MODULE 2: CONNECTED VEHICLES

Lesson 1: CONNECTED VEHICLES DEMONSTRATION

GRADE LEVEL: 6 - 8

Vehicles that communicate with each other creates possibilities whereby the vehicles themselves can work together to protect against collisions, erratic behavior of other drivers, or unexpected roadway conditions. This STEM lesson introduces students to the basic ideas of how vehicles can be interconnected to each other as well as to the transportation infrastructure, to provide driver safety prompts as well as direct vehicle control. Students will work hands on with a small wirelessly controlled model vehicle called a Sphero to demonstrate connected vehicle (CV) ideas.

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Lesson 1: Connected Vehicles Demonstration

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Grade Level: 6 - 8	**Lesson in this Module:** 1 of 1
Time Required: 120-180 minutes	**Lesson Dependency:** None
Keywords: transportation engineering; intelligent transportation systems; connected vehicles	

Related Curriculum

Subject Areas	Science; technology; engineering; mathematics
Curricular Units	Intelligent transportation systems
Activities	Discussion about transportation engineering, discussion about connected vehicles (including a short video), programming activity to demonstrate connected vehicle technology

Educational Standards

This lesson plan and its associated activities are correlated to the national standards in the each of the core discipline areas of STEM: Next Generation Science Standards, American Association for the Advancement of Science Standards, Standards for Technological Literacy, International Society for Technology in Education Standards, Common Core Mathematics Standards, and the National Council of Teachers of Mathematics Standards.

Pre-Requisite Knowledge

None.

Learning Objectives

- Students will be able to explain connected vehicle technology and its applications to transportation.
- Students will learn the basics of programming.

Introduction/Motivation

New technology allows vehicles to be connected together through wireless data communication networks, much the same way that we are in constant communication with each other via cell phones and wireless computer systems. Having our vehicles communicate with each other opens up possibilities whereby the vehicles themselves can work together to protect us against collisions, the erratic behavior of other drivers or unexpected roadway conditions. This STEM lesson introduces students to the basic ideas of how vehicles can be interconnected to each other as well as to the transportation infrastructure, to provide driver safety prompts as well as direct vehicle control. Students will work hands on with a small wirelessly controlled model vehicle called a Sphero to demonstrate connected vehicle (CV) ideas.

Lesson Background & Concepts for Teachers

Transportation engineering, a subset of civil engineering, is an engineering discipline that involves moving people and goods in a safe, efficient, economical, and environmentally-friendly manner. Transportation engineers are frequently tasked with designing roadways for all vehicle types and non-motorized users; selecting appropriate signs, pavement markings, and other traffic control devices; evaluating traffic movement; and programming traffic signals. While some transportation engineers focus on motorized traffic (like cars, trucks, and buses) and non-motorized traffic (like pedestrians and bicyclists), some transportation engineers work with other modes of transportation such as railroad systems and maritime transportation. This lesson will focus on technologies that transportation engineers are using to improve the safety and mobility of motorized, vehicular transportation.

Figure 1: Ford Model T (courtesy of Wikimedia Commons http://commons.wikimedia.org/wiki/File:BourbonStModelT20Nov06Side.jpg)

Keeping the travelling public safe and moving is a large part of a transportation engineer's job. The Ford Model T, produced in the early 1900's, is considered to be the first affordable automobile. Since that time, vehicles have undergone immense changes to improve the safety of its occupants in the event of a crash. Early technologies include simple restraint devices like the seatbelt and airbags, while more recent advancements include specialized cameras that monitor blind spots and other hard-to-see areas.

These special cameras are part of a system of technologies called crash avoidance systems. These systems generally use pre-installed computer programs to identify hazards along the road using images captured by infrared technology or radar devices. Recent examples of crash avoidance systems include forward collision warnings, blind spot detection warnings, lane change warnings, and pedestrian detection systems. These visual based systems are helpful for preventing crashes when a car or object is within the camera view; however, they fail to identify hazards that are outside of the device's field of view.

