UTCRS HIGH SCHOOL

STEM CURRICULUM

Table of Contents

Objectives

By the end of the curriculum lessons, the student will be able to:

1. Understand the relationship between force, mass, and acceleration with regard to MagLev systems.
2. Understand the benefits of MagLev trains as a viable transportation alternative.
3. Use the engineering design process to design, test, and evaluate a MagLev train system.
4. Think critically and find solutions to transportation engineering problems.
5. Work collaboratively in small groups.
6. Design the fastest and safest MagLev train possible.
7. Use problem-solving skills to read and interpret diagrams to build a robot.
8. Use problem-solving skills to create, run, and test programs created to control a robot.
9. Recognize and interpret transportation related traffic signs and signals.
10. Recognize and interpret railway safety signs and signals.
11. Plan a route through an obstacle course that is efficient and obeys all traffic and railroad safety signs and signals.
12. Use the color sensor and the touch sensor to build a robot that can follow a line and complete specific activities.
13. Apply principles of logic and critical thinking to find the most effective and efficient way to navigate a maze design.
14. Use variables in the context of programming to determine the state of an object, such as "true" or "false".
15. Understand and utilize the loop constructs in programming.
16. Complete the creation of a robot design arm and truck in the final challenge.

Texas Essential Knowledge and Skills (TEKS) and National Standards

TEKS Science 9-12

§112.38. Integrated Physics
(2) Scientific processes. The student uses scientific methods during laboratory and field investigations. The student is expected to:
   (A) know the definition of science and understand that it has limitations, as specified in subsection (b)(2) of this section;

(B) plan and implement investigative procedures, including asking questions, formulating testable hypotheses, and selecting equipment and technology;

(C) collect data and make measurements with precision;

(D) organize, analyze, evaluate, make inferences, and predict trends from data; and

(E) communicate valid conclusions.

(3) Scientific processes. The student uses critical thinking, scientific reasoning, and problem-solving to make informed decisions. The student is expected to:

(A) evaluate the impact of research on scientific thought, society, and the environment; and

(B) describe connections between physics and chemistry and future careers.

(4) Science concepts. The student knows concepts of force and motion evident in everyday life. The student is expected to:

(A) describe and calculate an object's motion in terms of position, displacement, speed, and acceleration;

(B) measure and graph distance and speed as a function of time using moving objects;

(C) investigate how an object's motion changes only when a net force is applied, including activities and equipment such as toy cars, vehicle restraints, sports activities, and classroom objects;

(D) assess the relationship between force, mass, and acceleration, noting the relationship is independent of the nature of the force, using equipment such as dynamic carts, moving toys, vehicles, and falling objects;

(E) apply the concept of conservation of momentum using action and reaction forces such as students on skateboards; and

(F) describe the gravitational attraction between objects of different masses at different distances.

(5) Science concepts. The student recognizes multiple forms of energy and knows the impact of energy transfer and energy conservation in everyday life. The student is expected to:

(A) recognize and demonstrate that objects and substances in motion have kinetic energy such as vibration of atoms, water flowing down a stream moving pebbles, and bowling balls knocking down pins;

(B) demonstrate common forms of potential energy, including gravitational, elastic, and chemical, such as a ball on an inclined plane, springs, and batteries; and

(C) demonstrate that moving electric charges produce magnetic forces and moving magnets produce electric forces.

TEKS Math 9-12

Algebra I

(1) Foundations for functions. The student understands that a function represents a dependence of one quantity on another and can be described in a variety of ways. The student is expected to:

 (A) describe independent and dependent quantities in functional relationships;

 (B) gather and record data and use data sets to determine functional relationships between quantities;

 (C) describe functional relationships for given problem situations and write equations or inequalities to answer questions arising from the situations;

 (D) represent relationships among quantities using concrete models, tables, graphs, diagrams, verbal descriptions, equations, and inequalities; and

 (E) interpret and make decisions, predictions, and critical judgments from functional relationships.

(3) Foundations for functions. The student understands how algebra can be used to express generalizations and recognizes and uses the power of symbols to represent situations. The student is expected to:

 (A) use symbols to represent unknowns and variables; and

 (B) look for patterns and represent generalizations algebraically.

(4) Foundations for functions. The student understands the importance of the skills required to manipulate symbols in order to solve problems and uses the necessary algebraic skills required to simplify algebraic expressions and solve equations and inequalities in problem situations. The student is expected to:

 (A) find specific function values, simplify polynomial expressions, transform and solve equations, and factor as necessary in problem situations.

International Technology and Engineering Educators Association (ITEEA) Standards

Grades 9-12

Standard 2. Students will develop an understanding of the core concepts of technology.
- System thinking applies logic and creativity with appropriate compromises in complex real-life problems.

- Systems, which are the building blocks of technology, are embedded within larger technological, social, and environmental systems.
- The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop.
- Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.
- Quality control is a planned process to ensure that a product, service, or system meets established criteria.

Standard 3. Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.
- Technological progress promotes the advancement of science and mathematics.

Standard 8. Students will develop an understanding of the attributes of design.
- The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype, testing and evaluating the design using specifications, refining the design, creating or making it, and communicating processes and results.
- Design problems are seldom presented in a clearly defined form.
- The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.
- Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.

Standard 12. Students will develop the abilities to use and maintain technological products and systems.
- Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.
- Operate systems so that they function in the way they were designed.

Engineering Design

NGSS (Next Generation Science Standards) suggest that all students should be able to do the following by the time they leave high school:

(A) Defining and delimiting engineering problems involves stating the problem to be solved as clearly as possible in terms of criteria for success, and constraints or limits.

(B) Designing solutions to engineering problems begins with generating a number of different possible solutions, and then evaluating potential solutions to see which ones best meet the criteria and constraints of the problem.

(C) Optimizing the design solution involves a process in which solutions are systematically tested and refined and the final design is improved by trading off less important features for those that are more important.

National Science Education Standards

Content Standard (A): generate and interpret graphs and charts describing different types of motion, including the use of real-time technology such as Vernier motion detectors or photogates

Content Standard (B): describe and analyze motion in one dimension using equations with the concepts of distance, displacement, speed, average velocity, instantaneous velocity, and acceleration

Content Standard (D): calculate the effect of forces on objects, including the law of inertia, the relationship between force and acceleration, and the nature of force pairs between objects

Content Standard (E): research and describe the historical development of the concepts of gravitational and electromagnetic forces

Content Standard (F): describe and calculate how the magnitude of the gravitational force between two objects depends on their masses and the distance between their centers

Content Standard (G): identify examples of electric and magnetic forces in everyday life

Content Standard (H): investigate and describe the relationship between electric and magnetic fields in applications such as generators, motors, and transformers

Content Standard (I): investigate examples of kinetic and potential energy and their transformations

Day 1 - Magnetic Levitation Train Systems

Activity #1

Estimated time needed: 15 minutes

Title: Icebreaker - Chalkboard Sentences

Lesson Overview: Students will work cooperatively to create a sentence describing their prior knowledge of railway safety. This activity will create team unity and pride as they will be competing against other teams to compose a sentence without talking to each other and writing only one word at a time. Sample sentence might look as follows: All buses stop at railroad crossings.

Objective:
1. To access prior knowledge of students pertaining to railway safety.

Materials Needed: (per class)
- Dry-erase markers and white board or
- Paper and regular markers

Lesson Flow:
1. For this exercise, ask the participants to work in teams. Within their teams, students are to discuss and formulate a sentence pertaining to what they already know about railway safety. Each team member adds a word to the sentence. The facilitator begins by explaining that participants will be competing to see which team is the first to complete a group sentence.
2. Next, ask group members to divide into two teams. If the group contains an uneven number, one participant may compete twice. Line up team members ten feet away from the board. After giving the first person in each team's line a dry-erase marker, the facilitator explains the following rules:
   - Each member is to add one word to his/her team's sentence.
   - The first person in each line is to come forward and write the first word of their team's sentence, go back and pass on the marker to the next team member, and return to the end of the line.
   - No preplanning of sentences is allowed.
   - Each player may participate only once.
   - The winner is the team that is the first to build a full sentence using words contributed by all of its group members.

Activity #2

Estimated Time: 30 minutes

Title: Designing a MagLev - Incline and Speed

Lesson Overview: Students will measure the speed of a MagLev train system using Vernier probes, and investigate changes in speed associated with three different ramp angles (heights).

Objectives:

1. Use engineering principles to design a simple MagLev train system using simple magnets.
2. Determine if the angle of the ramp (height of ramp) affects the speed of the MagLev train.
3. Calculate potential and kinetic energies of the train at different angles (heights).
4. Use appropriate technologies, i.e. – Vernier probes.

Materials Needed: (per group)

- MagLev Train Educational Kit
- Speed and Incline Data Table available in Appendix A.1.
- Protractor
- Complete ramp setup
- Vernier probes (if available)
- Stopwatch
- Spring scale _or_ electronic balance
- Journal (per student)

Lesson Flow:

1. Allow some flexibility in this lesson, but make sure students understand to change only one element of their design at a time.
2. Have students configure a variety of positioning possibilities for their magnets on the MagLev train system rails.
3. Have students construct four different inclines: 0, 20, 40, and 60 degrees. Using five washers (each washer represents a "passenger"), measure the distance traveled by the train and the elapsed time, record both in the data table of Appendix A.1.
4. Using the Vernier probes, determine the force, mass, and acceleration of the train at each ramp angle/incline. The mass can also be determined using a spring scale or electronic balance.
5. Students are to record the kinetic energy (KE) and potential energy (PE) of their individual MagLev train using the formulas provided.

