Engineering Lab: AI Object Detection with Raspberry Pi

Teacher: Joel Bianchi	**Date**:
Class Type: Engineering	**Grade**: 9-12
Time Frame: 2 90-minute blocks	

Lesson Overview

Unit/ Overarching Focus of Lesson:

- Use AI and physical computing to solve a real-world problem through a senior design project

Objectives/Aims: Students will demonstrate understanding/learning around the following Big Ideas:

- Identify and define a real-world problem that can be addressed using AI object detection.
- Acquire and utilize a pre-trained or custom-trained AI model (YOLO).
- Run AI detection models on a Raspberry Pi for "edge" computing.
- Integrate electronics (lights, sound, motion) to create a physical computing response based on AI output.
- Document and present their final project, including design decisions and Python code.

Aligned Standards

(New York State Standards):

- 3.4 *Students use an engineering design process to develop a solution to a problem.*
- 5.5 *Students use the skills and knowledge of technology and engineering to design, construct, and test a variety of technological products.*

(Next Gen Science Standards):

- *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.*

(Common Core State Standards):

- *CCSS.ELA-LITERACY.RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.*
- *CCSS.ELA-LITERACY.RST.11-12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.*

Key Vocabulary and Concepts:

- AI Neural Network: A computational model inspired by the human brain that can learn from data.
- YOLO (You Only Look Once): A real-time object detection model known for its speed and accuracy.
- Raspberry Pi: A small, low-cost computer used for physical computing and "edge" computing.
- Physical Computing: The use of technology to create systems that can interact with the physical world.
- GPIO (General Purpose Input/Output): The pins on a Raspberry Pi used to connect and control electronic components.
- Python: The programming language used to run the AI model and control the electronics.

Materials & Resources:

- Raspberry Pi 4/5 kits (one per group)
- SD cards pre-imaged with Raspberry Pi OS

- Monitors, keyboards, mice, power supplies, HDMI adapters
- USB cameras
- Electronic components: LEDs, servo motors, speakers, jumper wires, breadboards
- Pre-trained YOLO models (.pt files)
- Online resources: Hugging Face, Roboflow

Safety Practices:
- Standard lab safety practices when handling electronics and wiring.
- Proper handling of power supplies.

Preparation for Teaching Diverse Students:
- Students will be provided with a guided notes sheet
- New vocabulary will be highlighted and translated

Cultural context within which the lesson will be grounded, and specific ideas/practices to be included in the lesson:
- Students are encouraged to choose a project that is personally relevant to them or their community.
- Integrate brain science concepts like neuroplasticity and growth mindset to motivate students.
- Use "brain breaks" to help students stay engaged.

Prior Knowledge:
- Experience with basic electronics and wiring.
- Familiarity with simple coding (e.g., Arduino).
- Experience with project design.

Prior Lesson:	**Followup Lesson:**
• Introduction to AI Neural Networks	• Testing and optimization of the final AI model

Lesson Overview/ Abstract:
- This four-day lab sequence guides students through the process of designing and building a senior design project that uses AI object detection on a Raspberry Pi. Students will learn about AI models, physical computing, and the engineering design process as they create a project that responds to real-world inputs.

DAY 1 Lesson Activities		
Time	**Activities**	**Materials**
5	**Warmup:** In groups, brainstorm: “What are objects at home, in school, or on the street that you would want to identify or count?”	
15	**Project Hook/ Demo:** Show off example of completed lab exercise. • WATER BOTTLE DETECTION: “Did anyone bring a water bottle today? Put it on your desk” Have AI water bottle detector display number with lights of how many detected • HAND RAISING DETECTION: “Raise your hand if you’ve ever raised your hand and the teacher didn’t see it?” Have AI hand-raising detector show count and then the motor raises a hand.	RPI AI project setup with LED Strip and Servo motor • WaterBottleDetector Python Script • Hand Raising Detection Python Script • RPI shell files to run scripts (bottles, hands)

