The University of Texas
Rio Grande Valley

University Transportation Center for Railway Safety (UTCRS)

NSF CREST Center for Multidisciplinary Research Excellence in Cyber-Physical Infrastructure Systems (MECIS)

HIGH SCHOOL STEM CURRICULUM

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Learning Objectives

Day 1

Activity #1: Team Building – Logic Labyrinth Challenge
The students will be able to …

1. demonstrate the importance of effective teamwork and communication skills when working in interdisciplinary teams, and
2. collaborate by working as a team to solve a maze challenge through programming and logic.

Activity #2: Introduction to Variables
The students will be able to **…**

1. recognize how to name variables correctly using Python,
2. assign values to variables within their Python programming language, and
3. manipulate variables following instructions on the Further website.

Activity #3: Understanding Logic
The students will be able to …

1. create complex algorithms to solve advanced programming problems using logical, conditional, and relational statements, and
2. simplify repetitive tasks using programming loops.

Activity #4: Programming Hardware (Traffic Lights)
The students will be able to …

1. define functions with the Further website,
2. model a traffic light implementing various hardware with the pi-top [4] robotic kit, and
3. modify a function to process multiple events simultaneously using event handling.

Day 2

Activity #1: Understanding the Sensors
The students will be able to …

1. apply the Python programming language to understand how a photoresistor senses light, how the sound sensor detects sound, and how the ultrasonic sensor calculates the distance to the nearest object.

Activity #2: Simulating a Railroad Intersection (Active Sign Creation)
The students will be able to …

1. recognize the passive and active signs present at every railroad crossing,
2. integrate servo motors to create traffic gates, and
3. develop a code to build and design a railroad crossing.

Activity #3: Rover Build and Navigation

The students will be able to …

1. construct the basic design of the "Alex" robot by working in teams to build the necessary parts for the robot, and
2. develop a code that allows the robot to follow forward, left, and right commands.

Day 3

Activity #1: Rover Speed and Rotation

The students will be able to …

1. determine the speed of the robot using the acquired data, and
2. produce a programming code that pilots their robot to allow different turning angles.

Activity #2: Rover Race

The students will be able to …

1. understand the limitations of iterative statements from the Further website, and
2. apply the engineering design process to customize their controls and robot functions.

Activity #3: Line Follower (Rover Vision)

The students will be able to …

1. integrate a program to use a camera with their pi-top [4] and display it on the Further website,
2. use pre-defined functions to create a line follower program, and
3. recognize key terms, such as kernels, centroids, and masks, which are used for image processing.

Day 4

Activity #1: Collision Simulation

The students will be able to …

1. understand the relationship between force and energy through experimentation, and
2. create a work versus time graph that represents power from the collected data.

Activity #2: Forklift Assembly Challenge

The students will be able to …

1. design and build a forklift for their robot to pick up/drop off a wheel-axle assembly, and
2. create a program for their robot to approach, pick up, and drop off a wheel-axle assembly.

Day 5

Activity #1: Final Challenge

The students will be able to …

1. modify an operator code for their robot to pick up and drop off objects,
2. modify an operator code for their robot to drive utilizing the servo motors,

3. rewrite the program code for their robot to incorporate a camera to remotely drive their robot, and
4. interpret the limitations of hardware and wireless communication based on their performance and experience from this final challenge.

**Please note that these learning objectives may vary depending on the specific implementation of the curriculum.

** Note that some learning objectives may be repeated across activities that build upon each other to help students develop a deeper understanding of engineering concepts and principles.

Texas Essential Knowledge and Skills (TEKS)

SCIENCE TEKS

2021 Texas Essential Knowledge and Skills for Physics

Physics	
Process Standards	
P.P.1	asks questions, identifies problems, and plans and safely conducts classroom, laboratory, and field investigations to answer questions, explain phenomena, or design solutions using appropriate tools and models. P.1(B) apply scientific practices to plan and conduct descriptive, comparative, and experimental investigations and use engineering practices to design solutions to problems
P.P.2	analyzes and interprets data to derive meaning, identify features and patterns, and discover relationships or correlations to develop evidence-based arguments or evaluate designs. P.2(D) evaluate experimental and engineering designs
Readiness and Supporting Standards	
P.5(A)	analyze different types of motion by generating and interpreting position versus time, velocity versus time, and acceleration versus time using hand graphing and real time technology such as motion detectors, photogates, or digital applications
P.5(B)	define scalar and vector quantities related to one- and two-dimensional motion and combine vectors using both graphical vector addition and the Pythagorean theorem
P.5(D)	describe and analyze acceleration in uniform circular and horizontal projectile motion in two dimensions using equations
P.5(E)	explain and apply the concepts of equilibrium and inertia as represented by Newton's first law of motion using relevant real-world examples such as rockets, satellites, and automobile safety devices
P.5(F)	calculate the effect of forces on objects, including tension, friction, normal, gravity, centripetal, and applied forces, using free body diagrams and the relationship between force and acceleration as represented by Newton's second law of motion
P.5(G)	illustrate and analyze the simultaneous forces between two objects as represented in
P.6(B)	identify and describe examples of electric and magnetic forces and fields in everyday life such as generators, motors, and transformers

P.6(D)	analyze, design, and construct series and parallel circuits using schematics and materials such as switches, wires, resistors, lightbulbs, batteries, voltmeters, and ammeters
P.7(A)	calculate and explain work and power in one dimension and identify when work is and is not being done by or on a system
P.7(D)	calculate and describe the impulse and momentum of objects in physical systems such as automobile safety features, athletics, and rockets
P.8(E)	compare the different applications of the electromagnetic spectrum, including radio telescopes, microwaves, and x-rays