Adaptation/Extensions:

➤ Use distance and time data to graph the average velocity of the train. Printable graph paper is available in Appendix A.2.

➤ Use the Vernier probes to find the relationship between the ramp angle and velocity.

Additional Resources:

➤ How to use Vernier Probes:
- Photogate: http://www2.vernier.com/manuals/Logger_Pro_Introduction_to_the_Vernier_Photogate.pdf
- Motion Detector: http://www.vernier.com/manuals/md-btd/
- Dual-Range Force Sensor: http://www.vernier.com/manuals/dfs-bta/

➤ Formulas:

$$Potential\ Energy\ (PE) =\ mass \times acceleration\ due\ to\ gravity \times height\ = mgh$$

$$Kinetic\ Energy\ (KE)\ =\ 0.5 \times m \times v^2$$

where *m* = mass of the object, *h* = height of the object, *g* = gravitational field strength (9.81 m/s^2 on Earth) - sometimes referred to as the acceleration of gravity, and *v* = speed of the object.

➤ Videos:
- Show students the "World's Fastest Trains-MagLev" video related to real-world impact of activity (Note that the title of this video mistakenly states that the MagLev train's top speed is 3500 km/h, this value should be about 360 km/h): https://www.youtube.com/watch?v=aIwbrZ4knpg
- Talk to students about the difference between the German MagLev design and the Japanese MagLev design
  - German MagLev design Video: https://www.youtube.com/watch?v=hUATDtZble0
  - Japanese MagLev design Video: https://www.youtube.com/watch?v=SUBUTo82EQw#rpctoken=287669679&_methods=setNotificationWidgetSize%2CsetNotificationWidgetHeight%2CsetNotificationText%2ChideNotificationWidget%2CopenSharebox%2ConError%2C_ready%2C_close%2C_open%2C_resizeMe%2C_renderstart&id=I1_1446659761580&parent=https%3A%2F%2Fwww.y

Activity #3

Estimated Time: 30 minutes

Title: Mass, Force, and Acceleration

Lesson Overview: Students will use the MagLev train system to investigate the relationship between force, mass, and acceleration by changing the load or the number of passengers (represented here by "washers").

Objectives:

1. Determine how the mass added to the MagLev train affects the force needed to accelerate the train.
2. Calculate the acceleration of the train by measuring force and mass with Vernier probes.

Materials Needed: (per group)

● Constructed MagLev train kits
● Stopwatch (may be replaced with Vernier Photogate)
● Ramps/inclines
● Protractor
● Mass, Force, and Acceleration Data Table Worksheet available in Appendix A.3
● Electronic balance _or_ spring scale
● Journal (per student)

Lesson Flow:

1. Review what was learned in Activity #2 regarding speed and inertia.
2. Discuss speed, acceleration, and deceleration. Use examples like a car speeding up and slowing down, etc.
3. Using your findings from Activity #2, have student groups decide on the most efficient incline angle.
4. Have students add one washer to their car. Measure the distance traveled and time elapsed. Use the Vernier probe to measure acceleration and mass. Record all data in the Mass, Force, and Acceleration Data Table provided in Appendix A.3. Calculate the force or measure with Vernier probe.
5. Repeat step 4, adding one washer at a time and recording data in the chart provided.
6. Calculate the *Figure of Merit (FOM)* for each trial.

$$FOM = \frac{P \cdot X}{N \cdot T}$$

where *P* = number of washers, *X* = distance traveled in [cm], *N* = number of magnets, and *T* = elapsed time in seconds. Explain to students how the *FOM* is used to determine the

best design taking mass, distance, time, and number of passengers into account. The higher the FOM, the better the design is judged.

7. Facilitate student understanding of the relationship between force, mass, and acceleration with some questions; for example:

   a. *What happens to the distance traveled as the mass increases?*

   b. *What happens to the elapsed time when the mass increases?*

   c. *What happens to the acceleration as the mass increases?*

Additional Resources:

- ➢ Videos that use drawing illustrations
  - Potential and Kinetic Energy
    https://www.youtube.com/watch?v=BSWl_Zj-CZs
    https://www.youtube.com/watch?v=iYEWIuQBVyg

Activity #4

Estimated Time: 45-60 minutes

Title: Does the Number of Magnets Used Affect the Acceleration?

Lesson Overview: Students will continue to investigate force, mass, and acceleration by changing the number of magnets on their railcar.

Objectives:

1. Determine the relationship between the number of magnets and the acceleration of the MagLev train.
2. Calculate acceleration by measuring force and mass, while changing the number of magnets on the train.

Materials Needed: (per group)

- Constructed MagLev train kits
- Stopwatch
- Ramps/inclines
- Protractor
- Worksheet
- Vernier probes
- Journal (per student)

Lesson Flow:

1. Repeat the same steps in Activity #3, except have the students vary the number of magnets used on the train. Be sure they record all data in the data table provided in Appendix A.3.
2. Facilitate student understanding of the relationship between force, mass, and acceleration with some questions; for example:
   a. *What happens to the distance traveled as the number of magnets increases?*
   b. *What happens to the distance traveled as the number of magnets decreases?*
   c. *What happens to the acceleration as the number of magnets increases?*
   d. *What happens to the acceleration as the number of magnets decreases?*
   e. *What happens to the mass of the car as the number of magnets increases?*
   f. *What happens to the mass of the car as the number of magnets decreases?*

Activity #5

Estimated Time: 30-45 min
Title: Railway Safety – Positive Train Control (PTC)
Lesson Overview: Students will participate in hands-on investigative activities that will allow them to apply their understanding of magnetic forces to create a positive train control (PTC) mechanism. Students need to create a more creative/effective PTC which does not stop the train abruptly (i.e., crash).

Objectives:
1. Determine the best MagLev train design that will stop the train at the end of the ramp without crashing or obstructing the train track in any way.
2. Define and investigate effective PTC techniques.
3. Evaluate various engineering MagLev train designs.

Materials Needed: (per group)
- Constructed MagLev train kits
- Stopwatch
- Ramps/inclines
- Protractor
- Extra track
- Miscellaneous materials: magnets, rubber bands, paper clips, etc., that students can utilize to create an effective PTC mechanism
- Journal (per student)

Lesson Flow:
1. Review the concepts of magnetic forces (opposite poles attract, like poles repel) and north and south poles.
2. Show a simulation that explains PTC: www.youtube.com/watch?v=33y3E7mqZYM.
3. Explain that each group will use their extra track to create an intersection.
4. Give students a challenge: Another train has stalled at the intersection. Your challenge is to use the materials at your desk to create a PTC mechanism that will stop your train before a collision occurs.
   a. Have students brainstorm their ideas verbally first, and record them in their journals.
   b. One possible solution is to position the extra bar magnets in the tracks just before the intersection, aligning the polarity so that the magnets on the bottom of the train are opposite to the bar magnet (the magnets will attract and stop). Other solutions are possible! Encourage students to explore more than one solution.

<u>Days 2 & 3 - Robotics Programming</u>

Activity #1

Estimated Time: 45-60 min
Title: Assemble the Basic Robot Design
Lesson Overview: Students will be building and programming an mBot Ranger 3-in-1 Robot. Students will follow the basic instructions for building and programming their own robot.
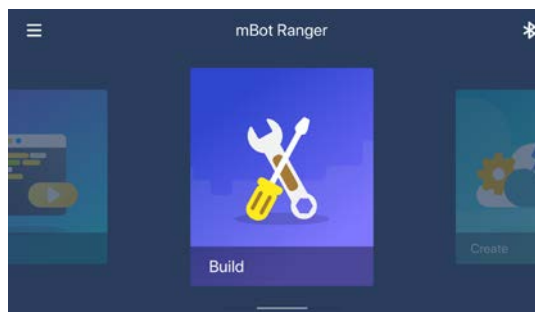
Objectives:
1. Learn to work in groups, modeling teams of engineers.
2. Learn and assume different roles in teams, lead engineer and assistant engineers.

Materials Needed: (per group)
- mBot Ranger completed robot (three versions if possible to show as example)
- mBot Ranger 3-in-1 Educational Robot Kit
- iPad
- Makeblock and mBlock Blockly application software installed on iPad
- Electric tape
- Journal (per student)

Lesson Flow:
1. Inform students that they are going to be learning more about transportation engineering by working with robots. Tell them that they will be building and programming their own robot.
2. Show students a completed basic robot and pass it around to all of the teams.
3. Have students briefly look at the directions for building the Land Raider Robot in the mBot Ranger 3-in1 Educational Robot Kit manual (pg. 15-21) included in the kit. Additionally, the Makeblock App can supply you with virtual instructions. These can be found by sliding over to the "Build" Menu on the app. See image on the top right of the page.
4. Instruct students to begin building their robot. Students need to role play working as a team of engineers; during each round of three steps, there will be one "lead engineer" and the rest of the team will be "assistant engineers". The function of the lead engineer is to construct the robot. The assistant engineers are to look for parts and help the lead engineer assemble the robot. Emphasize that there are approximately 101 pieces in each robot kit and they must take care not to lose or misplace any of the parts.

Activity #2

Estimated Time: 10-15 min

Title: Overview of Programming Basics

Lesson Overview: Students will become familiar with writing basic programming commands for their robot.

Objectives:

1. Students will use problem-solving skills to read and interpret diagrams to build a robot.
2. Students will use problem-solving skills to create, run, and test programs created to control a robot.

