



University Transportation Center for Railway Safety (UTCRS)

MIDDLE SCHOOL STEM CURRICULUM

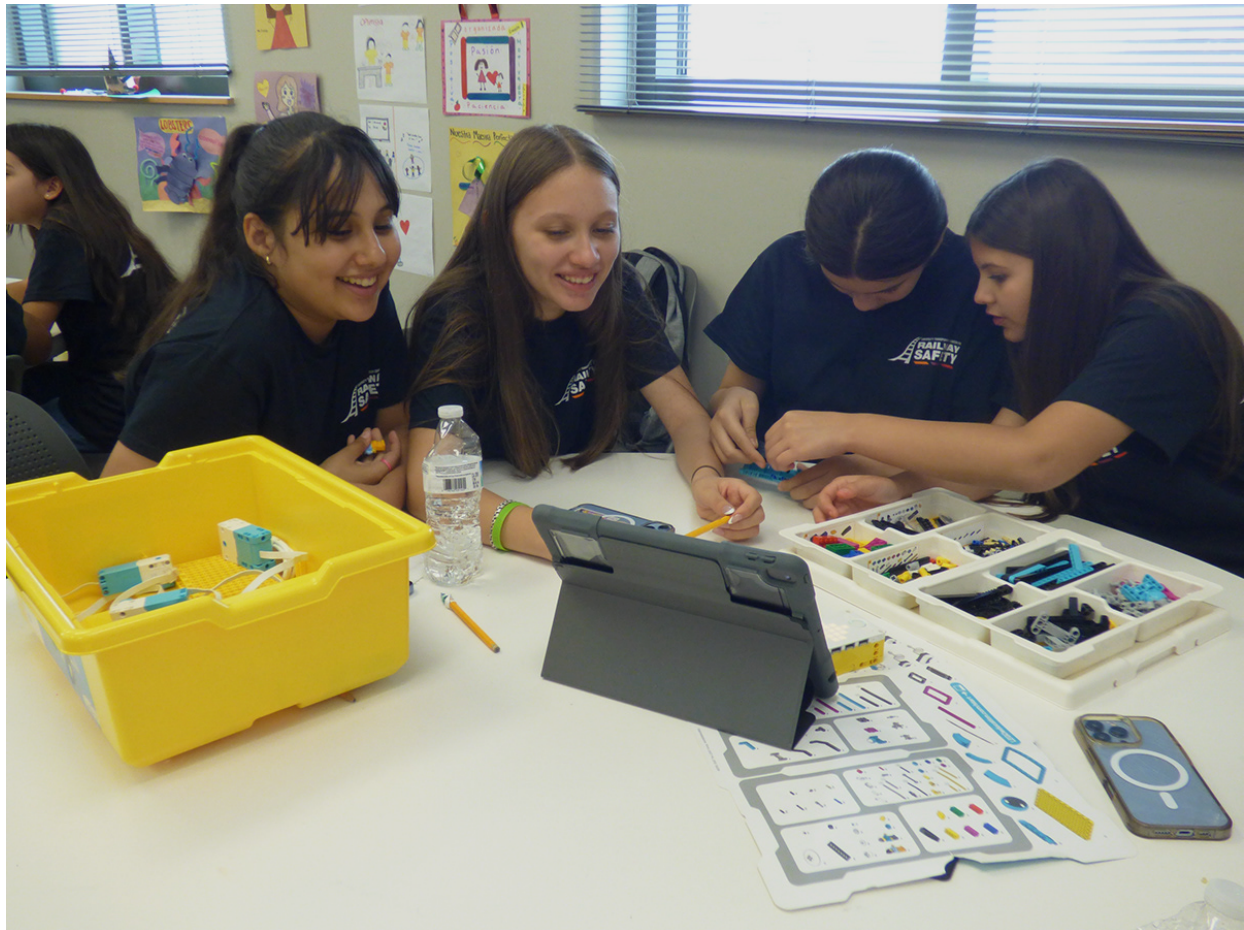




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Learning Objectives

Day 1: Welcome Aboard

Activity #1: I See... I Think... I Wonder...

- Differentiate between observations, inferences, and questions using visual evidence.
- Develop evidence-based explanations by supporting their thinking with observations.
- Generate questions that promote curiosity about engineering and railway transportation.

Activity #2: Balloon Rescue Team Builder

- Demonstrate effective communication and collaboration working within engineering constraints.
- Analyze how changing constraints influence problem-solving strategies and team performance.
- Reflect on the importance of teamwork, adaptability, and communication in engineering design.

Activity #3: What is Engineering? (Think-Pair-Share)

- Explain how engineers apply science, mathematics, creativity, and technology to solve real-world problems.
- Identify the characteristics and habits of successful engineers.
- Evaluate how collaboration, and problem-solving contribute to engineering design.

Activity #4: Engineering Design Process

- Explain the purpose of each stage of the Engineering Design Process.
- Analyze engineering scenarios to determine which stage of the design process is being applied.
- Recognize that successful engineering requires testing, evaluation, and continuous improvement.

Activity #5: Railway Systems: Gravity, Force, Mass, Density, and Energy

- Analyze how gravity, force, mass, density, and energy influence the movement of objects.
- Explain how potential and kinetic energy are transferred as objects move through a system.
- Use scientific reasoning to predict how changes in physical variables affect motion and engineering design.

Activity #6: Hot Wheels Engineering Investigation

- Design and conduct an engineering investigation to examine how ramp height affects the motion of a Hot Wheels car.
- Collect, analyze, and interpret data to identify relationships among gravity, force, and energy.
- Use evidence from multiple trials to develop scientific explanations and justify conclusions.

Activity #7: LEGO® Education SPIKE™ Prime Bike Bot

- Construct and program a LEGO® Education SPIKE™ Prime Bike Bot.
- Explain how sensors, motors, and programming works together to control robotic systems.
- Test, evaluate, and improve a robotic design using evidence gathered during multiple trials.

Activity #8: Egg Drop Engineering Challenge (*Extension or Time Permitting*)

- Apply the Engineering Design Process to develop, test, and improve a prototype that protects an egg from impact.
- Evaluate prototype performance using evidence gathered during testing.
- Justify design improvements based on engineering data, observations, and identified constraints.



Day 2: Vaquero Station

Activity #1: Conductors in Training – Cup Challenge

- Demonstrate effective teamwork and communication while working within engineering constraints.
- Develop collaborative problem-solving strategies to complete a shared engineering challenge.
- Explain how teamwork, planning, and adaptability contribute to successful engineering projects.

Activity #2: Electrical Circuits Investigation

- Construct and test a complete electrical circuit using batteries, wires, and a light source.
- Investigate the properties of conductors and insulators through experimental testing.
- Use evidence from observations to explain how electricity flows through a circuit.

Activity #3: Electromagnet Engineering Challenge

- Construct a functioning electromagnet using a battery, insulated wire, and an iron nail.
- Investigate how electric current creates a magnetic field capable of attracting metal objects.
- Evaluate and improve an electromagnet design using evidence gathered during testing.

Activity #4: Railway Systems Investigation

- Compare passive and active railroad crossings and explain how each contributes to railway safety.
- Differentiate among Class I, Class II, and Class III railroads based on their roles within the freight transportation system.
- Analyze how electrical systems, communication, and transportation infrastructure work together to improve railway operations and public safety.

Activity #5: LEGO® Education SPIKE™ Prime Hopper Robot

- Construct and program a LEGO® Education SPIKE™ Prime Hopper Robot using engineering design principles.
- Explain how sensors, motors, and programmed instructions work together within an automated system.
- Test, evaluate, and improve a robotic system by applying the Engineering Design Process.

Activity #6: Hopper Robot Engineering Challenge

- Apply the Engineering Design Process to improve the performance of a programmed robotic system.
- Analyze programming and design challenges to identify effective solutions.
- Use evidence gathered during testing to refine and optimize robot performance.

Activity #7: Engineering Reflection & Systems Debrief

- Evaluate how electricity, magnetism, and automation work together within railway systems.
- Reflect on how the Engineering Design Process supported their investigations and engineering decisions.
- Communicate evidence-based explanations describing how engineering improves transportation safety and efficiency.



Day 3: Freight Transportation Engineers

Activity #1: Rock, Paper, Scissors Engineering Team Builder

- Demonstrate effective communication and collaboration participating in a team-building activity.
- Adapt strategies and work cooperatively as team dynamics change throughout the challenge.
- Reflect on how teamwork, leadership, and communication contribute to successful engineering projects.

Activity #2: Maintenance, Derailments, & Wheel and Axle Engineering Investigation

- Explain how wheel-and-axle systems contribute to safe railway operation and help prevent derailments.
- Investigate how wheel shape, axle alignment, and stability influence the movement of a train along the tracks.
- Apply the Engineering Design Process to design, test, evaluate, and improve a wheel-and-axle model.

Activity #3: Freight Transportation Systems Investigation

- Compare the design and purpose of different freight railcars used in railway transportation.
- Analyze the physical characteristics of cargo to determine the most appropriate transportation method.
- Justify engineering decisions using evidence related to safety, efficiency, and railcar design.

Activity #4: LEGO® Education SPIKE™ Prime Driving Base

- Construct and program a LEGO® Education SPIKE™ Prime Driving Base using engineering design principles.
- Explain how motors and programmed instructions control the movement of a robotic system.
- Test and refine a robotic design through observation, troubleshooting, and iterative improvement.

Activity #5: Inspection Detection Engineering Challenge

- Apply the Engineering Design Process to design, test, and improve an automated railway inspection system.
- Program a LEGO® SPIKE™ Prime Driving Base to detect and respond to obstacles.
- Evaluate and refine programming solutions using evidence collected during multiple testing trials.

Activity #6: Engineering Reflection & Design Debrief

- Evaluate how mechanical engineering, transportation systems, and robotics work together to improve railway safety.
- Reflect on how the Engineering Design Process supported the development and improvement of engineering solutions.
- Communicate evidence-based explanations describing how engineering design, testing, and teamwork contribute to safe and efficient railway operations.



Day 4: The Final Freight Challenge

Activity #1: Good Listener Engineering Team Builder

- Demonstrate active listening, teamwork, and communication during a collaborative engineering challenge.
- Apply quick decision-making skills by accurately following verbal directions and responding to changing situations.
- Explain how communication, situational awareness, and teamwork contribute to safe engineering and railway operations.

Activity #2: High Bay Tour: Exploring Railway Engineering

- Observe how engineers apply science, technology, engineering, and mathematics (STEM) to solve real-world railway transportation challenges.
- Identify engineering concepts explored throughout the week within a professional research and testing environment.
- Connect classroom investigations to engineering careers and modern railway safety practices.

Activity #3: Balloon Racer Engineering Investigation

- Explain Newton's Third Law of Motion using the concepts of action and reaction forces.
- Design, build, and test a balloon-powered racer to investigate how forces create motion.
- Apply the Engineering Design Process to evaluate, improve, and optimize an engineering design using evidence gathered during testing.

Activity #4: Smart Railway Safety Systems Investigation

- Compare passive and active railroad crossings and explain how each improves railway safety.
- Analyze how sensors, warning systems, and automated technologies help prevent accidents and improve transportation efficiency.
- Explain how engineers integrate multiple systems to create safe and reliable railway transportation networks.

Activity #5: Final Engineering Challenge: Smart Railway Safety System Challenge

- Apply the Engineering Design Process to solve a simulated railway engineering challenge.
- Build, program, and operate a LEGO® Education SPIKE™ Prime Forklift to complete a railway transportation mission safely and efficiently.
- Demonstrate teamwork, computational thinking, and problem-solving skills while testing, evaluating, and improving a robotic engineering solution.

Activity #6: Engineering Reflection, Awards & Final Debrief

- Evaluate the effectiveness of their engineering solutions using evidence collected throughout the week.
- Reflect on how teamwork, communication, and the Engineering Design Process contributed to successful engineering outcomes.
- Communicate how science, technology, engineering, and mathematics work together to improve railway safety and inspire future engineering careers.



Science Texas Essential Knowledge and Skills (TEKS) TEKS

2021 Texas Essential Knowledge and Skills for Science (Grades 6-8)

MS.1(A)	Ask questions and define problems based on observations or information to determine explanations and engineering solutions.
MS.1(B)	Use scientific and engineering practices to plan and conduct investigations, develop models and prototypes, analyze data, and design solutions.
MS.1(C)	Collect, record, organize, construct, and analyze data using appropriate tools and scientific reasoning.
MS.1(D)	Use mathematical calculations and computational thinking to analyze data and support engineering decisions.
MS.1(E)	Construct explanations and design solutions using evidence gathered during investigations.
MS.1(F)	Engage in scientific argumentation using evidence to evaluate competing explanations and engineering solutions.
MS.1(G)	Communicate scientific and engineering information using appropriate vocabulary, models, diagrams, and evidence.

Math TEKS

2012 Texas Essential Knowledge and Skills for Mathematics

6.1(A)	Apply mathematics to solve problems arising in everyday life, society, and the workplace.
6.1(B)	Use a problem-solving model that incorporates analyzing information, formulating strategies, determining solutions, justifying conclusions, and evaluating the problem-solving process.
6.1(C)	Select appropriate tools, including technology, to solve problems.
6.1(D)	Communicate mathematical ideas, reasoning, and their implications using multiple representations.