MATH TEKS

2012 Texas Essential Knowledge and Skills for Algebra [A] / Algebra2 [2A] / Geometry [G]

Content and Process Standards	
2A.P.1(A) G.P.1(A)	apply mathematics to problems arising in everyday life, society, and the workplace
A.P.1(B) 2A.P.1(B) G.P.1(B)	use a problem-solving model that incorporates analyzing given information, formulating a plan or strategy, determining a solution, justifying the solution, and evaluating the problem-solving process and the reasonableness of the solution
A.P.1(C) 2A.P.1(C) G.P.1(C)	select tools, including real objects, manipulatives, paper and pencil, and technology as appropriate, and techniques, including mental math, estimation, and number sense as appropriate, to solve problems
A.P.1(D)	communicate mathematical ideas, reasoning, and their implications using multiple representations including symbols, diagrams, graphs, and language as appropriate
A.P.1(G)	display, explain, and justify mathematical ideas and arguments using precise mathematical language in written or oral communication
Readiness and Supporting Standards	
Algebra 1[A]	
A.2(A)	determine the domain and range of a linear function in mathematical problems; determine reasonable domain and range values for real-world situations, both continuous and discrete; and represent domain and range using inequalities
A.12(B)	evaluate functions, expressed in function notation, given one or more elements in their domains
A.12(C)	identify terms of arithmetic and geometric sequences when the sequences are given in function form using recursive processes
Algebra 2 [2A]	
2A.3(B)	solve systems of three linear equations in three variables by using Gaussian elimination, technology with matrices, and substitution
2A.7(I)	write the domain and range of a function in interval notation, inequalities, and set notation
2A.8(C)	predict and make decisions and critical judgments from a given set of data using linear, quadratic, and exponential models
Geometry [G]	
G.4(A)	distinguish between undefined terms, definitions, postulates, conjectures, and theorems

G.4(B)	identify and determine the validity of the converse, inverse, contrapositive of a conditional statement and recognize the connection between a biconditional statement and a true conditional statement with a true converse
G.4(C)	verify that a conjecture is false using a counterexample
G.9(B)	apply the relationships in special right triangles 30°-60°-90° and 45°-45°-90° and the Pythagorean theorem, including Pythagorean triples, to solve problems

2017 Next Generation Science Standards 9-12

HS-PS2-1	Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
HS-PS3-3	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
HS-PS4-1	Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.
HS-PS4-5	Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

International Technology and Engineering Educator Association (ITEEA) Standards

STEL-1N	Explain how the world around them guides technological development and engineering design.
STEL-2T	Demonstrate the use of conceptual, graphical, virtual, mathematical, and physical modeling to identify conflicting considerations before the entire system is developed and to aid in design decision making.
STEL-2Z	Use management processes in planning, organizing, and controlling work.
STEL-3H	Analyze how technology transfer occurs when a user applies an existing innovation developed for one function to a different purpose.
STEL-4P	Evaluate ways that technology can impact individuals, society, and the environment.
STEL-5H	Evaluate a technological innovation that arose from a specific society's unique need or want.
STEL-6F	Relate how technological development has been evolutionary, often the result of a series of refinements to basic inventions or technological knowledge.
STEL-7Y	Optimize a design by addressing desired qualities within criteria and constraints.
STEL-8P	Apply appropriate methods to diagnose, adjust, and repair systems to ensure precise, safe, and proper functionality.

Day 1: Introduction to Python

Day Overview: The students will gain an understanding of how engineers collaborate in teams to achieve common goals. Students will be introduced to the Python Language basics of variables and functions while learning to program with LED lights, buzzers, buttons, and other pi-top [4] accessories. Students will use logic statements to create program loops.

Activity #1: Team Building – Logic Labyrinth Challenge

Lesson Overview: Students will engage in a team building exercise using several logical functions to gain experience of "coding and acting like a computer to solve a maze challenge".

Estimated Time: 50 – 60 minutes

Learning Objectives:
The students will be able to …

3. demonstrate the importance of effective teamwork and communication skills when working in interdisciplinary teams, and
4. collaborate by working as a team to solve a maze challenge through programming and logic.

MATH TEKS:

1. A.P.1(B)

NGSS: N/A

Technology Standards:

1. STEL-2Z

Materials Needed: (per class)

1. Obstacle Course
2. Blindfold
3. Timer

Lesson Flow:

1. Prep Work: Create a maze with various pathways. Mazes can be created using tape on the floor or using chairs as a physical barrier. Keeping the maze a secret from students will increase the level of difficulty.
2. Divide students into groups of 3-4: One teammate will act as the "computer" and will follow all directions provided by the "programmers" to navigate through the maze without colliding with any obstacles. The remainder of the teammates will be the "programmers" and will devise an "algorithm" with the provided statements to get the computer through the maze without incident (i.e., collision).

3. Guide the students to the start of the maze. Blindfold the “computer” teammate and give the programmers one minute to devise an algorithm.
4. Start the timer when the programmers begin giving instructions to the computer. If the computer collides with any barrier, or deviates from the maze outline, add a 5 second penalty to the overall time for each infraction.
5. Record each team's performance based on maze completion time and number of collisions with obstacles. Add the time penalties to the completion time and the fastest overall time wins. Reflection questions can be used to engage the students in critical thinking and have them answer as a group (team).

Use the following reflection questions and have students discuss and then answer within their group:

1. What was challenging? How did you deal with those challenges?
2. Now that you have completed the challenge, what could you have done differently to improve your results?
3. How important was effective communication with your team? What did it affect?

Activity #2: Introduction to Variables

Lesson Overview: Students will be introduced to the Python programming language where they will learn about variables, their naming conventions, and how to use them in coding.

Estimated Time: 90 minutes

Learning Objectives:
The students will be able to **…**

1. recognize how to name variables correctly using Python,
2. assign values to variables within their Python programming language, and
3. manipulate variables following instructions on the Further website.