Materials Needed: (per group)

- Land Raider Robot constructed from Activity #1
- iPad
- Makeblock and mBlock Blockly application software installed on iPad
- Overhead projector and display screen to view programming software
- Journal (per student)

Lesson Flow:

1. Before students begin exploring, connect each robot to an iPad using Bluetooth. This might require some distancing of robots to make sure all robots are connected to the appropriate iPads. Open the MakeBlock App → Click Bluetooth Button on the top, right-hand corner and the system will begin to search for the robot.
2. Using the MakeBlock App, use the "Play" program in the software to review basic commands with the students.
   NOTE: This does not cover basic programming, but rather shows them basic controls of robots such as drive.
3. Review the "Draw and Run" and "Avoid Obstacle," explaining each sensor. A printable guide to the basics of the "Play" is available in Appendix A.5.
4. Explore the sensors: Color (LEDs), Ultrasonic, and Speaker, etc.

Activity #3

Estimated Time: 60-90 min

Title: Program Your Robot

Lesson Overview: Students will build their robot using diagrams from the handbook. In addition, they will create, test, and run programs to control a robot.

Objectives:

1. Students will use problem-solving skills to read and interpret diagrams to build a robot.
2. Students will use problem-solving skills to create, run, and test programs created to control a robot.

Materials Needed: (per group)

- mBot Ranger 3-in-1 Educational Robot Kit
- iPad
- Makeblock and mBlock Blockly application software installed on iPad
- Overhead projector to view programming software
- Journal (per student)

Lesson Flow:

1. Using the Makeblock App, scroll to the "Code" section – this will open the mBlock Blockly application to begin lessons on coding. Select the Ranger: Robot. Students are going to program simple commands to control a robot. They will learn to code utilizing the Ranger: Land Ranger menu. This will take them through an entire programming guide – Lesson by Lesson. See Appendix A.6 Coding with mBot Ranger.
   a. Program the robot to move in a straight line for one meter, play with sounds and lights.
   b. Once students have accomplished this task, students should now program their robot to move forward for one meter, wait one second, and then move in a straight line backwards for two meters.
2. To see an example of the Makeblock Software, you can go to the Makeblock Website. Select Education → Resources→ Coding Examples.
3. Have students test their program after every block to make sure it works correctly.

Activity #3A

(Instead of or along with the line follower and light sensor programing)

Estimated Time: 60 minutes

Title: Active Sign Creation

Lesson Overview: Students will learn about signs and signals and their meaning and significance.

Objectives:

1. Identify and interpret all passive railway safety signs.
2. Distinguish between "passive" and "active" signs and signals.
3. Create an active sign using mBot Ranger.

Materials Needed: (per group)

- mBot Ranger 3-in-1 Educational Robot Kit
- (optional) MagLev Train Educational Kit
- Cutout of safety signs available in Appendix A.2 or at:
  http://oli.org/education-resources/safety-tips/know-your-rails-signs-and-signals

Lesson Flow:

1. Ask students to share the usual route they take to school. Then, ask if they crossed any train tracks on the way. Engage them in further dialogue about the types of signs they noticed at a railroad crossing.

2. Show the video of train accident in which a person tried to get around the train tracks even though the lights were flashing. Go to:
   http://www.cnn.com/video/data/2.0/video/us/2014/04/03/lv-vo-train-slams-into-suv.cnn.html.
   View the video and engage the students in a discussion about the video.

3. Go to http://oli.org/education-resources/safety-tips/know-your-rails-signs-and-signals and show the students the various railway safety signs.

4. Tell students that the type of signs they will now have to create are "active" signs. 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." Discuss the flashing red lights, the bells, the gate, and the cantilever. Point out that the bells and flashing red lights are active signs. They will now use their robots to create an "active" sign. They may use any sensors they choose. The sign should activate with an incoming "train" (use Maglev components).

Activity #4

Estimated Time: 35 – 45 min

Title: Light Sensor Programming

Lesson Overview: Students will create, test, and run programs to command a robot to respond to a change in light intensity

Objectives:

1. Students will use problem-solving skills to read and interpret diagrams to build a robot.
2. Students will use problem-solving skills to create, run, and test programs created to control a robot.

Materials Needed: (per group)

- Land Raider Robot constructed
- iPad
- Makeblock and mBlock Blockly application software installed on iPad
- Overhead projector and display screen to view programming software
- Journal (per student)
- Dark place for your robot
- Flashlight

Lesson Flow:

1. The "Light Sensor" programming is available in Appendix A.7.
2. Before students begin programming, connect the robot via Bluetooth to the iPad. Press the button in the middle of the block to turn it on and follow the Makeblock App directions for Bluetooth.
3. **Scientific Knowledge**: A *semiconductor* is a kind of material whose conductivity is between that of an insulator and that of a conductor. A semiconductor's conductivity can be controlled in various ways. Common semiconductor materials include silicon, germanium, gallium arsenide, etc.

   A *photoresistor* is a kind of semiconductor whose conductive characteristics can change with light intensity. When the material is stimulated with light energy, the photoresistor will produce more conductive free electrons to reduce the resistance and allow more current to flow through. Therefore, it is used as an electronic component to convert optical signal to electrical signal.
4. Have students follow the "Light Sensor" programming steps to program their robot to recognize and respond to light intensity with a command.
5. Have students test their program after every block to make sure it works correctly.

Activity #5

Estimated Time: 35 – 45 min

Title: Music Making with mBot Ranger – The "Buzzer" Program

Lesson Overview: Students will create, test, and run programs designed for a robot to play a music piece utilizing the mBot Ranger.

Objectives:

1. Students will use problem-solving skills to read and interpret diagrams to build a robot.
2. Students will use problem-solving skills to create, run, and test programs created to control a robot.

Materials Needed: (per group)

- Land Raider Robot constructed
- iPad
- Makeblock and mBlock Blockly application software installed on iPad
- Overhead projector and display screen to view programming software
- Journal (per student)

Lesson Flow:

1. Introduce vibration and the idea that an object produces vibration (source). This vibration compresses the air around it (medium), and radiates outwards as waves (sound wave). This sound wave travels into the ear canal until it reaches the eardrum. The eardrum passes the vibrations through the middle ear bones or ossicles into the inner ear. Hair cells in the inner ear then change the vibrations into electrical signals that are sent to the brain through the hearing nerve. This is how sound is heard.
2. Emphasize the idea that range of human hearing is commonly between 20 Hz to 20000 Hz, which is why we cannot hear very low or very high frequencies. Hertz (Hz) is the unit of frequency, defined as the times of change per second. The sound we usually hear not only includes different frequencies, but also includes different intensities and tones.
3. Explain the following definitions:

   Sound volume: the loudness of the sound (intensity).

   Pitch: the pitch (low/high) of the sound. It depends on frequency of the sound wave. The higher the frequency of a waveform, the higher the pitch of the sound you hear.

   Tone: the characteristics of the sound. Different instruments have different tones.
4. Lesson can be found in the www.makeblock.com → Education → Resources → Ranger, The Mars Adventure of Mark

5. The "Buzzer" Program is available in Appendix A.8 Creating Musical Materpieces with mBot Ranger.

6. Introduce students to their next activity: Program robot to follow a line along a curved path while responding to different colors (safety signs) on the test path.

7. Print the Tone and Frequency Table Found in Appendix A.8.

8. You can visit http://www.mblock.cc/edu/7-play-music/ for a video tutorial.

Activity #6

(In place or added to build and program dashing raptor or nervous bird)

Estimated Time: 45 min

Title: Was the Train Exceeding Maximum Speed

Lesson Overview: Students will build a simulation of a train crash. They will program the train (robot) to crash against a cardboard box. The robot should accelerate until just before the collision and coast to the cardboard box. The ramp gears must be used in this assembly to maximize speed. The values for the calculations are provided below, and students should be guided towards finding the speed value using algebra and dimensional analysis.

Objectives:

1. Students will use problem-solving skills to read and interpret diagrams to build a robot.
2. Students will use problem-solving skills to create, run, and test programs created to control a robot.
3. Students will calculate the mass of a train by using Newton's 2nd law.

Materials Needed: (per group)

- Land Raider Robot constructed
- iPad
- Makeblock and mBlock Blockly application software installed on iPad
- Overhead projector and display screen to view programming software
- Journal (per student)
- Worksheet

Lesson Flow:

1. Begin by explaining to students that they will be designing and programming a "Train" to simulate a crash site.
2. Before students begin programming, connect each robot to the iPad using Bluetooth. Press the button in the middle of the block to turn it on and sync to the device.
3. This program is completely open-ended. Encourage students to use their creativity and imagination.
4. Create and build.

Discussion Activity: Energy, Work, and Power

1. Ask students what they think about when they hear the word "energy."
   a. *How do you use energy in your life?*
   b. *Name a few things that we do that use energy. What happens when we don't have enough energy?*

2. Explain to students the difference between our everyday definition for energy, and the scientific definition.

   Energy: *Energy is the capacity of a physical system to **perform work**. Energy exists in several forms such as heat, kinetic, potential, mechanical, light, electrical, magnetic energy, or other forms.*

3. Introduce students to the terms *force*, *work*, *energy*, and *power*. Give some everyday examples of each term.

4. Explain the formulas for computing force, work, and power to students.

$$Force = mass \ \times acceleration$$

$$Acceleration = \ \frac{Final \ \ velocity - Initial \ \ velocity}{Final \ \ time - Initial \ \ time}$$

$$acceleration \ \ due \ \ to \ \ gravity = [9.81 \frac{m}{s^2}]$$

$$Work = force \ \ \times \ \ distance$$

$$Power = \ \frac{Work}{time}$$

Using the above equations, guide students to calculate the speed of the train in the accident.