2017 Next Generation Science Standards 6-8

MS-PS2-1	Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.*
MS-PS2-2	Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
MS-PS2-3	Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.
MS-PS2-4	Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.
MS-PS2-5	Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.
MS-PS3-1	Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.
MS-PS3-2	Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.
MS-PS3-3	Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.*
MS-PS3-4	Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.
MS-PS3-5	Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.
MS-ETS1-1	Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
MS-ETS1-2	Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
MS-ETS1-3	Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
MS-ETS1-4	Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.



Day 1: Welcome Aboard! Engineering Design Process, Gravity, Force, Mass, Density, and Energy

Day Overview

The first day of the Middle School Railway Safety Camp introduces students to the engineering design process while establishing the collaborative and inquiry-based learning environment that will guide the remainder of the week. Students are welcomed to the program, introduced to camp expectations, and challenged to think like engineers through observation, discussion, teamwork, and problem-solving activities. These opening experiences encourage curiosity, communication, and critical thinking while helping students recognize that engineering is a process of continuous improvement.

Throughout the day, students investigate the scientific principles that influence railway transportation, including gravity, force, mass, density, and energy. Through demonstrations, guided discussions, and hands-on investigations, students explore how these concepts affect the movement of trains and how engineers apply them to design safer and more efficient transportation systems. Rather than simply learning scientific vocabulary, students collect evidence, analyze observations, and begin developing explanations using engineering and scientific reasoning.

Students are also introduced to the Engineering Design Process as the foundation for every challenge they will complete during the camp. By examining each stage of the process, framing the problem, investigating possible solutions, brainstorming ideas, planning, creating, testing, evaluating, and iterating. Students learn that successful engineering requires creativity, collaboration, perseverance, and evidence-based decision making. These practices prepare students to approach increasingly complex engineering challenges throughout the week.

The day concludes with students applying their understanding through engineering investigations using Hot Wheels experiments, LEGO® Education SPIKE™ Prime robotics, and an optional Egg Drop Engineering Challenge. By the end of Day 1, students will understand that engineering combines science, mathematics, technology, and teamwork to solve real-world transportation problems while improving the safety and reliability of railway systems.

Lesson Objectives:

By the end of Day 1, students will be able to:

- Describe the purpose and expectations of the Middle School Railway Safety Camp.
- Demonstrate effective collaboration, communication, and problem-solving skills during engineering activities.
- Explain how engineers use science, mathematics, technology, and teamwork to solve real-world transportation challenges.



- Apply each step of the Engineering Design Process to investigate, design, test, evaluate, and improve engineering solutions.
- Analyze how gravity, force, mass, density, and energy influence the motion of objects and railway systems.
- Collect and interpret data from engineering investigations to support scientific explanations.
- Construct, program, and evaluate a LEGO® Education SPIKE™ Prime Bike Bot using engineering and computational thinking practices.
- Apply scientific principles and the Engineering Design Process to develop, test, and refine a solution during an engineering design challenge.

Essential Questions

- How do engineers use the Engineering Design Process to solve real-world transportation problems?
- How do gravity, force, mass, density, and energy influence the movement of objects and railway systems?
- Why are collaboration, communication, and evidence-based decision making essential to successful engineering?
- How do engineers use investigations, data, and testing to improve the safety and efficiency of railway transportation?
- How can engineering, robotics, and technology work together to solve complex transportation challenges?

Day 1 at a Glance

Time	Activity	Focus / Goal
15 min	Welcome & Camp Introduction	Welcome students, review camp expectations, introduce the week's learning goals, and establish an engineering mindset for the Railway Safety Camp.
10 - 15 min	Activity 1: I See... I Think... I Wonder...	Activate curiosity through observation, evidence-based reasoning, and questioning using a railway-related image.
20–25 min	Activity 2: Balloon Rescue Team Builder	Develop communication, collaboration, adaptability, and problem-solving skills while working within engineering constraints.
15–20 min	Activity 3: What is Engineering? (Think-Pair-Share)	Explore the role of engineers and examine the characteristics of successful engineers through discussion and reflection.
25–30 min	Activity 4: Engineering Design Process	Investigate the stages of the Engineering Design Process and apply them to engineering scenarios through collaborative analysis.
25–30 min	Activity 5: Railway Systems – Gravity,	Explore the scientific principles that influence railway systems and prepare for engineering investigations through demonstrations and discussion.



	Force, Mass, Density, and Energy	
35–45 min	Activity 6: Hot Wheels Engineering Investigation	Conduct an engineering investigation to collect and analyze data on how gravity, force, and energy influence the motion of a Hot Wheels car.
45–60 min	Activity 7: LEGO® Education SPIKE™ Prime Bike Bot	Build, program, test, and refine a LEGO® SPIKE™ Prime Bike Bot while applying engineering design, computational thinking, and teamwork.
45–60 min (Extension or Time Permitting)	Activity 8: Egg Drop Engineering Challenge	Apply the Engineering Design Process to design, test, evaluate, and improve a prototype that protects an egg from impact.
5–10 min	Day 1 Reflection	Reflect on the Engineering Design Process, scientific investigations, teamwork, and how engineering principles apply to railway safety while preparing for Day 2.

Day 1 Vocabulary

Term	Student-Friendly Definition	Day 1 Connection
Engineering Design Process	A systematic process engineers use to define problems, develop ideas, build solutions, test designs, evaluate results, and improve prototypes.	Students use each step of the Engineering Design Process throughout the day's investigations, robotics activity, and engineering challenge.
Force	A push or pull that can change an object's motion.	Students investigate how forces influence the movement of Hot Wheels cars, LEGO® SPIKE™ Prime robots, and engineering prototypes.
Gravity	The force of attraction that pulls objects toward the Earth.	Students analyze how gravity affects ramps, train movement, robotics, and the Egg Drop Engineering Challenge.
Mass	The amount of matter contained in an object.	Students examine how an object's mass influences motion, energy, and engineering design decisions during investigations.
Density	The amount of mass packed into a given volume of an object.	Students compare how density affects the behavior of materials and discuss why engineers consider material properties when designing transportation systems.
Potential Energy	Stored energy an object has because of its position or condition.	Students investigate how changing the height of a ramp affects the amount of potential energy available to moving objects.



Kinetic Energy	The energy an object possesses because it is moving.	Students observe the transfer of potential energy into kinetic energy during the Hot Wheels investigation and robotics activities.
Conservation of Energy	The principle that energy cannot be created or destroyed but can be transferred or transformed from one form to another.	Students explain how potential energy changes into kinetic energy as objects travel through ramps, loops, and engineering investigations.
Prototype	An initial model or design built to test an idea before creating a final solution.	Students build, test, and improve prototypes during the LEGO® SPIKE™ Prime Bike Bot activity and the Egg Drop Engineering Challenge.
Iteration	The process of improving a design by making changes based on testing and evaluation.	Students refine their robotic programs and engineering designs by analyzing results and making improvements throughout the day's activities.



Activity #1: I See...I Think...I Wonder...

Activity Overview

Students begin the Railway Safety Camp by participating in an observation routine designed to develop the habits of mind used by engineers and scientists. Using a railway-related image, students first make careful observations, then develop evidence-based inferences, and finally generate questions that encourage curiosity about engineering and railway transportation. This introductory activity establishes a culture of inquiry while demonstrating that engineers rely on careful observation, critical thinking, and questioning before designing solutions to complex problems.

Estimated Time: 10-15 minutes

Learning Objectives:

The students will be able to:

- Differentiate between observations, inferences, and questions using visual evidence.
- Develop evidence-based explanations by supporting their thinking with observations.
- Generate meaningful questions that promote curiosity about engineering and railway transportation.

Science TEKS:

- MS.1(A) Ask questions and define problems based on observations or information from text, phenomena, models, or investigations.
- MS.1(G) Develop and communicate explanations supported by evidence.

Math TEKS:

- 6.1(A) Apply mathematics to problems arising in everyday experiences.
- 6.1(B) Use a problem-solving model that includes analyzing information and communicating reasoning.

NGSS:

- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution.

Materials Needed:

- Day 1 presentation
- Railway image for observation
- Student science journals or engineering notebooks (optional)
- Pencils



Teacher Preparation

Display the "I See... I Think... I Wonder..." image before students enter or at the beginning of class. Encourage students to observe silently for approximately 30 seconds before recording their responses. Emphasize that engineers first gather evidence through careful observation before making conclusions or proposing solutions. Establish classroom norms that value curiosity, respectful discussion, and multiple perspectives.

Facilitation Guide

1. Display the railway image and allow students 30 seconds of silent observation.
2. Ask students to independently record:
 - What do you see?
 - What do you think is happening?
 - What do you wonder?
3. Invite students to share observations with a partner before facilitating a whole-class discussion.
4. Guide students to distinguish between observations ("I see...") and inferences ("I think...").
5. Record student questions and explain that many of them will be investigated throughout the week.
6. Conclude by introducing the camp theme: engineers begin by observing, asking questions, and gathering evidence before solving problems.

Reflection & Discussion

Use the following questions to guide class discussion:

- Which observations were based on evidence rather than assumptions?
- How did your observations influence what you thought was happening?
- Why do engineers ask questions before designing solutions?
- Which question are you most interested in answering during this week's camp?

Teacher Tips

Resist the urge to confirm or correct student responses immediately. Instead, encourage students to justify their thinking using evidence from the image. Reinforce that engineers often begin with questions rather than answers and that thoughtful observation is the foundation of scientific investigation and engineering design.

Differentiation

Support

- Provide sentence stems such as:
 - I see...
 - I think... because...



- I wonder...

- Allow students to discuss their ideas with a partner before participating in the whole-group discussion.
- Model one example of an observation, an inference, and a question before students begin.

Extension

- Challenge students to identify additional information they would need before making engineering decisions about the scene. Have them explain how gathering more evidence could lead to better design solutions.

Activity #2: Balloon Rescue Team Builder

Activity Overview

Students participate in a collaborative engineering challenge in which their team must prevent a balloon from touching the ground while following a series of progressively more difficult constraints. During the activity, students experience how engineers rely on communication, planning, adaptability, and teamwork when solving complex problems. Following the challenge, students reflect on how changing constraints influence team performance and discuss the importance of collaboration in engineering projects.

Estimated Time: 20-25 min.

Learning Objectives

The students will be able to:

- Demonstrate effective communication and collaboration while working within engineering constraints.
- Analyze how changing constraints influence problem-solving strategies and team performance.
- Reflect on the importance of teamwork, adaptability, and communication in engineering design.

Science TEKS:

- MS.1(A) Ask questions and define problems based on observations and engineering challenges.
- MS.1(B) Apply scientific and engineering practices to collaboratively solve problems.
- MS.1(G) Develop explanations and communicate solutions using evidence from the activity.

Math TEKS:

- 6.1(A) Apply problem-solving strategies to real-world situations.
- 6.1(B) Analyze information, develop strategies, and communicate reasoning while solving problems.



NGSS:

- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution.

Materials Needed:

- One balloon per team
- Open classroom or gym space
- Timer (optional)

Teacher Preparation

Inflate one balloon for each group and designate a safe playing area with sufficient space between teams. Review the challenge rules and emphasize that students must work collaboratively while following all constraints. Explain that engineers frequently work within limitations such as time, resources, safety requirements, and communication challenges, and that today's activity models those real-world experiences.

Facilitation Guide

1. Divide students into small teams and provide each group with one balloon.
2. Explain the objective: keep the balloon from touching the floor while following the established rules.
3. Complete the first round using verbal communication.
4. Increase the level of difficulty by requiring students to complete the second round using only nonverbal communication while maintaining physical contact with their teammates.
5. Observe how each team adapts its strategy as new constraints are introduced.
6. Facilitate a class discussion connecting the activity to teamwork, engineering, and real-world problem solving.

Reflection & Discussion

- How did your team's strategy change as new constraints were introduced?
- Which communication methods were most effective during each round?
- What challenges did your team encounter, and how did you overcome them?
- Why do engineers often work within constraints?
- How did teamwork influence your team's success?

Teacher Tips

Emphasize that the goal is not simply to keep the balloon in the air, but to observe how teams communicate, adapt, and solve problems under changing conditions. During the reflection, connect the activity to engineering by discussing how real engineering projects involve constraints such as budgets,



deadlines, safety requirements, and limited resources. Encourage students to recognize that successful engineering depends on effective collaboration as much as technical knowledge.

Differentiation

Support: Allow teams additional planning time before beginning or reduce the number of constraints during the first round. Encourage students to assign informal team roles to support communication and participation.

Extension: Challenge teams to develop and justify a strategy before beginning the final round. After the activity, have students identify which engineering habits of mind, such as communication, adaptability, persistence, or systems thinking, were most important to their team's success and explain why.

Activity #3: What is Engineering? (Think-Pair-Share)

Activity Overview

Students participate in a Think-Pair-Share activity to explore the role of engineers in solving real-world problems. After independently reflecting on what engineering means, students discuss their ideas with a partner before participating in a class discussion. Using the presentation, students examine the characteristics of successful engineers and discover that engineering is a collaborative process that combines science, mathematics, creativity, communication, and critical thinking to develop solutions that improve society. Students conclude the activity by connecting engineering practices to railway safety and transportation systems.