SCIENCE TEKS:

1. P.P.2

MATH TEKS:

1. A.P.1(G)
2. A.12(B)

NGSS: N/A

Technology Standards:

1. STEL-6F

Materials Needed: (per group)

1. Pi-top [4] Robotics Kit

2. Laptop with Internet Access
3. LED Lights

Lesson Flow:

1. Teacher will show students how to turn on the pi-top [4] and connect it to a smart device (Recommended: laptop with access to internet and Further lessons; Alternative: iPad/Tablet). See Teacher Note 1.
2. Connect the LEDs to the device.
3. Sign up for an account on https://www.further.pi-top.com on the device web browser.
4. On your dashboard, add a class using the join code provided to gain access to the "2024 UTCRS Summer Camps" class. (Use join code: 4FVZV8K73F).
5. Open the lesson entitled "Intro to Variables".
6. Connect the pi-top [4] to the Further website by typing the pi-top [4] IP address and pressing the connect button.
7. Provide the students with instructions and guide them through the lesson.

Use the following reflection questions and have students discuss and then answer within their group:

1. Why should programmers be specific when writing code?
2. How can we teach a computer what an LED is, and what port should be provided power?

Activity #3: Understanding Logic

Lesson Overview: Students will learn to implement logic statements such as "not, and, or" operators to create higher-complexity algorithms. They will also use logical statements such as "true" and "false" and relational operators like "less than" and "greater than" to understand how to iterate through loops to simplify repetitive tasks.

Estimated Time: 30 minutes

Learning Objectives:

The students will be able to …

1. create complex algorithms to solve advanced programming problems using logical, conditional, and relational statements, and
2. simplify repetitive tasks using programming loops.

SCIENCE TEKS:

1. P.P.1
2. P.P.2

MATH TEKS:

1. A.2(A)
2. A.12(C)
3. 2A.7(I)

4. 2A.3(B)
5. G.4(A)
6. G.4(B)

NGSS: N/A

Technology Standards:
1. STEL-7Y

Materials Needed: (per group)
1. Pi-top [4] Robotics Kit
2. Laptop with Internet Access

Lesson Flow:
1. Open Further website and navigate to the "2024 UTCRS Summer Camps" class and open the "Understanding Logic" course.
2. Open the "If statements" lesson.
3. Go through the Further lesson and help explain the topic as the students work through it.
4. Next, open the "Loops" lesson and repeat step 3.

Use the following reflection questions and have students discuss and then answer within their group:
1. What is an "if statement" and why is it used in programming?
2. Describe what happens when a computer decides that a condition is met versus if it is not met.
3. What are the different types of loops when it comes to programming? How do they differ?
4. Why would programmers want to include a loop when using a sensor?
5. Why would 'and' work in some instances and not others?
6. When should a "for loop" be used?

Activity #4: Programming Hardware (Traffic Lights)

Lesson Overview: Students will be taught how to define and implement functions by incorporating multiple components (LED lights and buttons) to mimic a traffic light.

Estimated Time: 120 minutes

Learning Objectives:
The students will be able to …
1. define functions with the Further website,
2. model a traffic light implementing various hardware with the pi-top [4] robotic kit, and
3. modify a function to process multiple events simultaneously using event handling.

SCIENCE TEKS:

1. P.6(D)
2. P.8(E)

MATH TEKS:

1. A.P.1(A)
2. A.P.1(B)
3. A.P.1(C)
4. A.P.1(G)
5. A.2(A)
6. 2A.7(I)
7. A.12(B)
8. A.12(C)
9. 2A.3(B)
10. 2A.8(C)
11. G.9(B)

NGSS: N/A

Technology Standards:

1. STEL-1N
2. STEL-3H
3. STEL-4P
4. STEL-5H

Materials Needed: (per group)

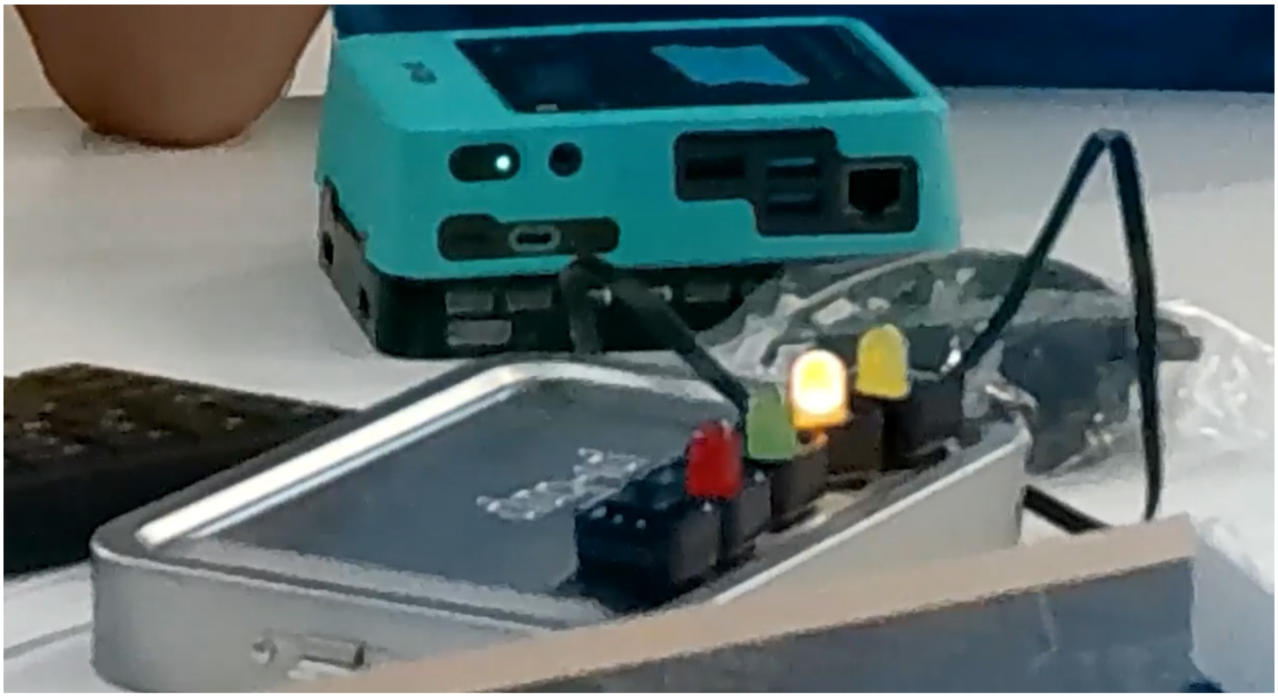
1. Pi-top [4] Robotics Kit
2. Laptop with Internet Access
3. LEDs
4. Buttons
5. Potentiometers
6. Buzzer

Lesson Flow:

1. Show students the following video: "How Do Traffic Signals Work" to help demonstrate the basics of traffic lights and how they can incorporate it with the pi-top [4].
2. Open Further website and access the “2024 UTCRS Summer Camp” class.
3. Open the “Programming Hardware” course.
4. Open the “Traffic Lights” lesson and follow the instructions provided while guiding the students through the lesson.