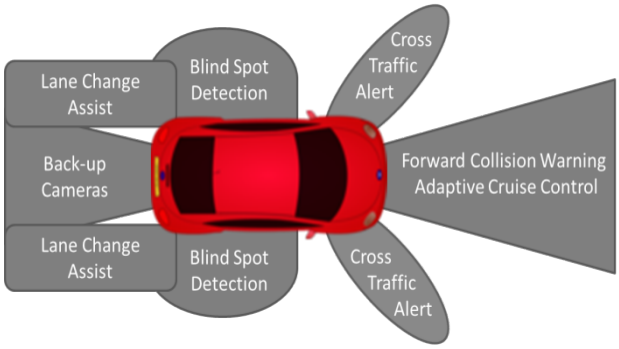

Figure 2: Coverage zones provided by crash avoidance systems (courtesy of Kelly Donoughe)

With the ever-evolving capabilities of technologies, new vehicular safety devices are being developed and refined. The newest system, called connected vehicle technology, has the ability to revolutionize the way cars navigate on the road by essentially providing a 360-degree field of view around a vehicle. The system relies on wireless networks to send messages between cars and transportation infrastructure (roadway, traffic signals, signs, etc.). Generally, vehicles are sending out basic safety messages (BSM) that essentially say "Here I am!" and provide basic location information such as GPS location, speed, and direction of travel. Devices on the transportation infrastructure receive the messages and respond by providing helpful information back to the driver. For example, if a vehicle is approaching a traffic signal, the traffic signal can detect that it is the only vehicle around and provide an automatic green light without requiring the vehicle to slow down. Another example is a vehicle detecting other vehicles quite a ways in front of them slowing down quickly. In this case, messages can be sent to let vehicles know that congestion/quick braking is happening ahead.

This lesson explains three types of intersection-related collision avoidance systems that utilize the connected vehicle technology:

- Red light or stop sign violation: This system sends an alert to nearby vehicles when another vehicle ignores or doesn't react to a red light or stop sign. By warning other drivers that a vehicle has violated or is about to violate the traffic signal or stop sign instructions, the system hopes to prevent crashes by making the other drivers exhibit caution when entering the intersection.
- Signalized left turn assist: This system uses the basic safety messages of all vehicles to identify when a turning vehicle has a sufficient gap in which to turn left. This type of system is especially valuable at signalized intersections that do not provide a protected green light for left-turning vehicles.
- Collision avoidance at intersections: This system uses vehicle-to-vehicle communication to help vehicles proceed through an intersection that doesn't have stop lights or stop signs without colliding with other vehicles. Using the basic safety messages, vehicles communicate their intended path with all other vehicles and the computer algorithms within the vehicles determine how to proceed through the intersection in the safest manner. For example, two

vehicles are expected to arrive at an intersection at the same time. The algorithm slows one vehicle down by five miles per hour and, to compensate, speeds up the other vehicle by five miles per hour in order to offset their arrival times. The system becomes more complicated once more vehicles are considered, but the intent is to find ways to optimize the number of vehicles proceeding through the intersection.

Vocabulary/Definitions

Vocabulary Word	Definition
Transportation Engineering	An engineering discipline that involves moving people and goods in a safe, efficient, economical, and environmentally-friendly manner.
Crash Avoidance Systems	A system of cameras and computers that identify potential crashes and either alert a driver of a potential hazard or automatically apply evasive maneuvers (commonly steering or braking) to prevent a crash.
Connected Vehicles	A system of communications between vehicles and transportation infrastructure that allows vehicles to make their presence known and improve transportation safety and mobility. This technology facilitates communication from vehicle-to-vehicle and vehicle-to-infrastructure (see definitions below).
Basic Safety Message	A message containing a vehicle's telemetry data that is wirelessly sent from one vehicle to another vehicle.
Telemetry Data	Data that describes a vehicles current position. This data may include GPS location, speed, acceleration/deceleration, and direction of travel.
Dedicated Short Range Communication	A wireless communication system used to send basic safety messages between vehicles and the transportation infrastructure or between vehicles and other vehicles
Vehicle-to-vehicle communication	Wireless communication between vehicles (does not require any additional interaction with infrastructure devices).
Vehicle-to-infrastructure communication	Wireless communication between vehicles and the infrastructure such as traffic signals or road signs (also infrastructure to vehicle).