Estimated Time: 15-20 min.

Learning Objectives

The students will be able to:

- Explain how engineers apply science, mathematics, creativity, and technology to solve real-world problems.
- Identify the characteristics and habits of successful engineers.
- Evaluate how communication, collaboration, and problem-solving contribute to engineering design.

Science TEKS:

- MS.1(A) Ask questions and define problems based on observations and real-world phenomena.
- MS.1(B) Apply scientific and engineering practices to design solutions to problems.
- MS.1(G) Develop and communicate explanations supported by evidence.



Math TEKS:

- 6.1(A) Apply mathematics to solve problems arising in everyday experiences.
- 6.1(B) Use a problem-solving process that includes analyzing information, developing strategies, and communicating mathematical ideas.

NGSS:

- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution.

Materials Needed:

- Day 1 PowerPoint
- Projector or interactive display
- Student engineering journals or notebooks (optional)
- Whiteboard or chart paper (optional)

Teacher Preparation

Review the Think-Pair-Share prompt and the slides describing engineering and the characteristics of successful engineers. Prepare examples of engineering careers beyond railroads to help students recognize the broad impact engineers have on everyday life. Encourage students to support their ideas using examples from their own experiences before connecting them to the presentation.

Facilitation Guide

1. Display the **What is Engineering?** Think-Pair-Share prompt.
2. Allow students one to two minutes to think independently and record their ideas.
3. Pair students to discuss their responses and compare their thinking.
4. Facilitate a whole-class discussion by recording common ideas and misconceptions.
5. Introduce the presentation slides defining engineering and highlighting the characteristics of successful engineers.
6. Guide students in discussing how these characteristics contribute to solving engineering problems and improving railway safety.

Reflection & Discussion

- How has your definition of engineering changed after today's discussion?
- Which characteristic of an engineer do you think is the most important? Why?
- Why do engineers need strong communication and teamwork skills in addition to technical knowledge?
- How do engineers improve the safety of railway systems and other forms of transportation?



Teacher Tips

Encourage students to move beyond thinking that engineers simply "build things." Guide the discussion toward the idea that engineers identify problems, analyze information, collaborate with others, and continuously improve designs based on evidence. Emphasize that successful engineering requires both technical knowledge and strong interpersonal skills.

Differentiation

Support: Provide sentence starters such as *"Engineers solve problems by..."* or *"A successful engineer needs to..."* Allow students to discuss their ideas with a partner before sharing with the class.

Extension: Ask students to select one engineering characteristic from the presentation and provide a real-world example of how it contributes to improving railway safety or another engineering field. Encourage students to justify their reasoning using evidence from the discussion.

Activity #4: Engineering Design Process

Activity Overview

Students explore the Engineering Design Process as the framework engineers use to solve complex problems and develop innovative solutions. Through discussion, collaborative activities, and real-world engineering scenarios, students examine each stage of the design process: Frame, Investigate, Brainstorm, Plan, Create, Test, Evaluate, and Iterate, and recognize that engineering is an ongoing cycle of improvement rather than a linear sequence of steps. Students conclude the lesson by applying the Engineering Design Process to engineering scenarios, preparing them to use this process throughout the remainder of the Railway Safety Camp.

Estimated Time: 25-30 min.

Learning Objectives

The students will be able to:

- Explain the purpose of each stage of the Engineering Design Process.
- Analyze engineering scenarios to determine which stage of the design process is being applied.
- Recognize that successful engineering requires testing, evaluation, and continuous improvement.

Science TEKS:

- MS.1(A) Ask questions and define problems based on observations, evidence, and engineering challenges.
- MS.1(B) Apply scientific and engineering practices to design, test, and improve solutions.



- MS.1(G) Develop and communicate explanations and engineering solutions supported by evidence.

Math TEKS:

- 6.1(A) Apply mathematics to solve problems arising in engineering investigations.
- 6.1(B) Use a problem-solving process that includes analyzing information, selecting strategies, evaluating solutions, and communicating reasoning.

NGSS:

- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Materials Needed:

- Day 1 PowerPoint
- Engineering Design Process cards or visual
- Engineering scenario cards
- Whiteboard or chart paper
- Student engineering journals (optional)

Teacher Preparation

Review each stage of the Engineering Design Process presented in the Day 1 PowerPoint. Prepare the Engineering Design Process cards and engineering scenario cards before class. Be ready to guide students through discussions that emphasize how engineers often revisit earlier stages of the process as they refine and improve their designs.

Facilitation Guide

1. Introduce the Engineering Design Process using the Day 1 presentation.
2. Discuss each stage of the process: Frame, Investigate, Brainstorm, Plan, Create, Test, Evaluate, Iterate
3. Explain that engineers move between these stages as new information becomes available rather than following a strict sequence.
4. Present engineering scenarios and have students identify which stage of the Engineering Design Process is being demonstrated.
5. Facilitate a class discussion comparing student responses and reasoning.
6. Conclude by explaining that every engineering activity completed during the remainder of the camp will follow this same design process.



Reflection & Discussion

- Why is it important to clearly define a problem before proposing a solution?
- Why do engineers often return to earlier stages of the Engineering Design Process?
- Which stage do you think is the most important? Explain your reasoning.
- How does testing improve an engineering design?
- Why is iteration an essential part of engineering?

Teacher Tips

Emphasize that the Engineering Design Process is iterative, not linear. Students often assume engineers move through the steps only once. Reinforce that engineers continuously collect evidence, evaluate results, and revise their ideas as new information becomes available. Encourage students to justify their responses when discussing the engineering scenarios by referring to the actions taking place rather than simply naming a step.

Differentiation

Support: Provide students with a visual reference of the Engineering Design Process and review each stage before introducing the engineering scenarios. Allow students to discuss their reasoning with a partner before sharing with the class.

Extension: Challenge students to identify examples of the Engineering Design Process from everyday life or previous STEM experiences. Have students explain how iteration leads to improved solutions and discuss why redesign is an expected part of professional engineering.

Activity #5: Ramp Railways

Activity Overview

Students investigate the scientific principles that influence the movement of trains and other transportation systems. Through guided discussion, demonstrations, and interactive examples, students examine how gravity, force, mass, density, and energy affect the motion of objects. As students explore these concepts, they begin connecting scientific principles to real-world railway engineering and recognize how engineers use scientific evidence to design safer and more efficient transportation systems. This lesson provides the scientific foundation for the engineering investigations that follow.

Estimated Time: 25-30 min.

Learning Objectives

The students will be able to:



- Analyze how gravity, force, mass, density, and energy influence the movement of objects in railway systems.
- Explain how potential and kinetic energy are transferred as objects move through a system.
- Use scientific reasoning to predict how changes in physical variables affect motion and engineering design.

Science TEKS:

- **MS.1(A)** Ask questions and define problems based on observations and scientific investigations.
- **MS.1(B)** Use scientific and engineering practices to investigate relationships among force, motion, and energy.
- **MS.1(G)** Develop explanations and communicate scientific reasoning supported by evidence.

Math TEKS:

- **6.1(A)** Apply mathematical reasoning to solve real-world engineering problems.
- **6.1(B)** Analyze data and communicate conclusions using appropriate mathematical strategies.

NGSS:

- **MS-PS2-2** Plan an investigation to provide evidence that changes in an object's motion depend on the sum of the forces acting on it and the object's mass.
- **MS-PS3-5** Construct and present arguments using evidence to support the claim that when kinetic energy changes, energy is transferred to or from an object.

Materials Needed:

- Day 1 PowerPoint
- Ramp demonstration materials (teacher)
- Hot Wheels car (for demonstration)
- Whiteboard or chart paper
- Student engineering journals (optional)

Teacher Preparation

Review the Day 1 presentation and prepare demonstrations illustrating gravity, force, mass, density, and energy transfer. Have a ramp and Hot Wheels car available to demonstrate how changes in height and slope affect motion. Encourage students to make predictions before each demonstration and justify their thinking using scientific evidence. Explain that these concepts will be investigated more deeply during the upcoming Hot Wheels Engineering Investigation.

Facilitation Guide

1. Introduce the scientific concepts of force, gravity, mass, density, potential energy, kinetic energy, and conservation of energy using the presentation.



2. Demonstrate how gravity causes an object to accelerate down a ramp.
3. Facilitate a discussion about how changing the height of the ramp influences the object's energy and motion.
4. Ask students to predict how changing an object's mass or the ramp angle might affect the results.
5. Connect each scientific concept to real-world railway engineering, discussing how engineers use these principles when designing trains and railway systems.
6. Conclude by explaining that students will apply these concepts during the next engineering investigation.

Reflection & Discussion

- How do gravity and force work together to influence motion?
- Why do engineers consider mass and density when designing transportation systems?
- How is energy transferred as an object moves down a ramp?
- Which scientific concept do you think has the greatest impact on railway safety? Explain your reasoning.
- How can scientific evidence help engineers make better design decisions?

Teacher Tips

Encourage students to support every prediction and explanation with scientific reasoning rather than guessing. Reinforce that engineers rely on observations, evidence, and repeated testing when making design decisions. Throughout the discussion, continually connect the science concepts to the engineering applications students will investigate during the Hot Wheels Engineering Investigation.

Differentiation

Support: Provide students with a vocabulary reference sheet and visual diagrams illustrating gravity, force, mass, density, and energy transfer. Pause after each concept to allow students to summarize the idea with a partner before continuing.

Extension: Challenge students to compare two hypothetical railway systems with different track heights, train masses, or cargo loads. Have them predict how these variables would influence motion, energy transfer, and railway safety, and justify their predictions using evidence from the lesson.

Activity #6: Hot Wheels Lab

Activity Overview

Students investigate how gravity, force, and energy influence the motion of a Hot Wheels car by conducting a controlled engineering investigation. Working in collaborative engineering teams, students design and perform multiple trials, collect quantitative data, and analyze how changes in ramp height



affect speed and distance traveled. Throughout the investigation, students use evidence to identify patterns, draw conclusions, and explain how engineers use experimentation to improve the safety and efficiency of transportation systems.

Estimated Time: 35-45 min.

Learning Objectives

The students will be able to:

- Design and conduct an engineering investigation to examine how ramp height affects the motion of a Hot Wheels car.
- Collect, analyze, and interpret data to identify relationships among gravity, force, and energy.
- Use evidence from multiple trials to develop scientific explanations and justify conclusions.

Science TEKS:

- **MS.1(A)** Ask questions and define problems based on observations and investigations.
- **MS.1(B)** Use scientific and engineering practices to design investigations, collect data, and analyze results.
- **MS.1(C)** Collect and organize quantitative data using appropriate tools and techniques.
- **MS.1(G)** Develop explanations and communicate conclusions supported by evidence.

Math TEKS:

- **6.1(A)** Apply mathematical reasoning to solve real-world problems.
- **6.1(B)** Analyze data, identify patterns, and communicate conclusions.
- **6.12(A)** Collect, organize, display, and interpret numerical data to solve problems.

NGSS:

- **MS-PS2-2** Plan an investigation to provide evidence that changes in an object's motion depend on the sum of the forces acting on it and the object's mass.
- **MS-ETS1-3** Analyze data from tests to determine similarities and differences among design solutions and identify characteristics of the best solution.

Materials Needed:

- Hot Wheels car (one per team)
- Adjustable ramp
- Meter stick or measuring tape
- Masking tape
- Student data collection sheet
- Pencil
- Calculator (optional)



Teacher Preparation

Assemble the ramp stations before class and ensure each team has the necessary materials. Review procedures for conducting fair tests and discuss the importance of controlling variables so that only one factor changes during the investigation. Encourage students to make predictions before collecting data and remind them that engineers rely on repeated trials to improve the reliability of their results.

Facilitation Guide

1. Introduce the investigation question and discuss the importance of controlling variables during an experiment.
2. Have each engineering team identify the independent, dependent, and controlled variables.
3. Students develop a prediction based on the concepts of gravity, force, and energy.
4. Conduct multiple trials using different ramp heights while keeping other variables constant.
5. Measure and record the distance traveled during each trial.
6. Analyze the collected data to identify patterns and relationships.
7. Facilitate a class discussion in which teams compare findings and justify their conclusions using evidence.
8. Conclude by connecting the investigation to how engineers test transportation systems before implementing new designs.

Reflection & Discussion

- Which variable did your team intentionally change during the investigation?
- Why is it important to control the other variables?
- What patterns did you observe in your data?
- Did your results support your original prediction? Why or why not?
- How do engineers use repeated testing to improve transportation systems?

Teacher Tips

Encourage students to think like engineers by focusing on the quality of their investigation rather than simply obtaining the "correct" answer. Reinforce the importance of repeated trials, accurate measurements, and evidence-based conclusions. During the discussion, ask students to justify their explanations using data collected during the investigation rather than personal opinions.

Differentiation

Support: Provide students with a structured data table and guide them through identifying the independent, dependent, and controlled variables before beginning the investigation. Model how to organize data and recognize patterns.