Use the following reflection questions and have students discuss and then answer within their group:

1. What are traffic signals and crosswalks? How do they improve safety?
2. How do your models compare to real life safety signals and processes?
3. Why should loops be incorporated in programs that mimic various safety signals?



Example Traffic Light Design

Day 2: Sensor Programming

Day Overview: The students will apply the Python programming language with various sensors, including light, sound, and ultrasonic. Students will design and build a railroad intersection using the sensor codes and the servo motor codes they have learned. Additionally, students will be building the "Alex" robot following the instructions provided and applying the drive functions.

Activity #1: Understanding the Sensors

Lesson Overview: The students will use various sensor types such as light, sound, and ultrasonic to understand their functionality and limitations.

Estimated Time: 30 – 45 minutes

Learning Objectives:
The students will be able to …

1. apply the Python programming language to understand how a photoresistor senses light, how the sound sensor detects sound, and how the ultrasonic sensor calculates the distance to the nearest object.

SCIENCE TEKS:

1. P.P.2
2. P.6.(D)
3. P.8(E)

MATH TEKS:

1. A.P.1(A)
2. A.P.1(B)
3. A.P.1(C)
4. A.P.1(G)
5. 2A.3(B)
6. 2A.8(C)
7. G.9(B)

NGSS:

1. HS-PS4-1
2. HS-PS4-5

Technology Standards:

1. STEL-1N
2. STEL-3H
3. STEL-4P
4. STEL-5H
5. STEL-6F

Materials Needed: (per group)

1. Pi-top [4] Robotics Kit
2. Laptop with Internet Access
3. Light Sensor
4. Sound Sensor
5. Ultrasonic Sensor
6. Flashlight
7. Acoustic Foam (Optional)

Lesson Flow:

1. Show the following video to explain the way Sound Sensors work:
    - See Teacher Note 2.
2. Show the following video to explain the way Ultrasonic Sensors work:
    - See Teacher Note 3.
3. Show the following video to explain the way Light Sensors (Photoresistors) work:
    - See Teacher Note 4.
4. Open Further website and go to the “2024 UTCRS Summer Camps” Class.
5. Open the “Understanding the Sensors” course.
6. Open the “Ultrasonic Sensor” lesson.
7. Follow the instructions provided in the lesson and guide the students through the lesson by explaining the basic concepts.
8. (Optional) Show the students how “Ultrasonic Sensors” do not work with all materials by trying to accurately measure distance to the acoustic foam.
9. Open the “Light Sensor” lesson.
10. Follow the instructions provided in the lesson and guide the students through the lesson by explaining the basic concepts.
11. Open the “Sound Sensor” lesson.
12. Follow the instructions provided in the lesson and guide the students through the lesson by explaining the basic concepts.

Use the following reflection questions and have students discuss and then answer within their group:

1. How can data be collected from a sound sensor using a computer code?
2. How can a sensor be used to detect distance from object using a computer code?
3. Describe how to modify the computer code so that the data prints in alternate standards of measurement.
4. Why do programmers use events in the code?
5. How can data be collected from a light sensor using a computer code?
6. What program would you write for an application in which a buzzer is used to inform the user that a room is too bright?

Activity #2: Simulating a Railroad Intersection (Active Sign Creation)

Lesson Overview: The students will review all the safety signs at a railroad crossing and try to build a miniature version of the crossing using the components provided in the robotics kit.

Estimated Time: 90 minutes

Learning Objectives:
The students will be able to …

1. recognize the passive and active signs present at every railroad crossing,
2. integrate servo motors to create traffic gates, and
3. develop a code to build and design a railroad crossing.

SCIENCE TEKS:

1. P.P.1
2. P.P.2
3. P.5E
4. P.6(B)
5. P.6(D)
6. P.7D
7. P.8(E)

MATH TEKS:

1. 2A.P.1(A)
2. A.P.1(B)
3. A.P.1(D)
4. A.P.1(G)

NGSS:

1. HS-PS4-5

Technology Standards:

1. STEL-2T
2. STEL-2Z
3. STEL-4P
4. STEL-5H
5. STEL-7Y
6. STEL-8P

Materials Needed: (per group)