Additional Resources:

➢ How to use Vernier Probes
- Photogate Video: https://www.youtube.com/watch?v=AzDjp3ifDek
- Motion Detector Manual: http://www.vernier.com/manuals/md-btd/
- Dual-Range Force Sensor Manual: http://www.vernier.com/manuals/dfs-bta/

Activity #7

Estimated Time: 30-45 min

Title: Build and Program Dashing Raptor and Nervous Bird

Lesson Overview: Students will build a Dashing Raptor or Nervous Bird using the mBot Ranger 3-in-1 Educational Robot Kit Manual. They will program the Raptor or Nervous Bird to perform several tasks.

Objectives:

4. Students will use problem-solving skills to read and interpret diagrams to build a robot.
5. Students will use problem-solving skills to create, run, and test programs created to control a robot.

Materials Needed: (per group)

- Dashing Raptor or Nervous Bird Robot constructed
- iPad
- Makeblock and mBlock Blockly application software installed on iPad
- Overhead projector and display screen to view programming software
- Journal (per student)

Lesson Flow:

5. Begin by explaining to students that they will be designing and programming a Nervous Bird or Dashing Raptor.
6. Appendix A.9 Dashing Raptor and Nervous Bird Design Examples has two images of possible robot designs.

Day 4 - Transportation Design Challenge!

Activity #1

Estimated Time: No time limit (up to teacher)
Title: Build and Program an mBot Ranger
Lesson Overview: Students will work through a realistic scenario challenge to learn the practical applications of the force, mass, and acceleration concepts in the transportation industry.
Objectives: Students will apply engineering design principles to a real-life scenario. In addition, students will apply principles of Newtonian physics to a real-life scenario.
Materials Needed: (per group)
- Small scale
- Small ramp
- Balloon hitch
- Lamp (Or other source of lighting)
- Black masking tape or vinyl electrical tape to delineate the challenge course
- Prize for winning team: to be determined by the teacher
- Journal (per student)

Lesson Flow:
1. Introduce students to the challenge at hand, letting them know this challenge will be judged. A winning team will be selected.
2. Introduce the challenge:

    A North Atlantic Rail freight train derailed near Edinburg, TX spilling an unknown number of barrels carrying hazardous chemicals. Your team has been hired by XXX Corporation to be the first responders to the site of this accident. Your team of engineers must create and program your mBot Ranger robot to:

    a. inspect the area where the hazardous materials have been spilled;
    b. remove the derailed train railcars from the accident site;
    c. check the rail tracks for any damage and ensure that they are safe to use; and
    d. signal the engineers on site by playing specific signals for safety or for hazards found on the accident site.
3. Explain to students that they will be judged on:
    a. Design, efficiency, and reliability of each mBot Robot constructed.
    b. Their PowerPoint Presentation on the design process they followed.

4. Additional Guidelines: Students can use the MagLev train kit and accessories to simulate the derailment of the North Atlantic Rail freight train described above. Students will be judged on their creativity and imagination in simulating the events leading to this accident.
5. Students will need to design and construct two mBot robots.
   a. Each model needs to be created from a different core set and must implement a balloon hitch transport hanging objects in the accident site.
   c. Appendix A.10 shows a schematic of the balloon hitch.

_____

Day 5 - Final Design Challenge and Competition!

Activity #1

Estimated Time: No time limit (up to teacher)

Title: Final Design Challenge and Competition

Lesson Overview: Students will participate in hands-on investigative activities that will allow them to apply their understanding of Newtonian physics and robotics to create a positive train control (PTC) mechanism. Students need to devise a more creative/effective PTC which *does not* stop the train *abruptly* (i.e., no railway debris, crashes, etc.).

Objectives:
1. Determine the best freight train design that will stop the train at the end of the ramp without crashing or obstructing the rail track in any way.
2. Define and investigate effective PTC techniques.
3. Evaluate various engineering freight train designs.

Materials Needed: (per group)
- Constructed Ranger Robot (act as locomotive)
- Stopwatch
- Ramps/inclines
- Tunnel
- Colored Electrical Tape (black, red, green, yellow, white)
- Protractor
- Miscellaneous materials (magnets, rubber bands, paper clips, etc.) for students to utilize in creating an effective PTC mechanism
- Railcars added to the robot (various toy cars that can be attached to the robot to generate freight cars.
- Journal (per student)

Lesson Flow:

1. Explain to students the following hypothetical scenario:

The Acme Train is starting a new trade route through a region that has rough and dangerous terrain. Your team has been hired by ZZZ Corporation to engineer a true PTC system for the train. Your team of engineers must create and program your mBot robot to:

a. go through the mountainous terrain involving ramps and tunnels;

    b. be able to push off any debris that the mountains and avalanches have dropped on the rail and keep the freight intact.

2. Explain and make sure that the students know they will be judged on:
   a. checking the tracks for any damage; and
   b. signaling the engineers on site by playing specific signals for safety or for hazards found on the dangerous track.
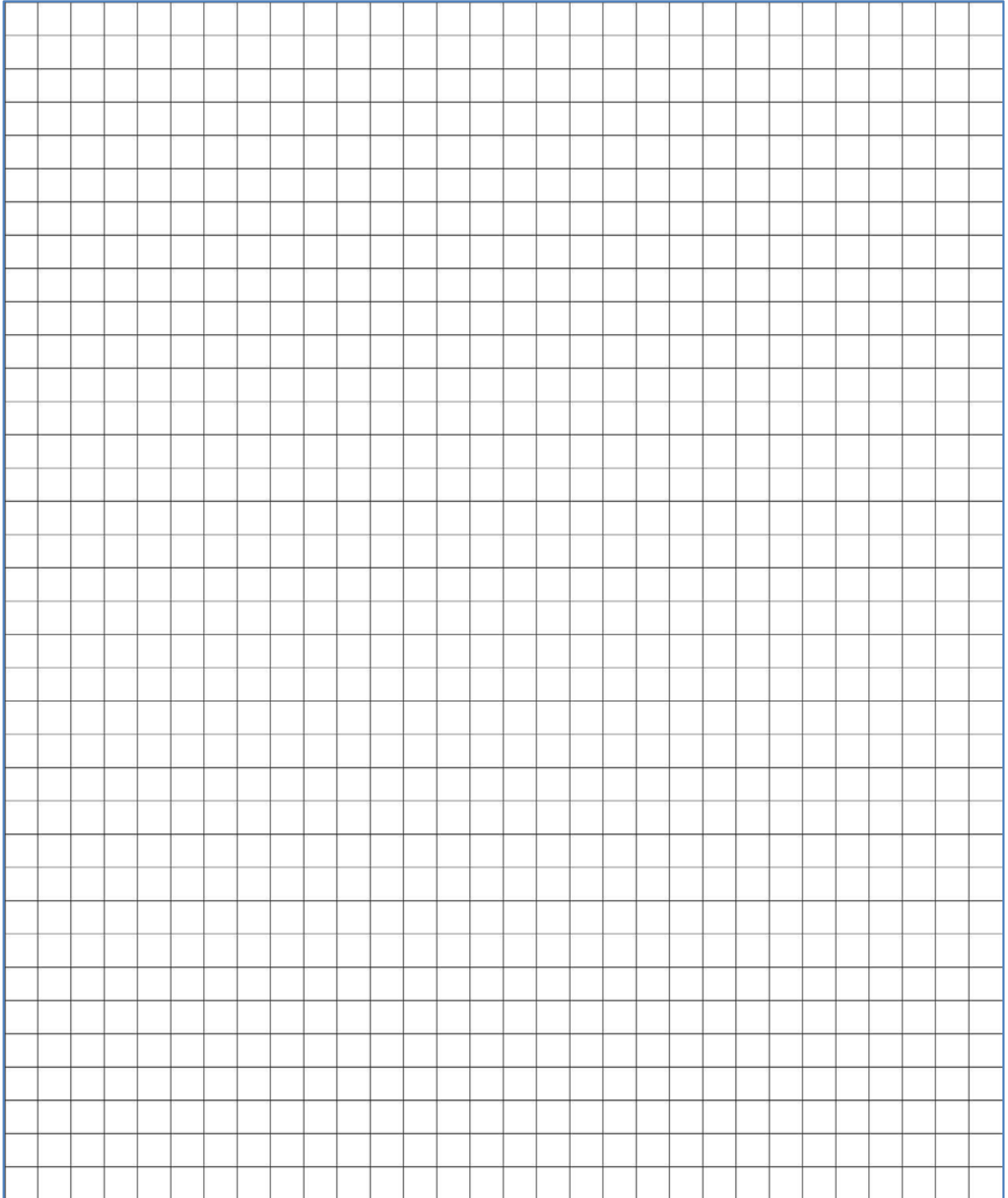   c. the amount of time it takes to accomplish tasks "a" and "b."