Extension: Challenge students to design an additional investigation by modifying one variable, such as the mass of the car or the surface material. Have teams predict how the change will influence the results and defend their conclusions using evidence collected during testing.

Activity #7: LEGO® Education SPIKE™ Prime Bike Bot

Activity Overview

Students apply the Engineering Design Process by constructing, programming, and testing a LEGO® Education SPIKE™ Prime Bike Bot. As they explore the relationship between signals, sensors, motors, and programming, students investigate how robotic systems collect information, make decisions, and perform specific tasks. Working in collaborative engineering teams, students troubleshoot, refine, and optimize their programs while recognizing how robotics and automation contribute to safer and more efficient railway transportation systems.

Estimated Time: 45-60 min.

Learning Objectives

The students will be able to:

- Construct and program a LEGO® Education SPIKE™ Prime Bike Bot using engineering design principles.
- Explain how sensors, motors, and programmed instructions work together to control robotic systems.
- Test, evaluate, and improve a robotic design using evidence gathered during multiple trials.

Science TEKS:

- **MS.1(B)** Apply scientific and engineering practices to design, test, and improve engineering solutions.
- **MS.1(C)** Collect observations and data to evaluate the performance of a design.
- **MS.1(G)** Develop explanations and communicate engineering solutions supported by evidence.

Math TEKS:

- **6.1(A)** Apply mathematical reasoning to solve engineering and programming challenges.
- **6.1(B)** Analyze information, evaluate solutions, and communicate reasoning during problem solving.

NGSS:

- **MS-ETS1-2** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.



- **MS-ETS1-3** Analyze data from tests to identify similarities and differences among design solutions and improve performance.

Materials Needed:

- LEGO® Education SPIKE™ Prime Kit (one per team)
- Tablet or computer with the SPIKE™ App
- Building instructions
- Engineering journals (optional)
- Challenge course (optional)

Teacher Preparation

Ensure each SPIKE™ Prime kit is complete and that all hubs are charged prior to the lesson. Verify that the SPIKE™ App is installed and functioning on each device. Review the Bike Bot building instructions and introductory programming sequence before class. Remind students that engineers rarely achieve a perfect design on the first attempt and that troubleshooting and iteration are expected parts of the engineering process.

Facilitation Guide

1. Introduce the concepts of **signals and systems**, discussing how robotic systems receive information and respond through programmed actions.
2. Divide students into engineering teams and distribute the LEGO® SPIKE™ Prime materials.
3. Guide students through constructing the Bike Bot according to the building instructions.
4. Introduce the basic programming sequence needed to operate the robot.
5. Allow teams to test their Bike Bot and observe its performance.
6. Encourage students to troubleshoot programming or construction issues and make improvements based on their observations.
7. Conclude with a class discussion connecting robotics, automation, and railway safety.

Reflection & Discussion

- How do sensors and motors work together to control a robot?
- What challenges did your team encounter while building or programming the Bike Bot?
- How did testing help improve your robot's performance?
- Why is troubleshooting an important part of engineering?
- How are robotic systems used to improve railway safety and transportation?

Teacher Tips

Encourage students to solve problems collaboratively before seeking teacher assistance. When teams encounter programming or construction errors, ask guiding questions rather than providing immediate



solutions. Reinforce that engineers continuously test, troubleshoot, and refine their designs, and emphasize that mistakes provide valuable information for improving a system.

Differentiation

Support: Provide students with completed example code or partially completed building steps. Pair students strategically so experienced programmers can support classmates while ensuring every student actively participates.

Extension: Challenge teams to modify their Bike Bot's program by changing speed, movement patterns, or sensor responses. Have students justify how their modifications improve the robot's performance or make it more effective for a transportation-related task.

Activity #8: Egg Drop Engineering Challenge

Activity Overview

Students apply the Engineering Design Process to design, construct, test, and refine a protective system that minimizes damage to an egg during a controlled drop. Working within specified design constraints, engineering teams develop prototypes, justify material selections, and evaluate the effectiveness of their designs using evidence collected during testing. Following each trial, students analyze the performance of their prototype and redesign their solution based on observed strengths and weaknesses, reinforcing that engineering is an iterative process driven by evidence and continuous improvement.

Estimated Time: 40-60 min.

Learning Objectives

The students will be able to:

- Apply the Engineering Design Process to develop, test, and improve a prototype that protects an egg from impact.
- Evaluate prototype performance using evidence gathered during testing.
- Justify design improvements based on engineering data, observations, and identified constraints.

Science TEKS:

- **MS.1(A)** Ask questions and define problems by identifying criteria and constraints for an engineering challenge.
- **MS.1(B)** Apply scientific and engineering practices to design, test, and improve solutions.
- **MS.1(C)** Collect and analyze qualitative and quantitative observations to evaluate prototype performance.



- **MS.1(G)** Develop and communicate engineering solutions supported by evidence.

Math TEKS:

- **6.1(A)** Apply mathematical reasoning to solve engineering design problems.
- **6.1(B)** Analyze results, evaluate solutions, and communicate reasoning using evidence collected during testing.

NGSS:

- **MS-ETS1-2** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- **MS-ETS1-3** Analyze data from tests to determine similarities and differences among design solutions and identify characteristics of the best-performing prototype.

Materials Needed:

- Raw eggs (one per team)
- Assorted construction materials (e.g., straws, craft sticks, index cards, cotton balls, tape, rubber bands, string, bubble wrap, cups)
- Scissors
- Meter stick or measuring tape
- Engineering journals or design recording sheets
- Drop zone

Teacher Preparation

Prepare the engineering materials and designate a safe drop-testing area before class. Review the design criteria and constraints with students, including any limitations on materials, time, or prototype size. Emphasize that engineers rarely achieve the best solution on the first attempt and that redesign based on testing is a critical part of the Engineering Design Process. Review safety expectations before conducting the egg drops.

Facilitation Guide

1. Present the engineering challenge and review the design criteria and constraints.
2. Allow teams to brainstorm ideas and sketch their prototype before construction.
3. Students build their prototypes using the provided materials.
4. Conduct the first round of testing and record observations about each design's performance.
5. Have teams evaluate their results, identify strengths and weaknesses, and determine improvements.
6. Allow time for redesign and a second round of testing, if time permits.
7. Facilitate a class discussion comparing solutions and highlighting how different engineering approaches met the same design challenge.



Reflection & Discussion

- Which design features were most effective at protecting the egg?
- How did the design constraints influence your team's decisions?
- What evidence supported the improvements you made between trials?
- If given additional time or materials, what changes would you make to your prototype?
- How does this challenge demonstrate the importance of testing and iteration in engineering?

Teacher Tips

Focus discussions on the engineering process rather than whether the egg broke. Encourage students to explain **why** their design succeeded or failed using evidence from their observations. Reinforce that unsuccessful prototypes often provide the most valuable information because they reveal opportunities for improvement. Celebrate thoughtful redesign and evidence-based decision making as much as successful outcomes.

Differentiation

Support: Provide students with a design planning template or prototype sketch sheet before construction. Encourage teams to assign engineering roles to ensure all members participate in brainstorming, building, testing, and evaluation.

Extension: Challenge teams to redesign their prototype while meeting an additional engineering constraint, such as reducing the amount of material used or limiting the overall size or mass of the prototype. Have students defend their final design by presenting evidence that explains how it met the challenge criteria.

Day 2: Next Stop: Vaquero Station

Day Overview

On Day 2, students expand their understanding of engineering by investigating the electrical systems that power modern railways. Building on the Engineering Design Process introduced on Day 1, students explore how electricity flows through circuits, how different materials conduct or resist electrical current, and how engineers use electromagnets to design safer and more efficient transportation systems. Through hands-on investigations, students discover the important relationship between electricity and magnetism while applying scientific concepts to authentic engineering challenges.

Throughout the day, students examine the role of electrical systems in railway operations, including railroad crossings, warning signals, and freight transportation networks. Students learn how engineers design transportation systems that safely move people and goods by integrating electrical circuits,



communication systems, and automation. By investigating the differences between passive and active railroad crossings, as well as the roles of Class I, II, and III railroads, students gain a broader understanding of how rail systems function across local, regional, and national transportation networks.

The day concludes with students applying their knowledge through robotics by constructing, programming, and testing a LEGO® Education SPIKE™ Prime Hopper Robot. Working collaboratively, students use computational thinking, problem-solving, and iterative design to refine their robotic systems while making connections between coding, engineering, and railway automation.

By the end of Day 2, students will recognize that electricity, magnetism, engineering design, and robotics work together to create safe, reliable, and efficient railway transportation systems.

Lesson Objectives:

By the end of Day 2, students will be able to:

- Demonstrate effective teamwork and communication during collaborative engineering challenges.
- Explain how electricity flows through a complete electrical circuit.
- Differentiate between conductors and insulators based on experimental evidence.
- Construct and test a simple electrical circuit.
- Investigate how electricity can generate a magnetic field through an electromagnet.
- Apply the Engineering Design Process to improve the performance of an electromagnet.
- Explain the role of electrical systems in railway crossings, warning signals, and train operations.
- Compare passive and active railroad crossings and describe how they improve railway safety.
- Differentiate among Class I, Class II, and Class III railroads and explain how each contributes to freight transportation.
- Construct, program, test, and improve a LEGO® Education SPIKE™ Prime Hopper Robot using computational thinking and engineering design principles.
- Use evidence from investigations to evaluate engineering solutions and justify design improvements.

Essential Questions

- How does electricity move through a circuit?
- Why are conductors and insulators important in electrical systems?
- How do engineers use electricity and magnetism to improve railway safety?
- How do railroad systems use technology, communication, and automation to transport people and goods safely?
- How does the Engineering Design Process help engineers improve electrical and robotic systems?



Day 2 at a Glance

Time Frame	Activity	Focus / Goal
10–15 min	Engineering Design Process Recap	Review the Engineering Design Process and connect Day 1 concepts to the electrical engineering challenges of Day 2.
20–25 min	Activity 1: Conductors in Training – Cup Challenge	Strengthen teamwork, communication, and problem-solving skills while working within engineering constraints.
35–45 min	Activity 2: Electrical Circuits Investigation	Build and test electrical circuits while investigating conductors, insulators, and the flow of electricity through a complete circuit.
45–60 min	Activity 3: Electromagnet Engineering Challenge	Design, build, test, and improve an electromagnet while exploring the relationship between electricity and magnetism.
35–45 min	Activity 4: Railway Systems Investigation	Investigate railroad crossings, freight transportation systems, and railroad classifications to understand how engineers design safe and efficient railway networks.
45–60 min	Activity 5: LEGO® Education SPIKE™ Prime Hopper Robot	Build and program a Hopper Robot while exploring signals, systems, sensors, and computational thinking.
30–45 min	Activity 6: Hopper Robot Engineering Challenge	Apply the Engineering Design Process to test, troubleshoot, and optimize the Hopper Robot through an engineering challenge.
10–15 min	Activity 7: Engineering Reflection & Systems Debrief	Reflect on electrical engineering, railway systems, robotics, and the Engineering Design Process while preparing for Day 3.

Day 2 Vocabulary

Students should review the following vocabulary before beginning the Day 2 activities. These terms will be used throughout the day during discussions about electricity, magnets, railway systems, crossings, and robotics.

Term	Student-Friendly Definition	Day 2 Connection
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Electrical Circuit	A complete path that allows electricity to flow from a power source through a device and back again.	Students build and test simple circuits to investigate how electricity powers lights and electrical devices.
Conductor	A material that allows electricity to flow easily through it.	Students test different materials to determine which ones conduct electricity and discuss why metals are commonly used in railway electrical systems.
Insulator	A material that resists or prevents the flow of electricity.	Students investigate insulating materials and explain how they improve electrical safety by protecting wires and equipment.
Electric Current	The movement of electrical energy through a complete circuit.	Students observe how electrical current flows through circuits and identify the conditions necessary for electricity to travel successfully.
Electromagnet	A temporary magnet created when electric current flows through a coil of wire wrapped around a metal core.	Students build, test, and improve an electromagnet while exploring how electricity and magnetism work together in engineering applications.
Magnetic Field	The invisible area surrounding a magnet where magnetic forces can attract or repel objects.	Students investigate how electromagnets generate magnetic fields capable of lifting paper clips and discuss how engineers use electromagnetism in transportation systems.
Passive Railroad Crossing	A railroad crossing that uses signs and pavement markings but does not include lights, bells, or gates.	Students compare passive and active crossings to understand how engineers improve public safety around railroad crossings.
Active Railroad Crossing	A railroad crossing equipped with warning devices such as flashing lights, bells, and crossing gates that activate when a train approaches.	Students analyze how electrical systems control railroad crossing signals and help prevent collisions.
Freight Railroad	A railway system that transports goods and materials from one location to another.	Students investigate how freight railroads move products across local, regional, and national transportation networks.
Automation	The use of technology and programmed systems to perform tasks with little or no human intervention.	Students explore how automated railway systems and LEGO® SPIKE™ Prime robots use sensors and programming to

		complete specific tasks safely and efficiently.
Sensor	A device that detects changes in its environment and sends information to a computer or programmed system.	Students use sensors while building and programming the LEGO® SPIKE™ Prime Hopper Robot and explore how sensors improve railway safety and automation.
Programming	Writing a sequence of instructions that tells a computer or robot how to perform a task.	Students create and modify programs that control the Hopper Robot while applying computational thinking and engineering design principles.