1. Pi-top [4] Robotics Kits
2. Laptop with Internet Access
3. 2 Servo Motors

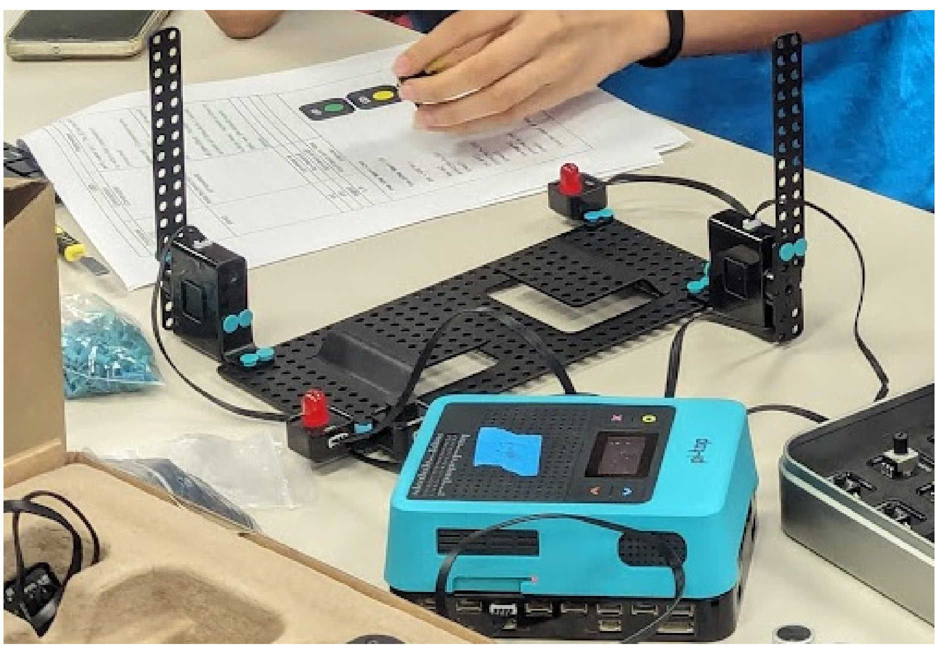
4. 2 Red LED Lights
5. 1 Buzzer
6. 1 Ultrasonic Sensor or Button

Lesson Flow:

1. Go to http://oli.org/education-resources/safety-tips/know-your-rails-signs-and-signals and click on "Learn More" under "Devices at the Crossing."
2. Discuss the flashing red lights, the bells, the gate, and the cantilever.
3. Point out that the bells, gates, and flashing red lights are active signs.
4. Open Further website and go to the "2024 UTCRS Summer Camps" Class.
5. Open the "Active Sign Creation" lesson.
6. Students will use any components in their robotics kit to create an "active" sign that activates with an incoming "train."

Use the following reflection questions and have students discuss and then answer within their group:

1. What are some railway crossing signals? Which are "active," and which are "passive"?
2. How do they improve safety?
3. How do your models compare to real life safety signals and processes?
4. What other sensors can you incorporate to your railroad crossing to improve safety?



Example Railroad Crossing Design

Activity #3: Rover Build and Navigation

Lesson Overview: Students will build the "Alex" robot model and will control it using basic commands.

Estimated Time: 120 minutes

Learning Objectives:
The students will be able to …

1. construct the basic design of the "Alex" robot by working in teams to build the necessary parts for the robot, and
2. develop a code that allows the robot to follow forward, left, and right commands.

SCIENCE TEKS:

1. P.5(D)
2. P.6(D),

MATH TEKS:

1. G.9(B)

NGSS:

1. HS-PS3-3

Technology Standards:

1. STEL-2T
2. STEL-2Z
3. STEL-8P

Materials Needed: (per group)

1. Pi-top [4] Robotics Kit
2. Laptop with Internet Access

Lesson Flow:

1. Have the students open their robotics kit and either follow the instructions on the Further website under the lesson entitled "The Build," or print out the instructions and provide them to each group so they can follow them to build the Alex robot.
2. Next, have the students practice moving the robot by showing them how to implement the drive controller which can be found on the Further class under "Navigation".

Use the following reflection questions and have students discuss and then answer within their group:

1. How can hardware and software be combined to collect and exchange data?
2. How is intelligent behavior conveyed through computers and robotics?
3. How is a rover's motion controlled through code?
4. How can the use of negative integer values change the motion of the rover?
5. Discuss the pros and cons of using sleep commands to control distance traveled.

Day 3: Driving the Rover

Day Overview: Students will continue to practice and implement the Python programming language with a focus on the concept of "Speed." Students will be introduced to the "Mini Baja Race" competition and will simulate a similar race using the coding knowledge they have gained thus far. Additionally, students will be introduced to computer vision and how it can be used to create a line follower program.

Activity #1: Rover Speed and Rotation

Lesson Overview: The students will run the rover at various speed factors and sleep times to explore its speed and angular velocity.

Estimated Time: 60 minutes

Learning Objectives:

The students will be able to …

1. determine the speed of the robot using the acquired data, and
2. produce a programming code that pilots their robot to allow different turning angles.

SCIENCE TEKS:

1. P.5.A
2. P.5(D)
3. P.5(E)
4. P.5(F)
5. P.5(G)
6. P.6(B)
7. P.6(D)
8. P.7(D)
9. P.8(E)

MATH TEKS:

1. A.P.1(D)
2. A.12(C)
3. G.9(B)

NGSS:

1. HS-PS3-3

Technology Standards:

1. STEL-2Z
2. STEL-7Y

Materials Needed: (per group)

1. Pi-top [4] Robotics Kit
2. Laptop with Internet Access
3. The "Alex" Robot Model
4. Measuring Tape
5. Activity Worksheet

Lesson Flow:

1. Open the Further website and navigate to the "2024 UTCRS Summer Camps" class and open the "Rover Speed and Rotation" lesson.
2. Start the lesson by explaining the definition of speed = distance over time.
3. Students will then move the robot forward at speed factors of 0.1, 0.3, 0.5, 0.7 for 1, 2, and 5 seconds then record the distance traveled during those speed factors and times to determine the robot speed (Nested for loop where speed_factor is the outer loop, and sleep_time is the inner loop).
4. Students will plot their data into a graph of distance versus time and observe the change in speed the longer the robot moves.
5. Continue the lesson by explaining angular velocity = radians over time.
6. Students will try to define the rotation of the robot for 45, 90, and 180 degrees, at speed factors 0.1, 0.3, and 0.5. The students will "guess" the time required to reach the angle with an iterative program.
7. Students will then plot their data into a graph of radians over time and observe the change in angular velocity the longer the robot moves.