Appendices

Appendix A. Worksheets and Guides

Appendix A.1 Speed and Incline Data Table

Angle	# of Washers P	Distance Traveled X [cm]	Elapsed Time T [sec]	Mass m [kg]	Acceleration a [m/s^2]	Force $F = m{\cdot}a$ [N or kg·m/s^2]	Potential Energy PE [J or kg·m^2/s^2]	Kinetic Energy KE [J or kg·m^2/s^2]
0°	5							
10°	5							
20°	5							
30°	5							
40°	5							
60°	5							

Appendix A.2 Graph Paper

Appendix A.3 Mass, Force, and Acceleration Data Table

# of Washers	Distance Traveled	# of Magnets	Elapsed Time	FOM	Mass	Acceleration	Force
P	X [cm]	N	T [sec]	$\dfrac{P \cdot X}{N \cdot T}$	m [kg]	a [m/s²]	$F = m \cdot a$ [N or kg·m/s²]

Appendix A.4 Magnet and Acceleration Data Table

Trial	# of Washers P	Distance Traveled X [cm]	# of Magnets N	Elapsed Time T [sec]	FOM $\dfrac{P \cdot X}{N \cdot T}$	Mass m [kg]	Acceleration a [m/s^2]	Force $F = m \cdot a$ [N or kg·m/s^2]
1	0		4					
2	5		4					
3	10		4					
4	15		4					
5	20		4					
6	25		4					
7	30		4					
8	35		4					
9	40		4					
10	45		4					
11	50		4					
12	75		4					
13	100		4					
14								
15								
16								
17								
18								
19								
20								

Appendix A.5 Basics of the mBlock Ranger Robot

Getting to know the Me Auriga (the mainboard of the mBot Ranger):
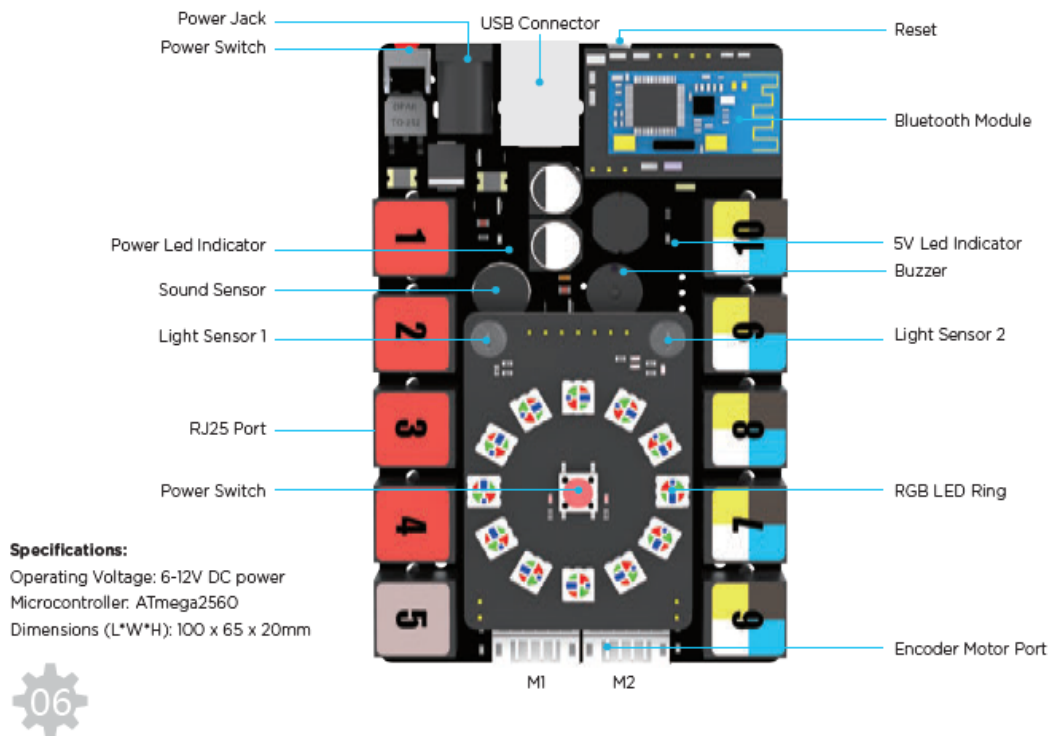
Based on Arduino Mega 2560, Me Auriga includes 10 easy-to-use RJ25 ports and 12 RGB LEDs. It integrates various sensors, such as gyro sensor, temperature sensor, light sensor and sound sensor. mBot Ranger Robot Kit also comes with two additional sensors: an ultrasonic sensor and a line follower sensor. These two sensors can be connected to the expansion ports of Me Auriga via RJ25 port, allowing mBot Ranger to move freely in various scenes.

The Bluetooth module in this kit enables you to connect Ranger with smartphones, tablets, or computers. You can also add a 2.4G module to realize wireless control over mBot Ranger, which is very suitable for teaching in the classroom.

Power Switch: turn on/off the power supply

Power Jack: can be connected with an external 6-12V power supply

USB Connector: can be used for data communication with computer or downloading programs from computer

Reset Button: restart the program on mainboard

Bluetooth Wireless Communication Module: can be used for data communication with computer or be connected with smart devices e.g. smart phones, tablets

Motor Expansion Port (1-4): can be connected with all kinds of motors, e.g. stepper motor driver

Sensor Expansion Ports (6-10): can be connected with various sensors, e.g. ultrasonic sensor

Sound Sensor: convert sound vibration to data of voltage variation through a microphone

Light Sensor 1 & 2: convert light variation to data of voltage variation through a transistor

Temperature Sensor: convert temperature variation to data of voltage variation through a thermistor

Ultrasonic Sensor (Must Connect): detect distance between the sensor and the objects in front of it

Line Follower Sensor (Must Connect): detect reflected infrared light from objects

Me 3-Axis Accelerometer and Gyro Sensor: measure the angular rate and the acceleration information

Buzzer: an electronic module that emits a sound via vibration produced by the varying voltage

RGB LED Ring: every RGB LED can be programmed to combine three colors (red, green, and blue) to produce various light colors

Hardware Serial Port (5): can be connected with Bluetooth module or 2.4G module

Start Me Auriga
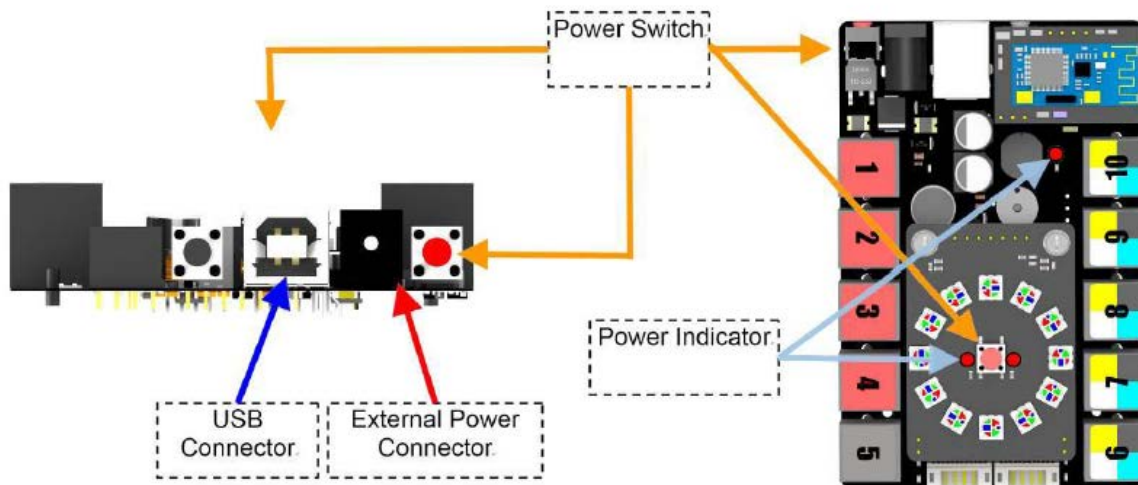
USB power supply:

We can connect the mainboard with the computer via USB when the mainboard is not driving motors. After connecting with the computer, the 5V LED indicator on the mainboard will light up.

External power supply:

If you want the robot working on its own (without connecting with the computer), or you want to use motors or 1-4 ports in the operation, please make sure you use an external power supply. After

connecting with the external power supply, press the power switch (the one in the middle of the RGB LED ring or the one next to the power jack). At this time, the Power LED Indicator on the mainboard will light up.

Turn off the power supply of Me Auriga (Mainboard)

You can press the power switch for 3-8 seconds to turn off the power supply. If the mainboard is still connected with the computer, turning off the power supply will stop the operation of motors and 1-4 ports, but the program in the mainboard will continue working.
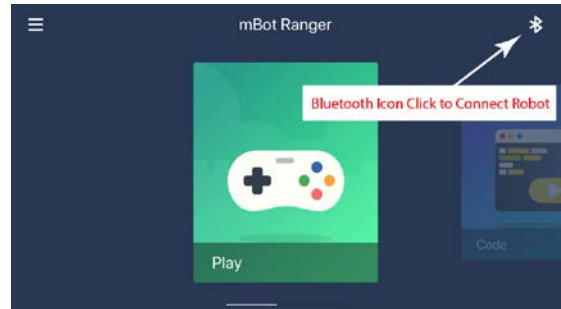
Connecting your mBot Ranger

Open the Makeblock App on the iPad . Connect your robot via Bluetooth, the system will prompt you for the robot when you open the program. If the system does not prompt you, then click on the icon as seen on the image on the right.
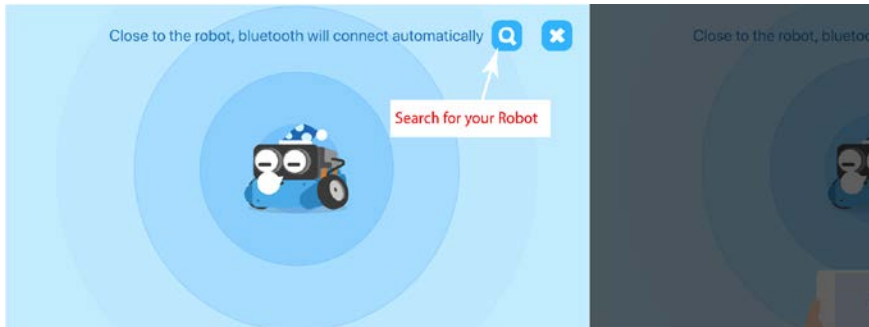
Steering your mBot Ranger