Activity #1: Conductors in Training: Cup Challenge

Activity Overview

Students begin Day 2 by participating in a collaborative engineering challenge in which teams use a rubber band, strings, and plastic cups to build cup pyramids without touching the cups directly. Working within engineering constraints, students must communicate effectively, develop strategies, and adapt their approach as they construct increasingly complex structures. Following the challenge, students reflect on how communication, teamwork, and planning contribute to successful engineering projects and prepare to investigate the electrical systems that power modern railway transportation.

Estimated Time: 20–25 minutes

Learning Objectives

The students will be able to:

- Demonstrate effective teamwork and communication while working within engineering constraints.
- Develop and refine collaborative problem-solving strategies to complete a shared engineering challenge.
- Evaluate how planning, communication, and adaptability contribute to successful engineering design.

Science TEKS:

- **MS.1(A)** Ask questions and define problems by identifying criteria and constraints for an engineering challenge.
- **MS.1(B)** Apply scientific and engineering practices to collaboratively design and improve solutions.



- **MS.1(G)** Develop and communicate explanations supported by evidence gathered during the activity.

Math TEKS:

- **6.1(A)** Apply mathematical reasoning to solve real-world engineering challenges.
- **6.1(B)** Use a problem-solving process that includes analyzing information, selecting strategies, and communicating reasoning.

NGSS:

- **MS-ETS1-1** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution.

Materials Needed:

- 10–15 plastic cups per team
- One large rubber band per team
- Four pieces of yarn or string attached to each rubber band
- Timer
- Open workspace

Teacher Preparation

Assemble one cup challenge kit for each engineering team by attaching four equal lengths of string to a rubber band. Arrange the cups at each workstation and review the challenge rules before students begin. Emphasize that students may only manipulate the cups using the rubber band tool and must rely on communication and teamwork to complete the task successfully. Connect the activity to the way engineering teams coordinate complex projects while working within safety and design constraints.

Facilitation Guide

1. Divide students into engineering teams and distribute one challenge kit to each group.
2. Explain the objective: construct a cup pyramid without touching the cups directly.
3. Review the engineering constraints and allow teams a few minutes to discuss their strategy before beginning.
4. Begin the challenge and encourage students to communicate clearly as they manipulate the cups using the rubber band tool.
5. Increase the difficulty by asking teams to construct a larger pyramid or complete the task within a shorter time limit.
6. Facilitate a class discussion in which students reflect on how their communication and teamwork changed throughout the activity.
7. Connect the challenge to engineering by discussing how successful engineering projects depend on planning, collaboration, and adaptability.



Reflection & Discussion

- What communication strategies helped your team work most effectively?
- How did your team adapt when your original strategy did not work?
- What engineering constraints made this challenge more difficult?
- Why is collaboration essential when engineers work on large transportation projects?
- How can effective communication improve safety in engineering and railway operations?

Teacher Tips

Encourage students to assign informal engineering roles such as communicator, observer, strategist, or timekeeper before beginning the challenge. During the reflection, emphasize that engineers rarely work alone. Large transportation projects require teams of professionals who must communicate clearly, adapt to changing conditions, and solve problems together to achieve a common goal.

Differentiation

Support: Allow teams additional planning time before beginning the challenge and provide a demonstration of how the rubber band tool works. Encourage students to discuss their strategy before each attempt.

Extension: Challenge teams to complete the pyramid using fewer verbal directions or within a reduced time limit. After the activity, have students identify specific engineering habits, such as communication, collaboration, perseverance, or systems thinking, that contributed to their success and justify their choices using examples from the challenge.

Activity #2: Conductors in Training: Team Builder & Collaboration Lab

Activity Overview

Students investigate how electricity flows through a complete circuit by constructing simple electrical circuits and testing a variety of materials to determine whether they function as conductors or insulators. Working in collaborative engineering teams, students develop predictions, conduct investigations, collect observations, and analyze evidence to explain how electrical current travels through a circuit. Students conclude the lesson by connecting their findings to the electrical systems used in railway crossings, warning signals, and train operations.

Estimated Time: 35–45 minutes

Learning Objectives

The students will be able to:



- Construct and test a complete electrical circuit using batteries, wires, and a light source.
- Investigate the properties of conductors and insulators through experimental testing.
- Use evidence from observations to explain how electricity flows through a circuit and why engineers select specific materials for electrical systems.

Science TEKS:

- MS.1(A) Ask questions and define problems based on observations and investigations.
- MS.1(B) Use scientific and engineering practices to conduct investigations and evaluate evidence.
- MS.1(C) Collect, organize, and analyze qualitative observations during scientific investigations.
- MS.1(G) Develop explanations and communicate scientific reasoning supported by evidence.

Math TEKS:

- 6.1(A) Apply mathematical reasoning to solve scientific and engineering problems.
- 6.1(B) Analyze observations, organize information, and communicate conclusions.

NGSS:

- MS-PS2-3 Ask questions about data to determine the factors that affect the strength of electric and magnetic interactions.
- MS-ETS1-2 Evaluate design solutions based on evidence and established criteria.

Materials Needed:

- D-cell batteries
- Battery holders
- Connecting wires with alligator clips
- Miniature light bulbs and bulb holders
- Assorted test materials (e.g., paper clip, aluminum foil, plastic spoon, wooden craft stick, coin, rubber band, pencil graphite, fabric)
- Conductors and Insulators recording sheet
- Pencil

Teacher Preparation

Prepare one circuit kit for each engineering team and verify that all batteries and bulbs are functioning properly before class. Organize the test materials at each station and create a Conductors and Insulators data table for students to record predictions and results. Review proper safety procedures for working with electrical components and emphasize that students should test one material at a time while keeping the remainder of the circuit unchanged.

Facilitation Guide



1. Review the parts of a simple electrical circuit and demonstrate how electrical current flows through a closed circuit.
2. Have engineering teams assemble a working circuit and verify that the light bulb illuminates.
3. Introduce the investigation by asking students to predict which materials will conduct electricity and which will act as insulators.
4. Students test each material by placing it into the circuit and recording whether the bulb lights.
5. Teams organize their findings into a Conductors and Insulators chart and compare results.
6. Facilitate a discussion about why certain materials allowed electricity to flow while others prevented it.
7. Conclude by connecting the investigation to real-world railway systems, explaining how engineers carefully select conductive and insulating materials when designing railroad crossings, warning signals, communication systems, and electrical infrastructure.

Reflection & Discussion

- What evidence helped you determine whether a material was a conductor or an insulator?
- Why is a complete circuit necessary for electricity to flow?
- Which materials surprised you during the investigation? Why?
- How do engineers use conductors and insulators to improve the safety and reliability of railway systems?
- Why is testing materials an important part of engineering design?

Teacher Tips

Encourage students to justify each conclusion using evidence collected during the investigation rather than relying on prior knowledge or assumptions. Reinforce that engineers test materials under controlled conditions before selecting them for real-world applications. Throughout the activity, continually connect the investigation to railway engineering by discussing how electrical systems operate warning signals, crossing gates, communication networks, and other critical infrastructure.

Differentiation

Support: Provide students with a partially completed data table and review the concepts of open and closed circuits before testing materials. Model one example together before allowing teams to complete the remaining investigation independently.

Extension: Challenge students to explain *why* certain materials conduct electricity by considering their physical properties. Have teams recommend which materials would be most appropriate for different railway applications, such as electrical wiring, protective coverings, or railroad crossing equipment, and justify their choices using evidence collected during the investigation.



Activity #3: Electromagnet Engineering Challenge

Activity Overview

Students investigate the relationship between electricity and magnetism by designing, constructing, and testing a simple electromagnet. Working in engineering teams, students explore how electric current flowing through a wire can generate a magnetic field capable of attracting metal objects. After constructing their electromagnets, students participate in an engineering challenge to determine how design modifications influence performance. Through testing, data collection, and redesign, students recognize that engineers continually optimize electrical systems to improve efficiency, reliability, and safety.

Estimated Time: 45–60 minutes

Learning Objectives

The students will be able to:

- Construct a functioning electromagnet using a battery, insulated wire, and an iron nail.
- Investigate how electric current creates a magnetic field capable of attracting metal objects.
- Evaluate and improve an electromagnet design using evidence gathered during testing.

Science TEKS:

- MS.1(A) Ask questions and define problems through investigations involving electricity and magnetism.
- MS.1(B) Apply scientific and engineering practices to design, test, and improve an engineering solution.
- MS.1(C) Collect, organize, and analyze qualitative and quantitative observations during an investigation.
- MS.1(G) Develop explanations and communicate conclusions supported by evidence.

Math TEKS:

- 6.1(A) Apply mathematical reasoning to solve engineering design challenges.
- 6.1(B) Organize, analyze, and communicate data collected during investigations.

NGSS:

- MS-PS2-3 Ask questions about data to determine the factors that affect the strength of electric and magnetic interactions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- MS-ETS1-3 Analyze data from tests to identify characteristics of the most effective design solution.



Materials Needed:

- Iron nail (one per team)
- Insulated copper wire
- D-cell battery
- Battery holder
- Alligator clip wires
- Paper clips
- Student data collection sheet

Teacher Preparation

Prepare one electromagnet kit for each engineering team and verify that all electrical components are functioning properly. Pre-strip the ends of the insulated wire if needed to ensure good electrical connections. Organize paper clips for the engineering challenge and review safe handling procedures when working with batteries and electrical equipment. Remind students that the wire and battery may become warm if connected for extended periods and should only remain connected while testing.

Facilitation Guide

1. Introduce the question: **Can electricity create a magnetic field?**
2. Review the relationship between electricity and magnetism using the Day 2 presentation.
3. Demonstrate how to construct a simple electromagnet.
4. Have engineering teams build their own electromagnet following the provided procedure.
5. Test each electromagnet by determining how many paper clips it can lift.
6. Record the results and encourage teams to identify possible improvements.
7. Allow students to modify one design variable (such as the number of wire wraps or the quality of electrical connections) and repeat the investigation.
8. Compare class results and discuss how engineers optimize electrical systems through repeated testing and redesign.

Reflection & Discussion

- What evidence showed that electricity created a magnetic field?
- Which design modifications improved your electromagnet's performance?
- Why is repeated testing an important part of engineering?
- How do engineers use electromagnets in transportation systems?
- How could electromagnets improve the safety or efficiency of railway operations?

Teacher Tips

Encourage students to modify **only one variable at a time** so they can determine which changes actually improve performance. Reinforce that engineers rely on controlled investigations and evidence when improving a design. During the discussion, connect the activity to real-world applications such as



magnetic cranes used to move steel, electric motors, railway signaling equipment, and other transportation technologies that rely on electromagnetism.

Differentiation

Support: Provide students with illustrated assembly instructions and review the purpose of each component before construction. Guide students through identifying the independent, dependent, and controlled variables before beginning the investigation.

Extension: Challenge teams to design the strongest electromagnet possible while working within established material constraints. Require students to justify each design modification using evidence from previous trials and present recommendations for improving future designs.

Activity #4: Railway Systems Investigation

Activity Overview

Students investigate how electrical systems, railroad crossings, and freight rail networks work together to support safe and efficient railway transportation. Through guided discussions, visual analysis, and collaborative activities, students compare passive and active railroad crossings, examine the purpose of railway warning systems, and explore the roles of Class I, Class II, and Class III railroads within the national freight transportation network. Students conclude the lesson by completing a Railway Class Matching Activity that reinforces how different rail systems work together to move goods across local, regional, and national transportation systems.

Estimated Time: 40-50 min.

Learning Objectives

The students will be able to:

- Compare passive and active railroad crossings and explain how each contributes to railway safety.
- Differentiate among Class I, Class II, and Class III railroads based on their roles within the freight transportation system.
- Analyze how electrical systems, communication, and transportation infrastructure work together to improve railway operations and public safety.

Science TEKS:

- MS.1(A) Ask questions and define problems related to engineering systems and transportation.



- MS.1(B) Apply scientific and engineering practices to analyze how multiple systems interact to solve real-world problems.
- MS.1(G) Develop explanations and communicate scientific reasoning supported by evidence.

Math TEKS:

- **6.1(A)** Apply mathematical reasoning to interpret information presented in maps, charts, and transportation data.
- **6.1(B)** Analyze information, identify patterns, and communicate conclusions using evidence.

NGSS:

- MS-ETS1-1 Define the criteria and constraints of engineering problems involving transportation systems.
- MS-ETS1-2 Evaluate how components within a transportation system work together to meet safety and operational goals.