Associated Activities

- **Activity 1 – Transportation Engineering Discussion**
  Begin this lesson by discussing the transportation engineering profession. Suggested questions and answers are provided below.

  - What is the role of a transportation engineer?
    Transportation engineers design our roadways and infrastructure systems to ensure safe and efficient transportation of people and goods. To accomplish this, they use a variety of guide books and manuals to safely design road systems. They also implement technology ranging from visual processing systems to advanced communication systems.

  - What types of problems do transportation engineers solve?
    Transportation engineers try to anticipate safety and mobility issues before they happen, then take steps to alleviate these issues. For example, if a small town is experiencing sudden population growth, a transportation engineer might be tasked to design a new roadway to accommodate the increased traffic on the road. In this case, the engineer will need to determine how many people and what types of people (i.e., pedestrians, vehicles, trucks, etc.) will need to use this road, select an appropriate path for the road, evaluate any environmental or societal concerns (for example, a neighborhood may object to a superhighway being built behind their homes), decide how many lanes to build, choose whether to install any roundabouts, traffic signals, or stop signs, and design the road within a specific budget.

  - How do engineers take safety into consideration when designing transportation infrastructure and systems?
    Transportation engineers always need to think about safety. When a transportation engineer designs a section of roadway, they need to consider things like how fast to set the speed limit, whether to include a stop sign or traffic signal at an intersection, whether the driver's sight will be restricted by vegetation or topography, the type of road users (large trucks, commuters, pedestrians, bicyclists) expected to use the road. All of these considerations are made to decrease a driver's probability of crashing his or her car.
    Automotive engineers also consider transportation safety when designing cars. Previously, most safety innovations were being designed and implemented inside of a vehicle, such as seatbelts and airbags, but in recent years, the automotive industry has been investigating radar and video-based systems to evaluate their surroundings and prevent crashes from happening. These systems are often called "crash avoidance systems". Recent examples of crash avoidance systems include forward collision warnings, blind spot detection warnings, lane change warnings, and pedestrian detection systems. These visual based systems are helpful for preventing crashes when a car or object is within the camera view; however, they fail to identify hazards that are outside of the device's field of view.

- **Activity 2 – Connected Vehicle Video**

  The second activity is to discuss connected vehicle technology. This lesson may start by viewing the connected vehicle video (see **Attachments**), or the instructor may choose to ask the discussion questions first. Suggested questions and answers are provided below.

  - An emerging technology in the transportation industry is connected vehicles. What do you think is the purpose of connected vehicles? How might they change the way you drive?

    Connected vehicle technology is an advanced technology that allows cars to communicate with their surroundings by sending coded messages back and forth. These messages typically include information on a vehicle's telemetry data (location, speed, acceleration/deceleration, and direction), type of vehicle, and more. In case of an emergency or other unexpected event, the messages may also include information such as whether there is a crash ahead, emergency vehicle approaching, or several instances of hard braking.

    The system uses a wireless communication system called Dedicated Short Range Communication (DSRC) to transfer messages in a secure environment. This system allows messages to be transmitted over ½ mile away in each direction so even if a hazard is out of the driver's sight, the driver will be notified and may be provided with instructions for how to reroute their path to avoid delays. Messages may be communicated through a computer screen, by a spoken voice over the sound system, or even through physical vibrations in the steering wheel.

    There are two main communication types: vehicle-to-infrastructure and vehicle-to-vehicle.

    Vehicle-to-infrastructure communication indicates that a vehicle can send and receive information from various roadside communication devices. For example, if a vehicle is approaching an intersection it will send its telemetry data to the roadside device. At that time, the roadside device will determine if there are any other vehicles that are also approaching the intersection. If there are no other cars, the roadside device will send a message to the approaching vehicle and indicate that they are safe to proceed through the intersection. If two vehicles were approaching the intersection at the same time, the device has the ability to indicate which vehicle has the right of way.