Once your robot has been paired with your iPad. Select the "Play" Menu. In the menu, you will see the different scenarios. Select "Drive."
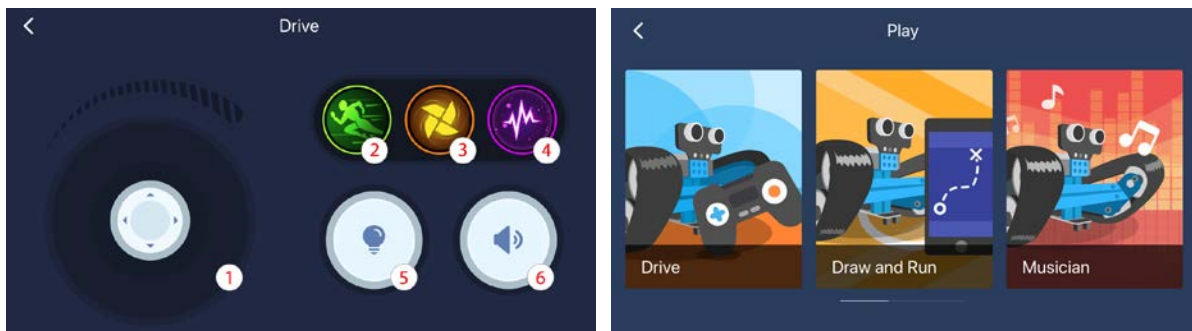
The "Drive" mBot Robot Management Interface controls are listed as follows:

1. **Digital Joystick:** Direction and speed of the robot
2. **Sprint:** moving forward at high speed
3. **Spin:** mBot will be spinning
4. **Trick:** click and mBot will dance
5. **Lights:** Turn lights on and off
6. **Sound:** Play short sound

Once the students have explored these controls, allow them to go back and interact with the "Draw and Run," "Musician," "Voice Control," "Line Follow," and "Avoid Obstacle." The "Racing Car" and "Nervous Bird" options are for alternate builds that are developed in Activity #3A.

Creating an Custom Control Interface

To create a custom control interface, open the Makeblock App and scroll to "Create."
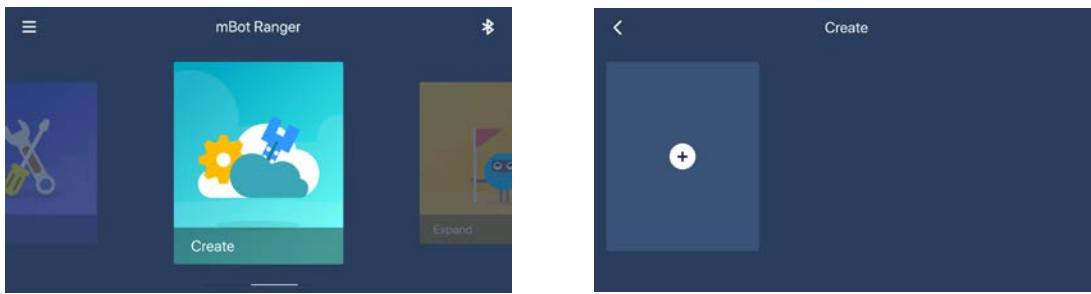
This feature will allow you to add custom controllers for better maneuverability. Select the "Plus Icon" to load "Move", "Display", "Sense", and other "Custom" features. Below are a list of the various menus and possibilities for your custom controller interface. Each of these can be placed on the design palette. By placing your finger on the controller for about a second will bring up a menu that will allow you to assign a "Port" (when involving a sensor), "Code", or "Delete." The menu panel for all the features can be opened and closed by selecting the bottom, left-hand corner + and x icons.

Move:

1. **Circular Digital Joystick:** Adjust direction and speed of the robot
2. **Square Digital Joystick:** Adjust direction of the robot
3. **Speaker:** Allows the user to speak commands to your robot

4. **Sprint:** mBot Ranger will sprint
5. **Shake it:** mBot Ranger will dance
6. **Control with Gravity:** Allows the user to utilize the sensors in your iPad or tablet to control the robot by tilting forward, backward, left, or right
7. **Path Control:** Allows the user to draw a path for the robot to follow
8. **Obstacle avoidance:** Keeps the mBot Ranger moving and avoiding obstacles
9. **Line Following:** Allows the robot to follow a line.
10. **Encoder Motor 1:** Allows motor M1 to move at a specific speed.
11. **Encoder Motor 2:** Allows motor M1 to move at a specific speed.

Display:

1. **Buzz:** mBot Ranger makes a sound
2. **Lightness:** Changes the strength of the LEDs on the top of the ranger
3. **Random:** Changes the LED color to a random color
4. **LED Color:** Changes the LED color to a specific color
5. **Marquee:** Makes the LEDs in the ranger alternate in a circle
6. **Radar Warning:** The LEDs in the ranger shine like a radar light

Sense:

1. **Ultrasonic Digital:** Shows the ultrasonic sensor readings numerically
2. **Ultrasonic Graph:** Shows the ultrasonic sensor readings graphically
3. **Brightness Digital:** Shows the light sensor readings numerically
4. **Brightness Graph:** Shows the light sensor readings graphically
5. **Loudness Digital:** Shows the speaker sensor readings numerically
6. **Loudness Graph:** Shows the speaker sensor readings numerically
7. **Temperature Digital:** Shows the temperature sensor readings numerically in Celsius
8. **Temperature Graph:** Shows the temperature sensor readings graphically in Celsius
9. **Line Follow Sensor:** Turns the sensor on and off

Custom:

This feature allows you to customize various sensors by editing the code. This can be done by placing the code on the design palette and placing your finger on the controller for about a second. This will bring up a menu that will allow you to "Code" or "Delete". By selecting "Code," the coding interface will pop-up allowing you to program each of these features:

10. **Line Graph:** Allows the user to see a sensor's readings in a line graph
11. **Dashboard:** Allows the user to see a sensor's readings as a meter
12. **Indicator:** Off-switch for a sensor or action
13. **Slider:** Reduces or increases an action or sensor's input

Appendix A.6 Coding with mBot Ranger

Coding your mBot Ranger

Open the Makeblock App on the iPad. Connect your robot via Bluetooth, see Appendix A.5 Basics of the mBlock Ranger Robot to recall how to connect the robot. Once your robot has been paired with your iPad. Select the "Code" Menu. This menu will re-direct you and open Makeblock Blockly.
If your Ranger is paired up then the following menu should show up:
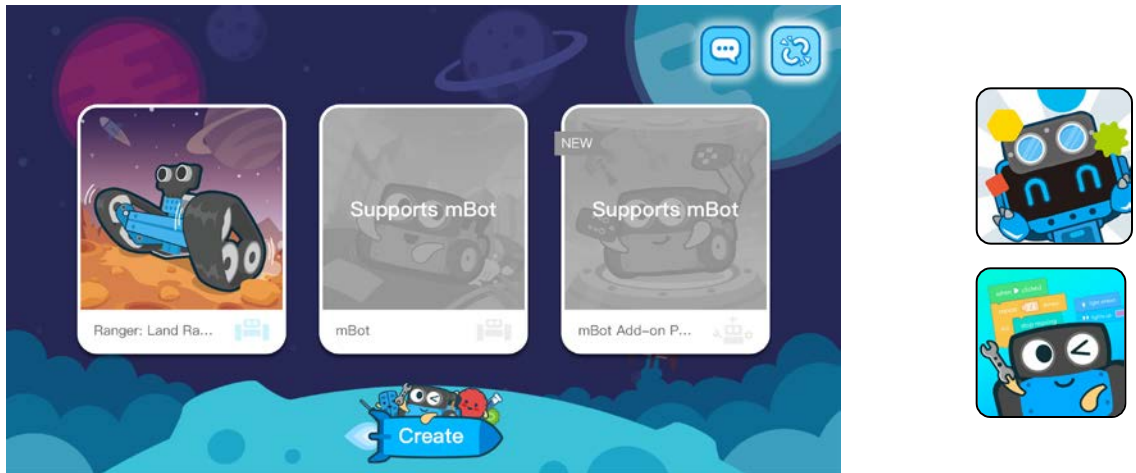
Select the Ranger: Land Ranger to open up the coding tutorial. The tutorial will begin with sequencing
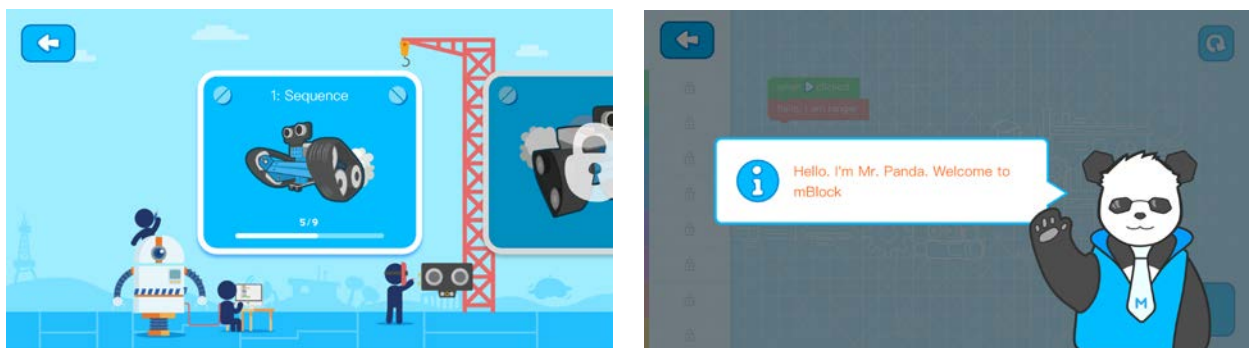
The tutorials will walk the students through learning how to code utilizing the various lessons. They will start with the sequencing lesson, move through the rest of them, and learn how to use each of the sensors that the robot board contains. Here are the list of the lessons:

1. **Sequence**
2. **Sound and Light**
3. **Loop**
4. **Ultrasonic**
5. **Following**

6. **Condition**
7. **Comparison**
8. **Lighting**
9. **Numbers**
10. **Variables**

Once the students meet the lesson objectives, they will be able to create their own programs by clicking the create button at the bottom of the screen:
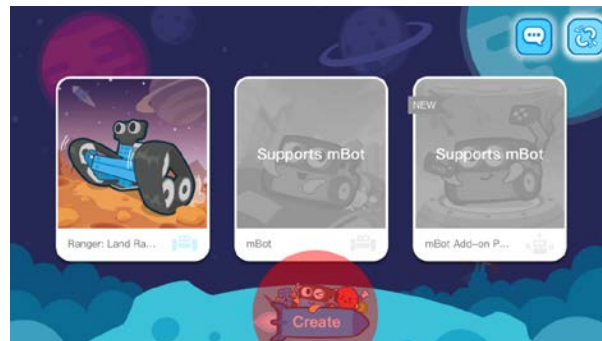
This will open the coding functionality and you will get a screen like the one below. Get to coding!
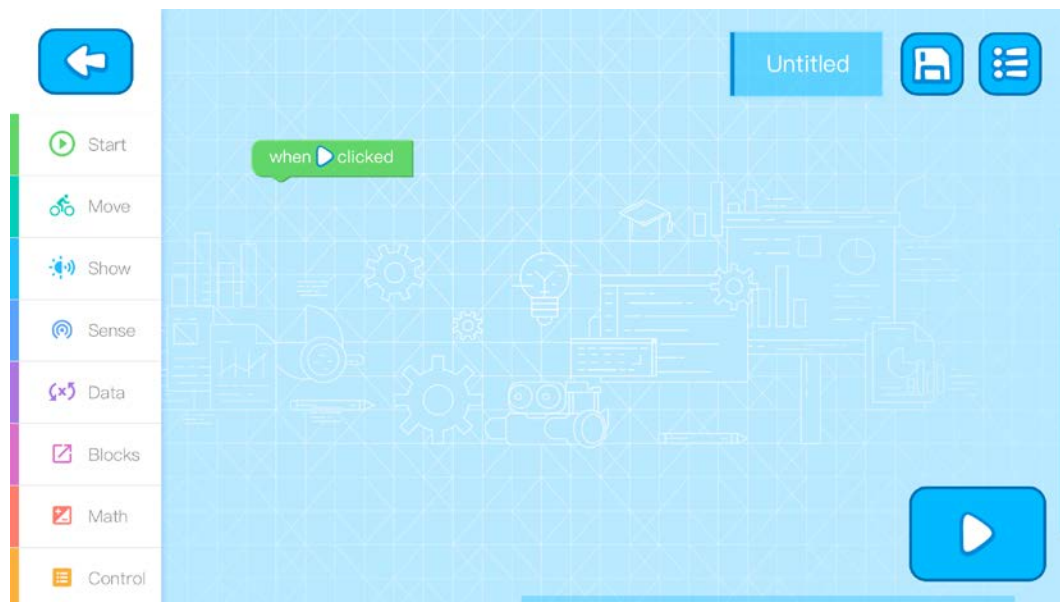
Appendix A.7 Light Sensor Program

Me Auriga uses two photoresistors whose conductivity can be altered by varying light intensity. As such, you will need the robot to be in a dark place and have a flashlight accessible.
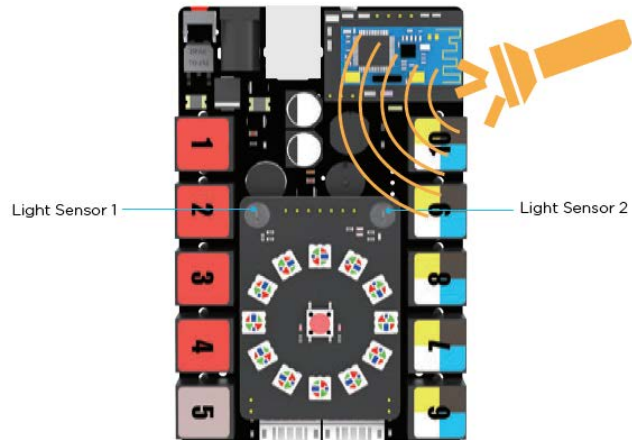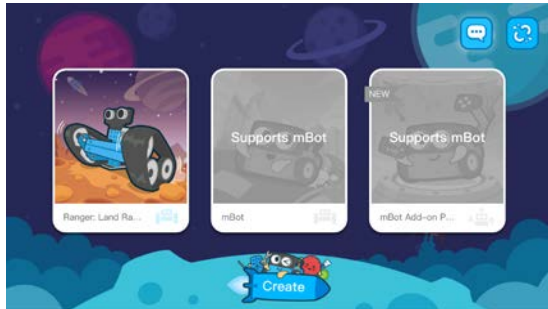
Once you have opened the Ranger coding tutorial. Go to the "Lightness" tutorial. The lesson will walk you through moving your robot by varying the light intensity.
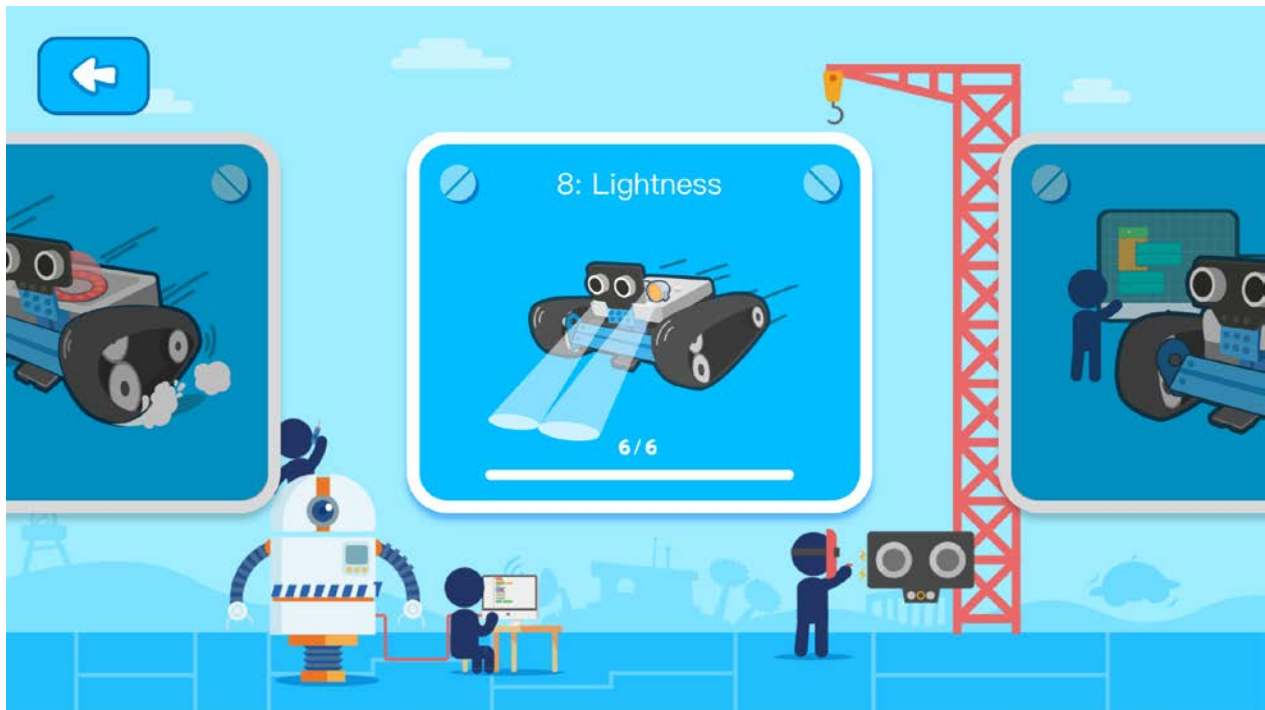
Appendix A.8 Buzzer Programming – Creating Musical Masterpieces with mBot Ranger

Me Auriga uses a passive buzzer as the sound device. *Passive* means the buzzer does not contain an oscillator circuit; hence, the frequency of the sound made by this buzzer is fully determined by the output signal of Me Auriga.

The buzzer is located between the expansion port 9 and port 2 on the Me Auriga. Connect your robot via Bluetooth and run through the "Sound and Light" Lesson on the iPad and be ready to code to make specific tones with the buzzer!
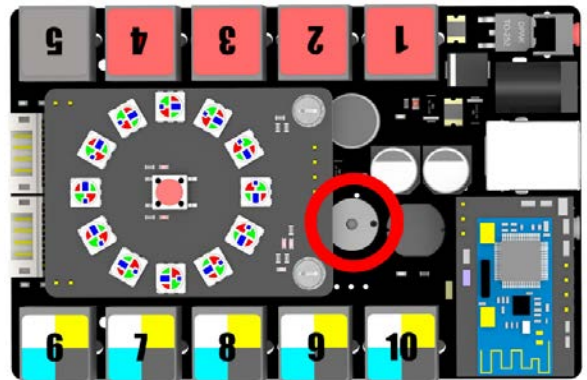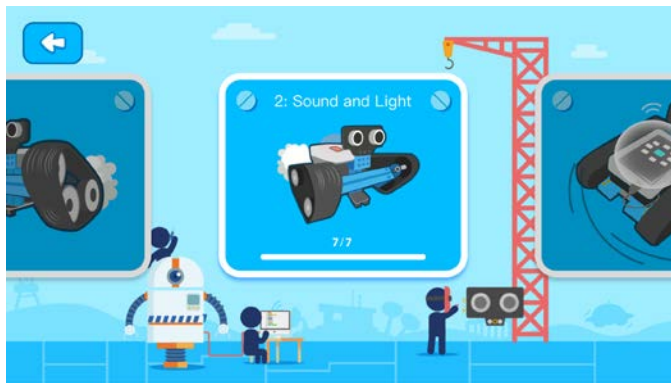
Figure: Play-Tone Command

The function of this block: control the sound of the buzzer on Me Auriga

Parameter Selection

Tone: set the tone (low or high) of sound, expressed as note names (C4 stands for Do).