Materials Needed:

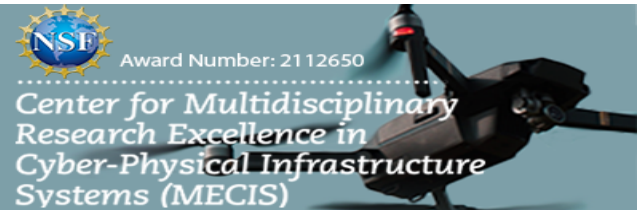
- Day 2 PowerPoint presentation
- Railroad crossing images
- Railroad classification maps
- Railway Class Matching Activity cards
- Student recording sheet
- Whiteboard or chart paper

Teacher Preparation

Review the Day 2 presentation, including the sections on railroad crossings, freight transportation, and railroad classifications. Prepare the Railway Class Matching Activity by organizing the classification cards before class. Familiarize yourself with the examples of Class I, Class II, and Class III railroads presented in the slides, and be prepared to guide students in making connections between local railroads and the larger national freight network.

Facilitation Guide

1. Introduce the purpose of railway systems and discuss why safe transportation depends on multiple interconnected engineering systems.
2. Compare passive and active railroad crossings, emphasizing how electrical warning systems improve public safety.
3. Discuss the purpose of freight rail transportation and examine examples of goods commonly transported by rail.
4. Introduce the characteristics of Class I, Class II, and Class III railroads using maps and diagrams from the presentation.



5. Have engineering teams complete the Railway Class Matching Activity by matching railroad companies to the appropriate classification.
6. Review the activity as a class and discuss how each type of railroad contributes to the movement of freight across local, regional, and national transportation networks.
7. Conclude by connecting the lesson to the role engineers play in designing, maintaining, and improving railway infrastructure.

Reflection & Discussion

- Why are active railroad crossings safer than passive crossings in certain locations?
- How do electrical systems improve railway safety?
- Why are different railroad classifications necessary within the freight transportation network?
- How do local railroads connect to larger national transportation systems?
- How do engineers ensure that multiple railway systems work together safely and efficiently?

Teacher Tips

Encourage students to think of the railroad as an interconnected engineering system rather than a collection of individual parts. As students examine railroad crossings, freight movement, and railroad classifications, continually ask them how each component supports the larger transportation network. Reinforce that engineers must consider communication, infrastructure, electrical systems, and public safety when designing transportation solutions.

Differentiation

Support: Provide students with a reference chart summarizing the characteristics of passive and active railroad crossings and the three railroad classifications. Encourage students to work collaboratively during the matching activity and discuss their reasoning before making decisions.

Extension: Challenge students to analyze how a shipment might travel from a local business to another state by moving through Class III, Class II, and Class I railroads. Have students create a simple transportation pathway and justify why each railroad classification is necessary to complete the journey.

Activity #5: LEGO® Education SPIKE™ Prime Hopper Robot

Activity Overview

Students investigate how engineers use signals, sensors, and automated systems to improve railway operations before constructing and programming a LEGO® Education SPIKE™ Prime Hopper Robot. Working in collaborative engineering teams, students assume engineering roles while building and programming the robot to perform specific tasks. Throughout the activity, students test, troubleshoot,



and refine their robotic system while exploring how automation, computational thinking, and engineering design contribute to safer and more efficient transportation systems.

Estimated Time: 50–60 minutes

Learning Objectives

The students will be able to:

- Construct and program a LEGO® Education SPIKE™ Prime Hopper Robot using engineering design principles.
- Explain how sensors, motors, and programmed instructions work together within an automated system.
- Test, evaluate, and improve a robotic system by applying the Engineering Design Process.

Science TEKS:

- MS.1(B) Apply scientific and engineering practices to design, construct, test, and improve engineering solutions.
- MS.1(C) Collect observations and analyze evidence to evaluate system performance.
- MS.1(G) Develop explanations and communicate engineering solutions supported by evidence.

Math TEKS:

- 6.1(A) Apply mathematical reasoning to solve engineering and programming challenges.
- 6.1(B) Analyze information, evaluate solutions, and communicate reasoning during collaborative problem solving.

NGSS:

- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet established criteria and constraints.
- MS-ETS1-3 Analyze data from tests to identify characteristics of the most effective design solution.

Materials Needed:

- LEGO® Education SPIKE™ Prime Kit (one per team)
- Tablet or computer with the SPIKE™ Prime App
- Hopper Robot building instructions
- Student engineering journal (optional)
- Challenge course (optional)

Teacher Preparation



Ensure each SPIKE™ Prime kit is complete and that all hubs are fully charged before class. Verify that the SPIKE™ App is installed and functioning properly on each device. Review the Hopper Robot building instructions and introductory programming sequence. Before students begin construction, introduce the concept of **signals and systems** and discuss how engineers use sensors, motors, and computer programming to automate railway operations and improve transportation safety.

Facilitation Guide

1. Introduce signals and systems by discussing how automated technologies are used throughout modern railway operations.
2. Assign engineering roles within each team (Lead Engineer, Systems Engineer, Mechanical Engineer, Programmer, or Tester).
3. Distribute the LEGO® SPIKE™ Prime kits and guide students through constructing the Hopper Robot.
4. Introduce the basic programming sequence needed to operate the robot.
5. Allow teams to test the Hopper Robot and observe its performance.
6. Encourage students to troubleshoot construction or programming issues and make improvements based on testing.
7. Facilitate a discussion about how engineers use automation, sensors, and robotics to improve safety and efficiency within railway systems.

Reflection & Discussion

- How do sensors and programmed instructions allow a robot to complete a task?
- What challenges did your engineering team encounter during construction or programming?
- How did testing improve your robot's performance?
- Why are teamwork and clearly defined engineering roles important during complex projects?
- How are robotic systems used in modern railway operations?

Teacher Tips

Encourage students to remain in their assigned engineering roles throughout the activity while recognizing that collaboration is essential to project success. Rather than immediately solving problems for students, ask guiding questions that encourage troubleshooting and evidence-based decision making. Reinforce that engineers continuously refine their designs through testing and iteration, and that programming errors provide valuable opportunities for learning and improvement.

Differentiation

Support: Provide students with step-by-step building guides and starter code to assist with programming. Pair experienced students with peers who may need additional support while ensuring every team member contributes to the engineering process.



Extension: Challenge teams to modify the Hopper Robot's programming by adjusting speed, timing, or movement patterns to improve efficiency. Have students justify each modification using evidence gathered during testing and explain how similar automation technologies are used in railway systems.

Activity #6: Hopper Robot Engineering Challenge

Activity Overview

Students apply the Engineering Design Process to complete a robotics challenge using their LEGO® Education SPIKE™ Prime Hopper Robot. Working in engineering teams, students program, test, and refine their robot to complete a designated task while working within established design constraints. Throughout the challenge, students analyze robot performance, troubleshoot programming and mechanical issues, and make evidence-based improvements. By the conclusion of the activity, students recognize that successful robotic systems are developed through collaboration, testing, and continuous refinement.

Estimated Time: 45–60 minutes

Learning Objectives

The students will be able to:

- Apply the Engineering Design Process to improve the performance of a programmed robotic system.
- Analyze programming and design challenges to identify effective solutions.
- Use evidence gathered during testing to refine and optimize robot performance.

Science TEKS:

- MS.1(A) Ask questions and define problems by identifying criteria and constraints for a robotics challenge.
- MS.1(B) Apply scientific and engineering practices to design, test, and improve a robotic solution.
- MS.1(C) Collect and analyze observations to evaluate system performance.
- MS.1(G) Develop explanations and communicate engineering solutions supported by evidence.

Math TEKS:

- 6.1(A) Apply mathematical reasoning to solve engineering and programming challenges.
- 6.1(B) Analyze data, evaluate solutions, and communicate reasoning during collaborative problem solving.

NGSS:



- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the established criteria and constraints.
- MS-ETS1-3 Analyze data from tests to determine similarities and differences among design solutions and identify characteristics of the most effective solution.

Materials Needed:

- LEGO® Education SPIKE™ Prime Hopper Robot
- Tablet or computer with the SPIKE™ Prime App
- Challenge course or testing area
- Challenge objects (as determined by the activity)
- Student engineering journal or data sheet
- Stopwatch (optional)

Teacher Preparation

Set up the challenge course before class and verify that each engineering team has a functioning Hopper Robot. Review the challenge criteria, scoring expectations, and engineering constraints with students. Remind teams that successful engineers improve their designs through repeated testing, careful observation, and thoughtful revision rather than expecting success on the first attempt.

Facilitation Guide

1. Introduce the Hopper Robot Engineering Challenge and review the design criteria and constraints.
2. Allow engineering teams time to discuss their strategy before programming or modifying their robot.
3. Students test their Hopper Robot on the challenge course and record observations about its performance.
4. Teams identify programming or mechanical adjustments that could improve performance.
5. Students revise their robot and complete additional testing rounds.
6. Compare team solutions and discuss how different programming strategies produced different outcomes.
7. Conclude by connecting the activity to how engineers continuously improve automated transportation systems through testing and refinement.

Reflection & Discussion

- What was the greatest challenge your team encountered during the robotics challenge?
- How did testing help improve your robot's performance?
- Which programming or design change had the greatest impact on your results?
- Why do engineers test and revise automated systems multiple times before implementation?
- How could robotics improve the safety and efficiency of railway operations?



Teacher Tips

Encourage students to change one programming or design variable at a time so they can determine which modification improved performance. Resist solving programming issues for students; instead, ask guiding questions that encourage troubleshooting and evidence-based decision making. Reinforce that iteration is an expected and valuable part of engineering.

Differentiation

Support: Provide students with a troubleshooting checklist that includes common programming and construction issues. Encourage teams to test their robot after each small modification rather than making multiple changes at once.

Extension: Challenge teams to optimize their Hopper Robot to complete the task more efficiently by reducing time, improving accuracy, or minimizing unnecessary movements. Have students present their final solution and justify their programming decisions using evidence collected during testing.

Activity #7: Engineering Reflection & Systems Debrief

Activity Overview

Students conclude Day 2 by reflecting on the engineering concepts explored throughout the day, including electrical circuits, conductors and insulators, electromagnets, railway systems, and robotics. Through individual reflection and collaborative discussion, students evaluate how each investigation contributed to their understanding of railway engineering and identify how engineers use electricity, automation, and teamwork to improve transportation safety. Students also consider how the Engineering Design Process guided their work and how today's learning prepares them for future engineering challenges.

Estimated Time: 10–15 minutes

Learning Objectives

The students will be able to:

- Evaluate how electricity, magnetism, and automation work together within railway systems.
- Reflect on how the Engineering Design Process supported their investigations and engineering decisions.
- Communicate evidence-based explanations describing how engineering improves transportation safety and efficiency.

Science TEKS:



- MS.1(G) Develop and communicate explanations and engineering solutions supported by evidence.

Math TEKS:

- 6.1(B) Communicate mathematical and scientific reasoning using appropriate evidence and representations.

NGSS:

- MS-ETS1-3 Analyze results from engineering investigations and use evidence to evaluate the effectiveness of design solutions.

Materials Needed:

- Student engineering journals
- Reflection questions
- Pencil
- Day 2 PowerPoint

Teacher Preparation

Prepare the reflection prompts prior to class and encourage students to support their responses with evidence gathered during the day's investigations. Create an environment where students feel comfortable discussing both successful designs and challenges they encountered. Emphasize that reflection is an essential part of the engineering process because it informs future improvements.

Facilitation Guide

1. Ask students to independently reflect on the day's engineering investigations.
2. Have students discuss their responses with a partner or small group.
3. Facilitate a whole-class discussion connecting the day's activities to real-world railway engineering.
4. Encourage students to describe how the Engineering Design Process was used throughout the day.
5. Preview Day 3 by explaining that students will shift from electrical engineering to mechanical engineering, exploring wheel and axle systems, freight transportation, and Newton's Laws.

Reflection & Discussion

- Which investigation helped you understand electrical engineering the most? Why?
- How did teamwork contribute to your success during today's activities?
- How do electricity and magnetism improve railway safety?
- How did the Engineering Design Process help you solve problems throughout the day?
- What engineering skill do you think will be most important during tomorrow's challenges?



Teacher Tips

Encourage students to support their reflections with specific examples from the circuit investigation, electromagnet challenge, railway systems lesson, or robotics activities. Reinforce that engineers regularly evaluate their work, identify areas for improvement, and communicate findings to other members of their team. This reflection helps students recognize that engineering involves continuous learning and refinement.

Differentiation

Support: Provide sentence starters such as *"One thing I learned today was..."* or *"The evidence that helped me understand..."* to guide student responses.

Extension: Ask students to write a brief engineering recommendation describing one improvement they would make to a railway electrical or robotic system based on what they learned during Day 2. Students should support their recommendation with evidence from the day's investigations.

Day 3: Freight Transportation Engineers

Day Overview

On Day 3, students explore how mechanical engineering and transportation systems work together to keep freight railroads operating safely and efficiently. They begin by strengthening teamwork through a collaborative engineering activity before investigating the causes of train derailments and the importance of wheel-and-axle design. Students then apply the Engineering Design Process by designing, testing, and improving a wheel-and-axle model to better understand how engineers reduce derailments and improve railway safety. Next, students investigate freight transportation by analyzing different cargo types and selecting the most appropriate railcars for transporting goods. The day concludes with students constructing and programming a LEGO® Education SPIKE™ Prime Driving Base and completing an engineering challenge that simulates a railway inspection vehicle capable of detecting obstacles and moving them to a designated safe zone. Throughout the day, students strengthen their understanding of mechanical systems, transportation engineering, robotics, and computational thinking while applying engineering practices to authentic railway safety challenges.