Use the following reflection questions and have students discuss and then answer within their group:

1. What is the top speed? How long does it take to reach that speed?
2. What happens when you keep the speed factor the same but change the sleep time?
3. Describe how to modify the code so that the robot reverses direction at similar speeds to a forward motion.
4. The rover weighs 3.18 kilograms and Perseverance, the Mars rover, weighs about 45 kilograms. How do you think mass affects speed?
5. NASA's Mars Rover drives with a top speed of 0.16 kilometers per hour (0.1 miles per hour). Calculate the speed of your rover and compare it to that of the Perseverance rover.

Activity #2: Rover Race

Lesson Overview: The students will build a controller that will enable them to use their Bluetooth keyboard to control their robot in a "Mini Baja Race." They will modify their robot design and map keyboard buttons to specific actions such as moving forward, reversing, turning left and right, and braking.

Estimated Time: 120 minutes

Learning Objectives:
The students will be able to …
1. understand the limitations of iterative statements from the Further website, and
2. apply the engineering design process to customize their controls and robot functions.

SCIENCE TEKS:
1. P.5.A
2. P.5(D)
3. P.5(E)
4. P.5(F)
5. P.5(G)
6. P.6(B)
7. P.6(D)
8. P.7(D)
9. P.8(E)

MATH TEKS:
1. A.P.1(B)
2. A.P.1(D)
3. A.P.1(G)
4. A.12(C)
5. 2A.8(C)
6. G.9(B)

NGSS:
1. HS-PS3–3

Technology Standards:
1. STEL-1N
2. STEL-2Z
3. STEL-3H
4. STEL-7Y
5. STEL-8P

Materials Needed: (per group)
1. Pi-top [4] Robotics Kit
2. Laptop with Internet Access
3. The “Alex” Robot Model
4. Ultrasonic Sensor
5. LEDs

Lesson Flow:

1. Open the Further website and navigate to the “2024 UTCRS Summer Camps” class and open the “USB Keyboard” lesson.
2. Start the lesson with the USB Keyboard tutorial in further.pi-top.com
3. Open the direction_arrows.py file and show students how to use a loop to poll for key press events with the keyboard to make a controller.
4. Use the function definitions from the previous activity for the movement controls.

Use the following reflection questions and have students discuss and then answer within their group:

1. How responsive is the robot using a loop? Did it get slower the more keys you added?
2. How did your robot design affect your performance in the race?

Activity #3: Line Follower (Rover Vision)

Lesson Overview: Students will be introduced to computer vision and how color detection can be used to create a line following robot.

Estimated Time: 60 minutes

Learning Objectives:
The students will be able to …

1. integrate a program to use a camera with their pi-top [4] and display it on the Further website,
2. use pre-defined functions to create a line follower program, and
3. recognize key terms, such as kernels, centroids, and masks, which are used for image processing.

SCIENCE TEKS:

1. P.P.2
2. P.5(A)
3. P.5(B)
4. P.5(D)
5. P.6(B)
6. P.6(D)
7. P.8(E)

MATH TEKS:

1. A.P.1(B)
2. A.P.1(G)
3. A.2(A)
4. A.12(C)
5. 2A.8(C)

6. G.9(B)

NGSS:
1. HS-PS3–3

Technology Standards:
1. STEL-1N
2. STEL-2Z
3. STEL-3H
4. STEL-7Y
5. STEL-8P

Materials Needed: (per group)
1. Pi-top [4] Robotics Kit
2. Laptop with Internet Access
3. The “Alex” Robot Model
4. Activity Worksheet
5. Pencil (or Pen) and Notebook
6. Calculator

Lesson Flow:
1. Show the students the video “Computer Vision” to help them understand the basics of how computer vision works.
2. Open the Further class and run through the “Rover Vision” and “Path Finder” lessons.

Use the following reflection questions and have students discuss and then answer within their group:
1. What is the fastest forward speed value you achieved?
2. List and describe two real life examples where a line detection process is used. If you plan to use a search site to help you answer the question, be sure to reference the source(s).
3. If the processes from this lesson were to be applied in real-world applications, what potential issues could arise for the user?
4. What is the benefit of using functions in your code?

Day 4: Hardware Applications

Day Overview: Students will apply the Python programming language to code their rover to simulate a collision. Students will determine the Acceleration of the robot, calculate Force, Energy, Work, and Power exerted on an object after displacement. The students will collaborate to design and build a forklift to lift and move a scaled-down (3D-printed) train wheel-axle assembly.

Activity #1: Collision Simulation

Lesson Overview: The students will simulate a collision at maximum speed and will determine the acceleration of the robot as it collides with an object and calculate its displacement after collision as well as the force, energy, work, and power exerted on the object.

Estimated Time: 90 minutes

Learning Objectives:
The student will be able to …

1. understand the relationship between force and energy through experimentation, and
2. create a work versus time graph that represents power from the collected data.

SCIENCE TEKS:

1. P.5(A)
2. P.5(D)
3. P.5(E)
4. P.5(F)
5. P.5(G)
6. P.6(B)
7. P.6(D)
8. P.7(A)
9. P.7(D)
10. P.8(E)

MATH TEKS:

1. A.P.1(A)
2. A.P.1(B)
3. A.P.1(C)
4. A.P.1(G)
5. A.2(A)
6. A.12(B)
7. A.12(C)
8. 2A.8(C)
9. G.9(B)

NGSS:

1. HS-PS-1
2. HS-PS3-3

Technology Standards:

1. STEL-2T
2. STEL-2Z
3. STEL-4P
4. STEL-6F
5. STEL-7Y
6. STEL-8P

Materials Needed: (per group)

1. Pi-top [4] Robotics Kit
2. Laptop with Internet Access
3. The "Alex" Robot Model
4. Activity Worksheet
5. Pencil (or Pen) and Notebook
6. Calculator
7. A Box with a Known Mass

Lesson Flow:

1. Open the Further website and navigate to the "2024 UTCRS Summer Camps" class and open the "Collision Simulation" lesson.
2. In this activity, you will simulate a collision at maximum speed.
    - See Teacher Note 5
3. Explain the relationship between acceleration ($a = \frac{\Delta V}{t}$), force ($F = m * a$), energy, work ($W = F * \Delta d$), and power ($P = \frac{W}{t}$).
   Acceleration is measured in meters per second squared $\frac{m}{s^2}$, Force is measured in Newtons which are kilogram meters per second squared $1N = 1kg\frac{m}{s^2}$, Work is measured in Joules $1J = 1\ kg\ \frac{m^2}{s^2}$, Power is measured in Watts $1W = 1\frac{J}{s}$.
4. Students will calculate the acceleration of the robot at top speed (speed factor of 1) and will determine the time it would take for the robot to reach its top speed.
5. Calculate the force used by the motors to move the robot. For that, you will need the mass of the robot which is 3.18 kilograms.
6. Place the robot far enough from an object (box) and allow the robot to collide with that object at maximum speed. Let the robot drift for about 2 to 3 seconds and record the distance traveled after collision.
7. Repeat the experiment several times (5-10).

8. Once the students finish collecting their data, calculate the Work performed on the box (object) by the robot.
9. Plot the power exerted by the robot in a graph of work (y-axis) versus time (x-axis).

Use the following reflection questions and have students discuss and then answer within their group:

1. What happened to the box during the collision? Why did the box move?
2. Did the robot maintain the same speed before and after the collision? Why?
3. Do you think the results will be different if the robot collided with a heavier box? How? What if the robot was heavier?
4. Which of Newton's Laws of Motion apply in this activity?

Activity #2: Forklift Assembly Challenge

Lesson Overview: Students will design a forklift using a single servo motor and the parts provided in their robotics kit to lift and move a scaled-down (3D-printed) train wheel-axle assembly.

Estimated Time: 120 minutes

Learning Objectives:

The students will be able to …

1. design and build a forklift for their robot to pick up/drop off a wheel-axle assembly, and
2. create a program for their robot to approach, pick up, and drop off a wheel-axle assembly.

Science TEKS:

1. P.5(D)
2. P.5(E)
3. P.5(F)
4. P.5(G)
5. P.6(B)
6. P.6(D)
7. P.7(D)
8. P.8(E)

Math TEKS:

1. A.P.1(A)
2. A.P.1(B)
3. A.P.1(C)
4. A.P.1(G)
5. A.2(A)
6. A.12(B)
7. A.12(C)
8. 2A.8(C)

9. G.9(B)

NGSS:
1. HS-PS3–3

Technology Standards:
1. STEL-1N
2. STEL-2T
3. STEL-2Z
4. STEL-4P
5. STEL-7Y
6. STEL-8P

Materials Needed (Per Group):
1. Pi-top [4] Robotics Kit
2. Laptop with Internet Access
3. 1 Servo Motor

Lesson Flow:
1. Open the Further website and navigate to the "2024 UTCRS Summer Camps" class and open the "Forklift Assembly Challenge" lesson.
2. Explain the importance of regular maintenance in rail operations using train wheel-axle assemblies as an example and discuss the consequences of bearing or wheel failure during train operation (e.g., discuss train derailments).
3. Show a demonstration of an axle being replaced on site in less than 3 minutes.
   - See Teacher Note 6
4. The students will then implement the Engineering Design Process (Cycle) to design and build a forklift that is able to pick up a wheel-axle assembly.
5. Present the following questions to test the limits of their forklift:
   a. How high do you need to lift the axle off the ground?
   b. How low can the forklift go before it hits the ground?

Use the following reflection questions and have students discuss and then answer within their group:
1. Did you use your first forklift design? If not, why did you change it?
2. Why do you think we need to add the angle limits to the up and down functions? What if you release your design and code to the public? Will they know the limits of your design?
3. What did you find to be successful in your design?
4. Was your design inspired by any real-world applications?

Example Forklift Design

Day 5: Final Challenge

Day Overview: The students will experience how engineers collaborate in teams and apply their knowledge towards completing a task. This will be accomplished through the final challenge where the team members within each group will work together and apply the programming skills they gained throughout the week to complete an obstacle course that requires them to remotely pilot their robot and swap the locations of two objects mimicking the replacement process of a wheel-axle assembly.

Activity #1: Final Challenge

Lesson Overview: Students will use the knowledge they gained during the week to complete an obstacle course that requires them to remotely pilot their robot and swap the locations of two objects mimicking the replacement process of a wheel-axle assembly. The groups will compete against each other and the team that accomplishes the task in the fastest time will win the challenge.

Estimated Time: 240 minutes

Learning Objectives:
The students will be able to …

5. modify an operator code for their robot to pick up and drop off objects,
6. modify an operator code for their robot to drive utilizing the servo motors,
7. rewrite the program code for their robot to incorporate a camera to remotely drive their robot, and
8. interpret the limitations of hardware and wireless communication based on their performance and experience from this final challenge.

Science TEKS:

1. P.5(D)
2. P.5(E)
3. P.5(F)
4. P.5(G)
5. P.6(B)
6. P.6(D)
7. P.7(D)
8. P.8(E)

Math TEKS:

1. A.P.1(A)
2. A.P.1(B)
3. A.P.1(C)
4. A.P.1(G)
5. A.2(A)

6. A.12(B)
7. A.12(C)
8. 2A.8(C)
9. G.9(B)

NGSS:

1. HS-PS3–3

Technology Standards:

1. STEL-1N
2. STEL-2T
3. STEL-2Z
4. STEL-4P
5. STEL-7Y
6. STEL-8P

Materials Needed: (per group)