15	**Project Intro Discussion:** Introduce the overall project design, explaining the "Input, Process, Output" model. Discuss the role of the Raspberry Pi and the AI model	Teacher Slides
25	**Acquire AI model Activity:** Students choose their AI model and objects to detect: ● Option 1: YOLO model pre-trained to identify objects on COCO dataset ● Option 2: YOLO-gestures model pre-trained to identify specific body parts of identified persons ● Option 3: Use a YOLO-based model found on Huggingface for object detection beyond the COCO dataset ○ Go to HuggingFace > Search for YOLO > See all models > Select an interesting model > Files > Look for. PT file > Upload .PT file to RPi ○ Example model: https://huggingface.co/keremberke/yolov8n-pokemon-classification	Computers, internet
30	**Practice Usage of AI model Activity:** Students use a teacher-provided Python Notebook to run the AI model from a webcam	Python notebook file USB Camera on Computer
DAY 2 Lesson Activities		
Time	**Activities**	**Materials**
10	**Intro to Raspberry Pi Discussion:** ● Explain why use RPi: ○ Better than regular computer (portability, electronics usage ○ Better than Arduino (processor capable of running AI models) ● Introduce parts of RPi	Teacher Slides
20	**RPI Setup Activity:** Students set up the Raspberry Pi hardware, install necessary Python packages, and run basic AI detection model ● Pre-setup SD card images (Download OS, Image Cards) ● Connect to room internet ● Monitor, Power, HDMI, HDMI adapter, keyboard, mouse, Camera	Raspberry Pi kits, SD cards, monitors, keyboards, mice RPi Setup Guide
10	**Electronics Setup Activity:** ● Prompt groups to make choice for electronics response: ○ MOTION: Servo Motor ○ LIGHT: LED Strip ○ SOUND: Speakers ● Show RPi pinout to students (Recommend pins to use for specific components)	Electronic components, jumper wires, breadboards

	• Students add a servo motor, LED light strip, or other electronics components to their RPi	

10	**Python code generation with AI:**
	• How to prompt AI to write code
	  ○ Start with provided AI code from teacher
	  ○ Feed to AI (Google Gemini or ChatGPT) to include new features
	  ○ Use detailed terminology and pseudocode in creating python script
	• Make sure students install required python packages (ie. lightstrip needs Blinka)
	• Teacher notes:
	  ○ Check for skills in using RPi web browser (slightly different OS than students typically use)
	  ○ Check for skills in using copy & paste in the RPi environment	

30	**Test & Optimize the AI Model**
	• Student groups test out AI projects
	• Teacher prompts group to consider:
	  ○ How does the model perform?
	  ○ Is it accurately detecting objects?
	  ○ Is it responding quickly enough?
	• Teacher highlights the following with groups individually:
	  ○ Speed and accuracy are key AI model considerations.
	  ○ Faster models may sacrifice some detection accuracy.
	  ○ Higher accuracy can lead to slower processing times.
	  ○ Choose the best balance for your project needs.
	• Students tweak python code to get better performance from AI model
	• Teacher Notes:
	  ○ Use PT for training (does backpropagation)
	  ○ Use NCNN instead for usage (much faster)
	  ○ YOLO models increase in size from s<m<n<l<x
	  ○ Increased YOLO model sizes will run slower	

5	**Submission** • Take video of working project • Submit design docs	Google Classroom
5	**Demo** • Each group shares (1 minute each) their project	

Lesson Assessments
Follow-Up Assignment:

- Create a video showing a working demo of the project.
- Submit design documents, including all Python code.

Additional Accommodations for Students:

- Provide pre-imaged microSD cards to save time and address potential technical challenges.
- Use provided starter code to scaffold the coding process.

Methods of Assessment:

- Formative Assessments:
  - Teacher observation during each lab activity, checks for understanding during discussions.
- Summative Assessments:
  - Final project video demonstration and submitted design documents
  - Group project rubric submission