Lesson Objectives:

By the end of Day 3, students will be able to:

- Explain how wheel-and-axle systems help prevent train derailments and improve railway safety.
- Apply the Engineering Design Process to investigate, test, and improve engineering solutions.
- Analyze how different freight railcars are designed to transport specific types of cargo safely and efficiently.



- Construct and program a LEGO® Education SPIKE™ Prime Driving Base to complete an engineering task.
- Apply teamwork, communication, and problem-solving skills while designing, testing, and refining engineering solutions.

Essential Questions

- Why are properly designed wheels and axles essential for safe railway transportation?
- How do engineers use testing and redesign to improve railway systems?
- How do different freight railcars safely transport different types of cargo?
- How do robotics and automation improve railway inspection and maintenance?
- How does teamwork contribute to solving complex engineering problems?

Day 3 at a Glance

Time Frame	Activity	Focus / Goal
10–15 min	Engineering Design Process Recap	Review the Engineering Design Process and connect Day 2 concepts in electrical engineering and robotics to the mechanical engineering challenges of Day 3.
15–20 min	Activity 1: Rock, Paper, Scissors Engineering Team Builder	Strengthen teamwork, communication, adaptability, and leadership while preparing students for collaborative engineering investigations.
50–60 min	Activity 2: Maintenance, Derailments, & Wheel and Axle Engineering Investigation	Investigate the causes of train derailments and apply the Engineering Design Process to design, test, and improve a wheel-and-axle system using the Styrofoam Cup Engineering Challenge.
30–40 min	Activity 3: Freight Transportation Systems Investigation	Analyze different freight railcars, classify cargo based on transportation needs, and justify engineering decisions that promote safe and efficient freight movement.
45–60 min	Activity 4: LEGO® Education SPIKE™ Prime Driving Base	Construct and program a Driving Base while exploring robotics, programming, and automated transportation systems.
45–60 min	Activity 5: Inspection Detection Engineering Challenge	Program, test, and refine a robotic railway inspection vehicle capable of detecting, removing, and safely



Time Frame	Activity	Focus / Goal
		relocating track obstacles using the Engineering Design Process.
10–15 min	Activity 6: Engineering Reflection & Design Debrief	Reflect on mechanical engineering, freight transportation, robotics, and engineering design while evaluating how testing, teamwork, and iterative improvement contribute to railway safety.

Day 3 Vocabulary

Students should review the following vocabulary before beginning the Day 3 activities. These terms will be used throughout the day during discussions about electricity, magnets, railway systems, crossings, and robotics.

Term	Student-Friendly Definition	Day 3 Connection
Wheel and Axle	A simple machine made of a wheel connected to a central axle that helps objects move more easily.	Students investigate how wheel-and-axle systems keep trains on the tracks and design their own model during the Styrofoam Cup Engineering Challenge.
Derailment	An event in which a train leaves the tracks, often because of mechanical failure, damaged tracks, or obstacles.	Students examine the causes of derailments and investigate how engineers design safer railway systems to reduce accidents.
Railway Maintenance	The inspection, repair, and upkeep of tracks, trains, and equipment to keep railways operating safely.	Students learn why routine maintenance is essential for preventing derailments and ensuring reliable railway transportation.
Mechanical Engineering	A branch of engineering that focuses on designing, building, and improving machines and moving systems.	Students explore how mechanical engineers design wheel-and-axle systems, freight equipment, and railway vehicles to improve transportation safety.
Freight Railcar	A specialized railroad car designed to transport a specific type of cargo.	Students investigate different freight railcars and determine which designs are best suited for transporting various materials safely and efficiently.
Cargo	Goods or materials transported from one location to another.	Students classify different cargo items and match them with the most appropriate freight railcars based on their characteristics.

Term	Student-Friendly Definition	Day 3 Connection
Logistics	The planning and coordination of moving people or goods efficiently from one place to another.	Students discover how engineers and transportation planners organize freight movement across railway networks.
Automation	The use of technology and programmed systems to perform tasks with little or no human intervention.	Students build and program a LEGO® SPIKE™ Prime Driving Base and investigate how automation improves railway inspection and maintenance.
Programming	Writing a sequence of instructions that tells a computer or robot how to perform a task.	Students develop and refine programs that allow the Driving Base to inspect tracks, detect obstacles, and complete engineering challenges.
Sensor	A device that detects information from its surroundings and sends that information to a robot or computer.	Students use sensors to help the Driving Base identify obstacles and respond appropriately during the Inspection Detection Engineering Challenge.
Iteration	The process of testing, improving, and repeating a design to make it work better.	Students repeatedly test and improve their wheel-and-axle models and robotic systems using the Engineering Design Process.
Obstacle Detection	The ability of a robotic or automated system to recognize an object in its path and respond appropriately.	Students program the Driving Base to detect obstacles, remove hazards, and continue safely along the inspection route during the engineering challenge.

Activity #1: Rock, Paper, Scissors Engineering Team Builder

Activity Overview

Students begin Day 3 by participating in a collaborative Rock, Paper, Scissors team-building activity that emphasizes communication, adaptability, and teamwork. As students compete and merge into larger teams, they experience how engineers work together, support one another, and adapt to changing situations while pursuing a common goal. Following the activity, students reflect on the importance of collaboration, leadership, and effective communication in engineering projects before transitioning into the day's mechanical engineering investigations.

Estimated Time: 15–20 minutes

Learning Objectives

The students will be able to:



- Demonstrate effective communication and collaboration while participating in a team-building activity.
- Adapt strategies and work cooperatively as team dynamics change throughout the challenge.
- Reflect on how teamwork, leadership, and communication contribute to successful engineering projects.

Science TEKS:

- MS.1(A) Ask questions and define problems while working within collaborative engineering tasks.
- MS.1(B) Apply scientific and engineering practices by working effectively within a team to solve problems.
- MS.1(G) Communicate ideas and reflect on collaborative problem-solving using evidence from the activity.

Math TEKS:

- 6.1(B) Use a problem-solving process that includes analyzing information, selecting strategies, evaluating solutions, and communicating reasoning.

NGSS:

- MS-ETS1-1 Define the criteria and constraints of a design problem while working collaboratively to develop solutions.

Materials Needed:

- Open classroom or gymnasium space
- Timer (optional)
- Reflection questions
- Whiteboard or chart paper

Teacher Preparation

Review the activity procedures before class and arrange an open space where students can move safely. Prepare reflection questions that encourage students to connect the experience to engineering teamwork. Emphasize that the purpose of the activity is not competition, but rather collaboration, communication, and adaptability, skills that engineers use every day when solving complex problems.

Facilitation Guide

1. Explain the rules of the Rock, Paper, Scissors Team Builder.
2. Have students begin playing in pairs.
3. After each round, the losing student joins the winner's team and continues encouraging them during future rounds.



4. Continue until all students become part of one final engineering team.
5. Facilitate a discussion about how team dynamics changed as groups became larger.
6. Connect the activity to engineering by discussing how engineers collaborate across different specialties to solve large transportation and infrastructure challenges.
7. Transition into the day's focus on mechanical engineering and railway systems.

Reflection & Discussion

- How did your communication change as your team became larger?
- What strategies helped your team work together successfully?
- Why is adaptability important when working on engineering projects?
- How do engineers benefit from collaborating with people who have different strengths and ideas?
- How can effective teamwork improve railway safety and transportation systems?

Teacher Tips

Keep the atmosphere energetic while continually reinforcing the purpose of the activity. During the reflection, emphasize that engineering projects require individuals with different areas of expertise who must communicate effectively, adapt to new information, and support one another. Help students recognize that successful engineering is built on collaboration as much as technical knowledge.

Differentiation

Support: Review the game rules with the class before beginning and model one or two practice rounds. Encourage students who may be hesitant to participate by pairing them with supportive classmates and providing positive reinforcement throughout the activity.

Extension: After the activity, ask students to identify specific engineering roles, such as mechanical engineer, electrical engineer, programmer, or project manager, and discuss how each role contributes to a successful engineering project. Have students explain how teamwork during the activity mirrored the collaboration required in professional engineering teams.

Activity #2: Maintenance and Derailments & Wheel and Axle Engineering Investigation

Activity Overview

Students investigate the role of mechanical engineering in railway safety by exploring the causes of train derailments and the importance of properly designed wheel-and-axle systems. Through guided discussion and demonstrations, students examine how wheel shape, axle alignment, and routine maintenance help trains remain safely on the tracks. Students then apply the Engineering Design Process



by designing, constructing, testing, and improving a wheel-and-axle model using Styrofoam cups. Throughout the investigation, students collect observations, evaluate performance, and refine their designs while recognizing how engineers use evidence and testing to improve transportation safety.

Estimated Time: 50–60 minutes

Learning Objectives

The students will be able to:

- Explain how wheel-and-axle systems contribute to safe railway operation and help prevent derailments.
- Investigate how wheel shape, alignment, and stability influence the movement of a train along the tracks.
- Apply the Engineering Design Process to design, test, evaluate, and improve a wheel-and-axle model.

Science TEKS:

- MS.1(A) Ask questions and define engineering problems related to railway safety and mechanical systems.
- MS.1(B) Apply scientific and engineering practices to design, test, and improve a mechanical solution.
- MS.1(C) Collect, organize, and analyze observations from engineering investigations.
- MS.1(G) Develop explanations and communicate engineering solutions supported by evidence.

Math TEKS:

- 6.1(A) Apply mathematical reasoning to solve engineering design challenges.
- 6.1(B) Analyze observations, evaluate solutions, and communicate conclusions using evidence.

NGSS:

- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- MS-ETS1-3 Analyze data from tests to identify characteristics of the most effective design solution.

Materials Needed:

- Day 3 PowerPoint
- Styrofoam cups
- Wooden skewers or dowels
- Tape
- Scissors
- Track or testing surface



- Meter stick or measuring tape
- Student engineering journal or data sheet

Teacher Preparation

Review the presentation sections on railway maintenance, derailments, and wheel-and-axle systems before class. Prepare one engineering kit for each team containing the materials needed to construct the wheel-and-axle model. Set up a testing station where students can evaluate the performance of their designs. Emphasize that engineers use repeated testing and routine maintenance to improve railway safety and reduce derailments.

Facilitation Guide

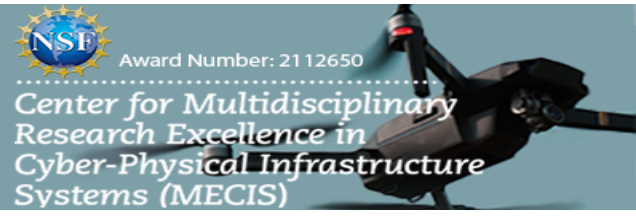
1. Introduce the lesson by discussing common causes of train derailments and the importance of routine railway maintenance.
2. Explain how wheel shape, axle alignment, and track conditions influence train stability.
3. Demonstrate examples of effective and ineffective wheel-and-axle designs.
4. Divide students into engineering teams and present the Styrofoam Cup Wheel and Axle Challenge.
5. Students brainstorm, sketch, and construct their wheel-and-axle models.
6. Test each design on the track and record observations about stability, alignment, and performance.
7. Encourage teams to identify weaknesses in their designs and make evidence-based improvements.
8. Repeat testing after redesign and facilitate a class discussion comparing the effectiveness of different solutions.

Reflection & Discussion

- Why is wheel-and-axle design critical for railway safety?
- What factors caused some designs to perform better than others?
- How did testing help improve your engineering solution?
- Why is regular railway maintenance just as important as good engineering design?
- How do engineers use evidence collected during testing to reduce derailments?

Teacher Tips

Encourage students to modify one design feature at a time so they can clearly identify which changes improve performance. Reinforce that engineers depend on testing, maintenance, and continuous improvement to ensure transportation systems remain safe and reliable. Throughout the investigation, connect students' observations to real-world railway engineering by discussing how mechanical engineers design wheels, axles, and track systems that can safely support heavy freight trains.



Differentiation

Support: Provide students with a labeled diagram of a railway wheel-and-axle system before construction. Model how to assemble a basic prototype and encourage teams to discuss potential improvements before testing.

Extension: Challenge students to redesign their wheel-and-axle model to improve stability while using the same materials. Have teams justify each design modification using evidence gathered during testing and compare the performance of their original and revised prototypes.

Activity #3: Freight Transportation Systems Investigation

Activity Overview

Students investigate how freight railroads safely transport goods by examining the purpose and design of specialized railcars used throughout the transportation industry. Working in engineering teams, students analyze the characteristics of various cargo items and determine which type of freight car is best suited to transport each material. Through a collaborative sorting activity, students justify their decisions using evidence about cargo properties, railcar design, and transportation safety. The lesson emphasizes that engineers must carefully design transportation systems that maximize efficiency while protecting both people and cargo.

Estimated Time: 30–40 minutes

Learning Objectives

The students will be able to:

- Compare the design and purpose of different freight railcars used in railway transportation.
- Analyze the physical characteristics of cargo to determine the most appropriate transportation method.
- Justify engineering decisions using evidence related to safety, efficiency, and railcar design.