    Vehicle-to vehicle communication allows for communication from one vehicle to another. These basic safety messages that are being passed back and forth between vehicles contain GPS data, speed data, acceleration data, and directional data. By knowing the location of all other vehicles on the road, a vehicle can advise against or prevent a driver from making an unsafe maneuver that could damage a nearby vehicle or harm its occupants.

- **Activity 3 – Introduction of the Sphero**
    - The instructor will introduce the Sphero as an example of connected technology. They will demonstrate how the Sphero works and its capabilities.
    - Using the attached lab handout, students will use tablets to develop an understanding of connected vehicles using basic programming skills to program the Sphero. Ultimately, the students will program the Spheros to complete a simple maze or travel through a simulated intersection without colliding with other Spheros.
    - Students will complete a written lab report by summarizing their Sphero activities and answering the analysis questions in the lab handout.

Lesson Closure

- The connection between the Sphero and Connected Vehicles
    - What is the connection between the Sphero and connected vehicle technology?
      The Sphero programming demonstrates vehicle-to-infrastructure communication. Vehicle-to-infrastructure communication acts in a similar manner allowing one vehicle to directly communicate speed, position, heading, and other messages with another vehicle. In the demonstration, the students are acting as the infrastructure devices when they program their "vehicles" to travel through the intersection at a certain speed to avoid a collision.
    - If we were transportation engineers, how would we use these concepts in the real world?
      Programming skills, vehicle trajectory calculations, and accounting for various travel surfaces are all skills that transportation engineers may use on any given day. Transportation engineers use computer programing to integrate connected vehicle technologies, run traffic simulations, and perform calculations. Just as the students may need to adjust their vehicle's programming depending on the type of "road surface" they are traveling on (carpet versus tile), transportation engineers frequently need to consider the road and environmental conditions when designing roadways. A vehicle traveling on dry pavement reacts much differently than a vehicle traveling on an icy road.
    - What other types of maneuvers can you envision the connected vehicle technology doing?
      Connected vehicle technology can enhance nearly any transportation maneuver the students can conceive. The systems capabilities range from collision warnings, to traffic signal optimization, to improving traffic flow at interstate on-ramps and off-ramps, to integrating multi-modal systems (cars, trucks, buses, trains, ferries, etc.), to even helping

a driver find a parking space in a big city. Connected vehicle technologies may one day lead to completely automated driving. The possibilities are endless.

Attachments

- Lab handout for programming Spheros

Extensions/Multimedia

- Connected Vehicle Videos:
    - https://www.youtube.com/watch?v=waGenp5uIt8
    - https://www.youtube.com/watch?v=POcQUTlOvZs&list=PLjP1oRdEKVdRuN4Sk9blVyhdumTalvaQN&index=1
    - https://www.youtube.com/watch?v=kOlL1fWBYAI
- Additional Connected Vehicle Information from the Intelligent Transportation Systems Joint Program Office:
    - Background information: http://www.its.dot.gov/connected_vehicle/connected_vehicle_tech.htm
    - Frequently Asked Questions: http://www.its.dot.gov/connected_vehicle/connected_vehicles_FAQs.htm
    - Research Programs: http://www.its.dot.gov/connected_vehicle/connected_vehicle_research.htm
- Utilize Edmodo (www.edmodo.com) to provide further questioning and discussion between students and teacher. Edmodo is safe social learning website made specifically for teachers and students. It is a way to collaborate on assignments, homework, projects, and after-school STEM programs and is used as a communication tool to provide additional questioning and feedback from teachers and students.
- Students can go to the following website for examples coding activities geared toward a middle and high school level: http://code.org/learn
- Teachers can go to the following website to learn how to implement the "hour of code" into your curriculum: http://hourofcode.com/us/resources/how-to