Beat: set the length of sound, expressed as fractions (half beat represents 0.5 milliseconds). Click the inverted triangle to select different values in the drop-down list. The buzzer will stop according to the beat you set:

Beat and Time Table

Beat	Length of Time	Note
½ beat	500 ms (0.5 second)	= Eighth Note
¼ beat	250 ms (0.25 second)	= Sixteenth Note
1/8 beat	125 ms (0.125 second)	= Eighth Note
1 beat	1000 ms (1 second)	= quarter note
2 beats	2000 ms (2 second)	= Half Note

Tone & Frequency Table

Syllable	Do	Re	Mi	Fa	Sol	La	Si
Note	C2	D2	E2	F2	G2	A2	B2
Frequency Hz	65.4	73.4	82.4	87.3	98	110	124
Note	C3	D3	E3	F3	G3	A3	B3
Frequency Hz	130.8	146.8	164.8	174.6	196	220	247
Note	C4	D4	E4	F4	G4	A4	B4
Frequency Hz	261.6	293.6	329.6	349.2	392	440	494
Note	C5	D5	E5	F5	G5	A5	B5
Frequency Hz	523.2	587.3	659.3	698.5	784	880	988
Note	C6	D6	E6	F6	G6	A6	B6
Frequency Hz	1046.5	1174.7	1318.5	1397	1568	1760	1976
Note	C7	D7	E7	F7	G7	A7	B7
Frequency Hz	2093	2349.3	2637	2793.8	3136	3520	3951
Note	C8	D8	E8	F8	G8	A8	B8
Frequency Hz	4186	4698.6	5274	5587.7	6271.9	7040	7902

Try it Out!

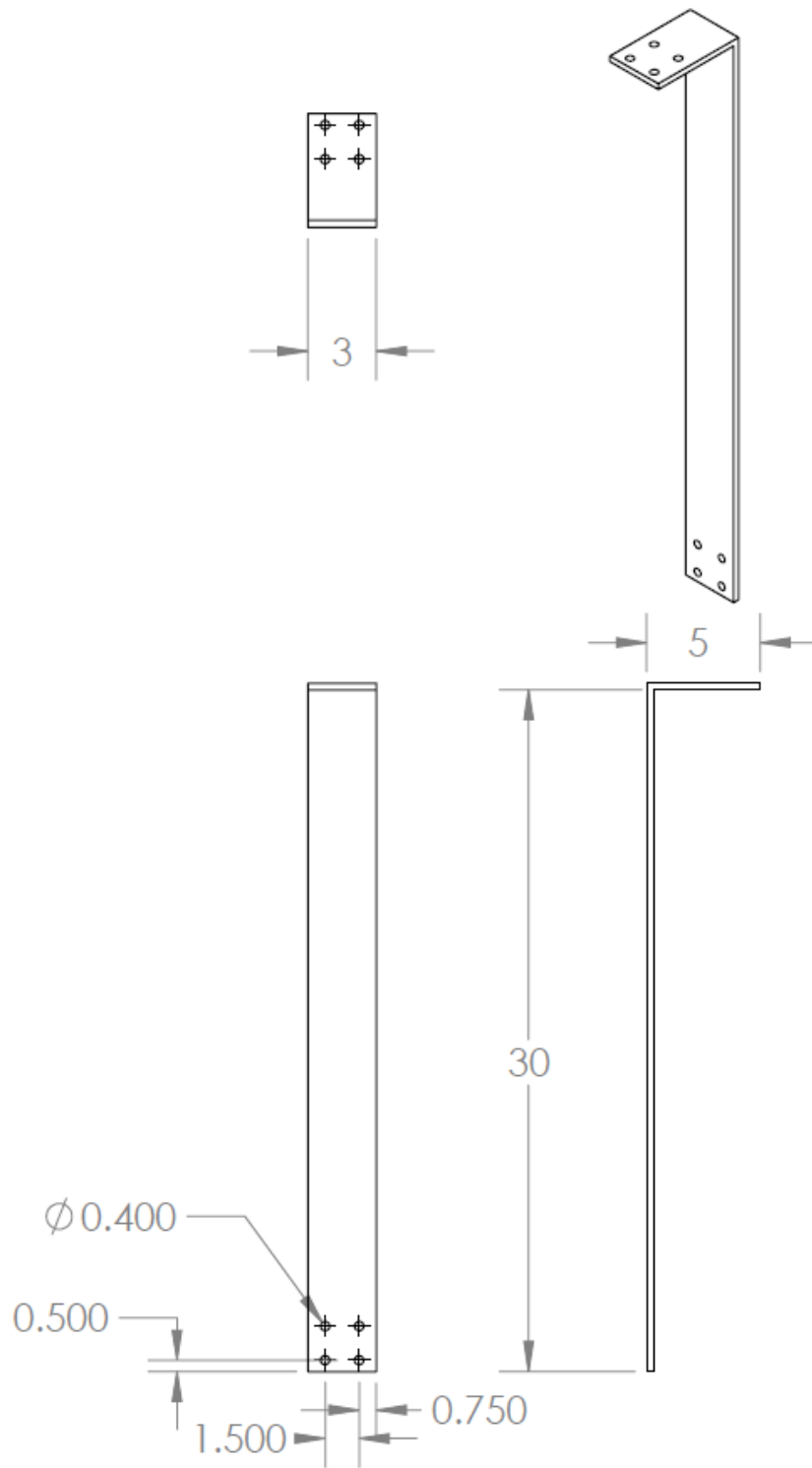*Appendix A.9 Dashing Raptor and Nervous Bird Design Examples*

Nervous Bird
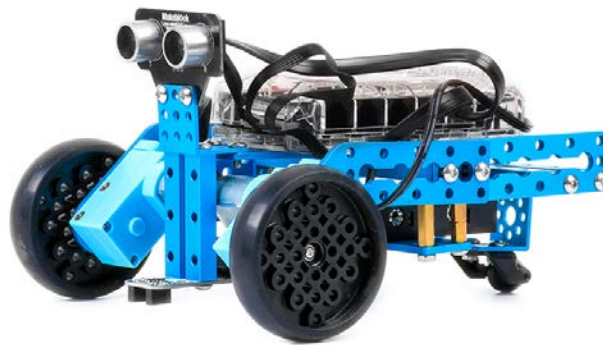
Dashing Raptor

Notes: These robots are very versatile and accommodating. Any number of sensors can be used in conjunction with the Dashing Raptor or Nervous Bird Designs.

Appendix A.10 Balloon Hitch

Appendix B. Video and Resource List

Day 1
Activity #1
Engage video: https://www.youtube.com/watch?v=cXgB3lIvPHI

Activity #2
Photogate:
http://www2.vernier.com/manuals/Logger_Pro_Introduction_to_the_Vernier_Photogate.pdf
Motion Detector Manual: http://www.vernier.com/manuals/md-btd/
Dual-Range Force Sensor Manual: http://www.vernier.com/manuals/dfs-bta/
World's Fastest Trains - MagLev Video: https://www.youtube.com/watch?v=aIwbrZ4knpg
German MagLev design Video: https://www.youtube.com/watch?v=hUATDtZble0
Japanese MagLev design Video:
https://www.youtube.com/watch?v=SUBUTo82EQw#rpctoken=287669679&_methods=setNotifi
cationWidgetSize%2CsetNotificationWidgetHeight%2CsetNotificationText%2ChideNotificationW
idget%2CopenSharebox%2ConError%2C_ready%2C_close%2C_open%2C_resizeMe%2C_renders
tart&id=I1_1446659761580&parent=https%3A%2F%2Fwww.y

Activity #3
Watch: Potential and Kinetic Energy Videos
https://www.youtube.com/watch?v=BSWl_Zj-CZs
https://www.youtube.com/watch?v=iYEWIuQBVyg

Day 2
Make Block Tutorials – Playlist
https://www.youtube.com/playlist?list=PLuuf1TKEkEqQ9_2hGTHx5XRxlyTOVUJzS

Day 3
Traffic Signs and their meanings
https://www.youtube.com/watch?v=41dPJ322pK0
Using the Line Follower: Explore mBot Tutorials #3: Line Following
https://youtu.be/hLMbPLToo-A
Using the Light Sensor Sensor- Explore mBot Tutorial #1: Light Sensor
https://youtu.be/JwDHsSc0u7A

*Play Music with MBlock Robot:

http://www.mblock.cc/edu/7-play-music/

Day 4
Newton's Laws
1st Law:
https://www.youtube.com/watch?v=lbHt5mg_33w
2nd Law:
https://www.youtube.com/watch?v=qu_P4lbmV_I   (NFL)
https://www.youtube.com/watch?v=iwP4heWDhvw
https://www.youtube.com/watch?v=nJTKiS444BQ

Day 5
This video can be used any day.
https://www.youtube.com/user/Makeblock

Additional Resources

mBot Ranger Balloon Fight
https://www.youtube.com/watch?v=aPK6PgTTeAw

Scratch Programming
https://scratch.mit.edu/