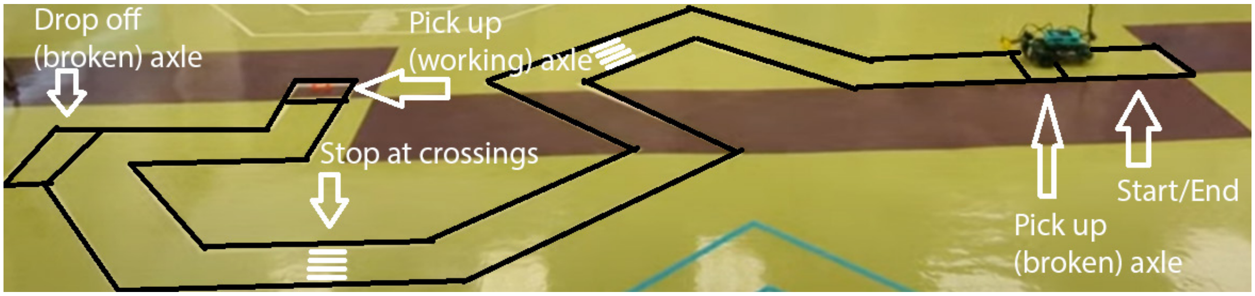
1. Pi-top [4] Robotics Kit
2. Laptop with Internet Access
3. The “Alex” Robot Model
4. 2 Servo Motors
5. 2 Red LED Lights
6. 1 Buzzer
7. 1 Ultrasonic Sensor

Lesson Flow:

1. Open the Further website and navigate to the “2024 UTCRS Summer Camps” class and open the “Final Challenge” lesson.
2. Let students practice the engineering design process by having them try to incorporate the different challenge requirements such as turning on rear lights when reversing, obstacle detection, and low light detection.
3. Build a track so that students can test their robot’s functionalities before the competition.
4. Create and explain the final track challenge.
    - See Teacher Note 7

Use the following reflection questions and have students discuss and then answer within their group:

1. How much delay did you see in the camera? Why do you think that is?
2. Can you add any sensors to help you pick up the axle?
3. Can you add the line follower to help you stay within the track?
4. Was your camera fixed or controlled by a servo motor?



Example Track for Final Challenge

Appendices

Appendix A: Video Links

Day 1
Activity 4:
Traffic Signals: How Do Traffic Signals Work?

Day 2
Activity 1:
Ultrasonic Sensor: How Do Ultrasonic Distance Sensors Work? - The Learning Circuit
Light Sensor (Photoresistor): How does a photoresistor work?
Sound Sensor: Sound Sensors

Activity 3:
The Alex Robot: pi-top [4] Robotics Kit: Build instructions - Alex

Day 3
Activity 3:
Computer Vision: Computer Vision: Crash Course Computer Science #35

Day 4
Activity 2:
Wheel-Axle Assembly Replacement: Wheel-Axle Assembly Replacement

Appendix B: Teacher Notes

1	To connect a tablet or iPad to a wireless keyboard using Bluetooth, first ensure the keyboard is turned on and in pairing mode. On your tablet or iPad, go to Settings, select Bluetooth, and turn it on if necessary. Your device will search for available Bluetooth devices; when the keyboard appears in the list, tap on its name. You may need to enter a pairing code displayed on your screen using the keyboard. Once paired, your device should show the keyboard as connected. [Use the pi-top [4] with the Hotspot and RealVNC Viewer] To connect a tablet to the pi-top [4] using Wi-Fi, follow these steps: First, using the pi-top [4] mini-screen, ensure your pi-top [4] is powered on and has Wi-Fi Hotspot enabled in the Settings page. Now, navigate to the Network page in the pi-top [4] mini-screen then look for the hotspot credentials there. On your tablet, go to the Wi-Fi Settings and look for the pi-top [4] network name (SSID) in the list of available networks. Select this network and enter the password. Once connected to the pi-top [4] hotspot, you may open the RealVNC Viewer App and create a connection to the pi-top [4] IP address (192.168.90.1), and connect to that address with the following credentials: Username: *pi*, and Password: *pi-top.* [Use the pi-top [4] with Wi-Fi and the Further website] Continue after connecting to the pi-top [4] hotspot. Once connected, open a web browser on your Tablet, iPad, or Laptop and navigate to the pi-top [4] IP address (192.168.90.1). This should give you access to the pi-top [4] dashboard. Select Wi-Fi Settings and connect to your own Wi-Fi network. After a successful connection, the pi-top [4] will get a different IP address (e.g. 10.0.0.1), check any Further lesson to access and use this new IP address on the Further website. [Use the pi-top [4] with the Display Cable and Further/RealVNC Viewer] Alternatively, if you have the green pi-top [4] display cable, you may use it to connect to your Laptop or Tablet by connecting it with the USB Adapter, and the other end to the pi-top [4] USB-C display port (the one next to the charging port). After doing this, the pi-top [4] can be accessed through the RealVNC Viewer or the Further website with the IP address 192.168.64.1.
2	The Sound Sensor consists of a simple microphone that detects the vibrations of the air entering the sensor and produces an analog reading based on the amplitude of these vibrations.
3	The Ultrasonic Sensor consists of two main components: a transmitter that sends ultrasonic sound waves forward, and a receiver that detects those waves once they bounce off an object in front (both components are labeled in the sensor as T and R, respectively). The sensor calculates distance based on the time it takes the sound wave to bounce and return to the receiver (distance = speed of sound in the medium * time).
4	The Light Sensor consists of a photoresistor and a pair of wires; a photoresistor is a light-sensitive device, the resistance of which decreases (more current can pass through the wire) with the increase in light intensity detected by the sensor.
5	Instruct your students to remove the Servo Motors and other components that might get damaged at the front of the robot.
6	Explain to students that a wheel-axle assembly replacement in under 3 minutes is preferred because several train cars may require several wheel-axle assemblies to be replaced while in the railyard. To minimize downtime and avoid costly delays associated with prolonged train stoppages in railyards, optimizing the time needed to complete the wheel-axle assembly replacement is of utmost importance.
7	Make sure that when the students compete in the final challenge, the pilot cannot see the track with anything other than their device. A teammate may help with axle placement if it goes out of the track.

Appendix C: Worksheets

Day 3

Activity 1 Rover Speed and Rotation Worksheet

Activity 3 Name of Worksheet

Day 4

Activity 1: Name of Worksheet

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