction. Additional Items to Consider Having on Hand: • Additional Popsicle sticks (structure) • Cotton balls (as an alternate projectile to limit bounce) • Plastic spoons (basket) • Tape measure or yardstick to measure distance for gathering data
Optional Pre-Work	Have students watch the first 21 minutes of the intro video providing the background for the challenge and answer the questions through slide 6 of the student workbook.
Class #1 Introduction, Research, and Design	Watch the Engineering Tomorrow: Algorithms & AI Intro Recording on the Algorithms & AI webpage either as a class or assign background section as pre-work (see above). ➔ Have students answer the questions in the first 6 slides of the student workbook ➔ Watch the rest of the video that outlines the instructions for the challenge. Students begin to design their catapult→ research designs, review materials, generate an initial design concept and describe in their workbook (slides 1-13) or worksheet *(1 workbook or worksheet per team suggested)*

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Class #2 Building, Testing, and Analyzing	➔ Students build their initial design ➔ Students test their design and document catapult performance data ➔ Students use Google Sheets or Microsoft Excel to analyze the data they recorded ➔ Students use the analysis they just performed to complete their workbook or worksheet
Part of Class #3 Possible Closing Questions and Activities	*Students may not have completed the analysis of their data or their workbook/worksheet. Data analysis and subsequent notebook completion could be moved to a third class period, followed by a thought provoking question and group discussion* Class Discussion Question: How do ethical considerations impact the development and deployment of machine learning models and AI systems? Machine learning and AI systems, while beneficial, can perpetuate biases, lack transparency, and raise privacy concerns. These issues highlight the importance of developing ethical AI practices to ensure fairness, accountability, and respect for privacy.

INTRODUCTION TO ENGINEERING TOMORROW:

- Click here to see an introduction of what Engineering Tomorrow can do for your students.

INTRODUCTION TO THE ENGINEERING DESIGN PROCESS:

- Students should complete the Engineering Design Process Introduction Activity before starting the lab
  - NOTE: This activity only needs to be completed before the student's **first** ET lab, not repeated for every lab.

TEACHER NOTES:

- Students will work through the Algorithms and AI Student Workbook or Abbreviated Student Worksheet.
  - When assigning this lesson on Google Classroom, first make a copy of the slides to save within your Google Drive, then assign so that each student has their own copy.
  - The workbook and worksheet are designed to be interactive so that students can type directly into the files. It is suggested that the workbook or worksheet be completed over a few class periods (as the information is delivered to students).
  - Students may work individually or within groups (at the discretion of the instructor).

ASSESSMENT:

- Informal assessments can be completed by looking at the reflection slides within the Student Workbook and/or the discussion questions in the Abbreviated Worksheet.

- **Answer Keys** can be found here for:
  - Abbreviated Worksheet Answer Key
  - Student Workbook Answer Key

OPTIONAL EXTENSION ACTIVITY #1:

Create an AI sorter using Google's Teachable Machine

- Students will decide on two classes (or categories) of items they want to identify and sort. Students upload pictures to provide the machine data for classifying the objects.
- [Note - the 'train' function is similar to short videos that provide multiple pictures of an object].
- Once the computer is "trained", the students will test the computer's ability to sort various objects. Students will also calculate the machine's efficiency based on the number of correct answers and the number of trials completed.

OPTIONAL EXTENSION ACTIVITY #2:

Explore a simple neural network using TensorFlow Playground, a free, open-source software simulation that gives students a chance to tinker with a real machine learning program.

- Students will see the connections between the catapult challenge they just completed and the machine learning algorithm used in the Playground
- Students will adjust the number of Features and the number of Neurons to build a simple neural network capable of classifying data consisting of colored dots
- Students will record the error loss for their neural network model for each of the four data sets built into the TensorFlow Playground simulation.

OTHER EXTENSION ACTIVITIES:

- Watch the video to learn more about the physics of catapults
- Read this article to learn about machine learning and artificial intelligence

ADDITIONAL TEACHING RESOURCES:

Curriculum Connections:

- Physics: 2D-Motion; Projectile Motion
- Freshman Computing: Predictive Analysis; Using computers to analyze data and make predictions based on patterns and relationships
- Statistics: Plotting Trendlines; Modeling based on sample data

Students will be able to:

- Define machine learning and provide real world applications for where it is used.
- Describe the engineering design process and apply it to the design and construction of a catapult.
- Develop a mathematical model that describes the performance of the catapult.
- Create an algorithm based on the performance analysis of the catapult.

Content Vocabulary/Terms:

- Machine Learning: a type of artificial intelligence that allows computers to learn from and make predictions based on data without being explicitly programmed
- Mathematical Model: a representation of a system using mathematical concepts and language to describe and predict its behavior

- Factor: an independent variable that is manipulated or controlled in an experiment to observe its effect on the response

- Response: the dependent variable that represents the outcome or effect measured in an experiment as a result of changing the factor

ENGINEERING DESIGN STANDARDS:

- ***Next Generation Science Standards:***

  HS-ETS1-3 Engineering Design: Evaluate a solution to a complex problem based on prioritized criteria and trade-offs that account for a range of constraints.

  HS-PS3-3 Energy: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

- ***Computer Science Standards:***

  3A-AP-13: Create prototypes that use algorithms to solve computational problems by leveraging prior student knowledge and personal interests.

  3B-AP-08: Describe how artificial intelligence drives many software and physical systems.

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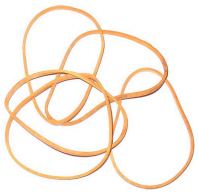
KIT MATERIALS: 1 kit per 3 students

Kit Item	Photo	Link (if applicable)
50 x Popsicle Sticks		link
20 x Rubber Bands		link
3 x Ping Pong Balls		link
1 x Measuring Tape		link
Masking Tape/ Duct Tape	 	link

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`UTILITY KIT: 1 utility kit per 10 students`

Kit Item	Photo	Link (if applicable)
1 x Hot Glue Gun + 3 x Hot Glue Sticks		link
1 x Ruler		link
1 x Permanent Marker		link
1 x Scissors		link