Science TEKS:

- MS.1(A) Ask questions and define transportation engineering problems based on cargo characteristics and system requirements.
- MS.1(B) Apply scientific and engineering practices to analyze how transportation systems are designed to safely move goods.
- MS.1(G) Develop explanations and communicate engineering decisions supported by evidence.



Math TEKS:

- 6.1(A) Apply mathematical reasoning to analyze information and solve engineering problems.
- 6.1(B) Evaluate information, justify decisions, and communicate reasoning using evidence.

NGSS:

- MS-ETS1-1 Define the criteria and constraints of an engineering problem involving transportation systems.
- MS-ETS1-2 Evaluate multiple design solutions to determine which best meets transportation needs and safety requirements.

Materials Needed:

- Day 3 PowerPoint
- Projector or interactive display
- Images or diagrams of a train wheel, axle, and bearing
- Wheel and axle demonstration model (if available)
- Student science journal or recording sheet
- Pencils

Teacher Preparation

Review the presentation sections introducing freight transportation and the different types of freight railcars. Prepare one set of cargo cards and railcar classification cards for each engineering team. Familiarize yourself with the purpose of each railcar type so you can guide students in justifying their decisions using engineering reasoning rather than guessing. Emphasize that engineers select transportation equipment based on the physical properties of the cargo, operational efficiency, and safety requirements.

Facilitation Guide

1. Introduce the role of freight railroads in transporting goods across local, regional, and national transportation networks.
2. Review the characteristics and purposes of the different freight railcars presented in the lesson.
3. Divide students into engineering teams and distribute the cargo cards and freight railcar reference cards.
4. Have each team analyze the properties of each cargo item and determine the most appropriate railcar for transportation.
5. Require students to justify each match using evidence related to cargo characteristics, railcar design, and safety considerations.
6. Review the activity as a class, comparing different team decisions and discussing the engineering reasoning behind each selection.



7. Conclude by connecting the activity to how transportation engineers design systems that safely and efficiently move goods around the world.

Reflection & Discussion

- Why do different types of cargo require different railcars?
- Which cargo items were the most difficult to classify? Why?
- How do engineers balance efficiency and safety when designing freight transportation systems?
- What problems might occur if cargo is transported in the wrong type of railcar?
- How does freight transportation support communities and the economy?

Teacher Tips

Encourage students to explain **why** they selected a particular railcar instead of simply identifying the correct answer. Ask follow-up questions that require students to consider factors such as weight, size, liquid versus solid materials, weather protection, and loading methods. Reinforce that engineering decisions are based on evidence and design criteria rather than personal preference.

Differentiation

Support: Provide students with a reference chart that includes illustrations and descriptions of each freight railcar. Allow teams to discuss each cargo item before making their final selection and encourage them to eliminate unsuitable options using evidence.

Extension: Challenge teams to design a transportation route for a shipment that requires multiple types of cargo. Students should determine which railcars are needed, explain why each was selected, and describe how engineers ensure that different cargo types can be transported together safely and efficiently.

Activity #4: LEGO® Education SPIKE™ Prime Driving Base

Activity Overview

Students construct and program a LEGO® Education SPIKE™ Prime Driving Base while exploring how engineers use robotics, programming, and automation to solve transportation challenges. Working in collaborative engineering teams, students assemble the Driving Base, develop a basic movement program, and investigate how speed, turning, and movement affect robot performance. Throughout the activity, students test, troubleshoot, and refine their robotic system while preparing for the Engineering Design Challenge that follows.

Estimated Time: 45–60 minutes



Learning Objectives

The students will be able to:

- Construct and program a LEGO® Education SPIKE™ Prime Driving Base using engineering design principles.
- Explain how motors and programmed instructions control the movement of a robotic system.
- Test and refine a robotic design through observation, troubleshooting, and iterative improvement.

Science TEKS:

- MS.1(B) Apply scientific and engineering practices to design, construct, test, and improve a robotic system.
- MS.1(C) Collect observations and analyze evidence to evaluate system performance.
- MS.1(G) Develop explanations and communicate engineering solutions supported by evidence.

Math TEKS:

- 6.1(A) Apply mathematical reasoning to solve engineering and programming challenges.
- 6.1(B) Analyze results, evaluate solutions, and communicate reasoning during collaborative problem solving.

NGSS:

- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- MS-ETS1-3 Analyze data from tests to identify characteristics of the most effective design solution.

Materials Needed:

- LEGO® Education SPIKE™ Prime Kit (one per team)
- Tablet or computer with the SPIKE™ Prime App
- Driving Base building instructions
- Student engineering journal (optional)
- Open testing area

Teacher Preparation

Ensure each SPIKE™ Prime kit is complete and that all hubs are fully charged before class. Verify that the SPIKE™ Prime App is installed and functioning properly on each device. Review the Driving Base building instructions and introductory programming sequence. Before students begin construction, explain that this robot will serve as the foundation for the upcoming engineering challenge and encourage students to build carefully, test frequently, and troubleshoot collaboratively.



Facilitation Guide

1. Introduce the Driving Base and explain its purpose in robotics and transportation engineering.
2. Assign engineering roles within each team (Lead Engineer, Mechanical Engineer, Programmer, Systems Engineer, or Tester).
3. Guide students through constructing the Driving Base using the LEGO® SPIKE™ Prime instructions.
4. Introduce a basic programming sequence that allows the robot to move forward, backward, and turn.
5. Have teams test their Driving Base and observe how programming affects movement.
6. Encourage students to troubleshoot mechanical or programming issues and make improvements based on testing.
7. Conclude by discussing how engineers use robotic vehicles to inspect railways, transport materials, and improve worker safety.

Reflection & Discussion

- How do programmed instructions control the movement of the Driving Base?
- What challenges did your team encounter during construction or programming?
- How did testing improve your robot's performance?
- Why is troubleshooting an important part of engineering?
- How might robotic vehicles improve railway inspection and maintenance?

Teacher Tips

Encourage students to test their robot after completing each major programming change rather than waiting until the entire program is finished. Remind students that engineers expect to troubleshoot both mechanical and programming issues throughout the design process. Reinforce that careful construction, teamwork, and systematic testing lead to more reliable robotic systems.

Differentiation

Support: Provide students with a printed copy of the Driving Base building instructions and a sample program demonstrating basic movement. Pair students strategically to encourage collaboration and peer support during construction and programming.

Extension: Challenge engineering teams to modify the Driving Base by adjusting speed, turning radius, or travel distance. Have students explain how these changes could improve the robot's ability to complete future railway inspection tasks and support their reasoning with observations from testing.



Activity #5: Inspection Detection Engineering Challenge

Activity Overview

Students apply the Engineering Design Process to complete an authentic railway inspection challenge using their LEGO® Education SPIKE™ Prime Driving Base. Working in collaborative engineering teams, students program their robot to inspect a section of railway track, detect an obstacle, move it to a designated safe zone, and continue along its route. Throughout the challenge, students analyze robot performance, troubleshoot programming and mechanical issues, and refine their solutions based on evidence gathered during testing. The activity demonstrates how robotics and automation improve railway safety by reducing hazards and assisting engineers with inspection and maintenance tasks.

Estimated Time: 50–60 minutes

Learning Objectives

The students will be able to:

- Apply the Engineering Design Process to design, test, and improve an automated railway inspection system.
- Program a LEGO® SPIKE™ Prime Driving Base to detect and respond to obstacles.
- Evaluate and refine programming solutions using evidence collected during multiple testing trials.

Science TEKS:

- MS.1(A) Ask questions and define engineering problems by identifying the criteria and constraints of a robotics challenge.
- MS.1(B) Apply scientific and engineering practices to design, test, and improve an automated engineering solution.
- MS.1(C) Collect and analyze observations to evaluate robotic system performance.
- MS.1(G) Develop explanations and communicate engineering solutions supported by evidence.

Math TEKS:

- 6.1(A) Apply mathematical reasoning to solve robotics and engineering challenges.
- 6.1(B) Analyze data, evaluate programming solutions, and communicate reasoning during collaborative problem solving.

NGSS:

- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet established criteria and constraints.
- MS-ETS1-3 Analyze data from tests to identify characteristics of successful design solutions and improve system performance.



Materials Needed:

- LEGO® Education SPIKE™ Prime Driving Base
- Tablet or computer with the SPIKE™ Prime App
- Obstacle objects
- Designated "Safe Zone"
- Challenge mat or testing course
- Student engineering journal or data sheet
- Stopwatch (optional)

Teacher Preparation

Set up the inspection course before class by placing obstacles along the designated railway path and identifying a safe zone where obstacles will be relocated. Ensure each engineering team has a functioning Driving Base and access to the SPIKE™ Prime App. Review the challenge criteria and remind students that engineers improve automated systems through repeated testing, troubleshooting, and refinement. Encourage students to focus on developing reliable solutions rather than completing the challenge on their first attempt.

Facilitation Guide

1. Introduce the Inspection Detection Engineering Challenge and review the design criteria and engineering constraints.
2. Have engineering teams discuss and plan their programming strategy before beginning.
3. Students program the Driving Base to:
 - a. Move forward along the railway.
 - b. Detect an obstacle.
 - c. Stop and provide a warning signal.
 - d. Move the obstacle to the designated safe zone.
 - e. Resume its inspection route.
4. Teams test their programs and record observations about robot performance.
5. Encourage students to troubleshoot programming or mechanical issues and modify one variable at a time.
6. Conduct additional testing rounds to improve accuracy, efficiency, and reliability.
7. Conclude with a class discussion comparing engineering solutions and identifying the strategies that produced the most effective robotic systems.

Reflection & Discussion

- How did your robot detect and respond to the obstacle?
- Which programming or design changes improved your robot's performance?
- What challenges did your engineering team overcome during the investigation?
- Why is repeated testing essential when developing automated transportation systems?



- How can robotics improve railway inspection, maintenance, and public safety?

Teacher Tips

Encourage students to approach the challenge systematically by modifying only one programming element at a time before retesting. Reinforce that engineers rely on evidence rather than trial and error when improving automated systems. During the debrief, highlight how robots are increasingly used in the transportation industry to inspect infrastructure, identify hazards, and perform tasks that improve worker safety and operational efficiency.

Differentiation

Support: Provide students with a programming flowchart or pseudocode template before they begin coding. Encourage teams to test each programmed action separately before combining them into a complete solution.

Extension: Challenge teams to optimize their robot by reducing the time required to complete the inspection, increasing movement accuracy, or improving obstacle removal efficiency. Have students present their final design, explain the programming decisions they made, and justify their improvements using evidence collected during testing.

Activity #6: Engineering Reflection & Design Debrief

Activity Overview

Students conclude Day 3 by reflecting on the engineering concepts explored throughout the day, including wheel-and-axle systems, railway maintenance, freight transportation, robotics, and automated inspection systems. Through individual reflection and collaborative discussion, students evaluate how engineers use mechanical systems, computational thinking, and teamwork to solve real-world transportation challenges. Students also analyze how the Engineering Design Process guided each investigation and identify how today's learning prepares them for the final engineering challenges on Day 4.

Estimated Time: 10–15 minutes

Learning Objectives

The students will be able to:

- Evaluate how mechanical engineering, transportation systems, and robotics work together to improve railway safety.



- Reflect on how the Engineering Design Process supported the development and improvement of engineering solutions.
- Communicate evidence-based explanations describing how engineering design, testing, and teamwork contribute to safe and efficient railway operations.

Science TEKS:

- MS.1(G) Develop and communicate explanations and engineering solutions supported by evidence collected during investigations.

Math TEKS:

- 6.1(B) Communicate mathematical and scientific reasoning using evidence gathered from engineering investigations.

NGSS:

- MS-ETS1-3 Analyze data from engineering investigations and use evidence to evaluate and improve design solutions.

Materials Needed:

- Student engineering journal
- Reflection questions
- Pencil
- Day 3 PowerPoint

Teacher Preparation

Prepare the reflection prompts before class and encourage students to reference specific engineering investigations completed throughout the day. Foster a classroom environment where students feel comfortable discussing both successful designs and challenges they encountered. Reinforce that reflection is an essential step in the Engineering Design Process because it helps engineers improve future designs and make informed decisions.

Facilitation Guide

1. Ask students to independently reflect on the day's engineering investigations and challenges.
2. Have students discuss their responses with a partner or within their engineering team.
3. Facilitate a whole-class discussion connecting wheel-and-axle design, freight transportation, and robotics to railway safety.
4. Encourage students to explain how the Engineering Design Process influenced their decisions during each activity.
5. Preview Day 4 by explaining that students will apply everything they have learned throughout the week during a series of culminating engineering design challenges.



Reflection & Discussion

- Which engineering investigation helped you better understand railway safety? Why?
- How did testing and redesign improve your engineering solutions today?
- How do wheel-and-axle systems contribute to safe freight transportation?
- How did teamwork strengthen your ability to solve engineering challenges?
- Which engineering skill do you think will be most valuable during tomorrow's final engineering challenges?

Teacher Tips

Encourage students to support each reflection with specific examples from the Wheel and Axle Investigation, Freight Transportation Systems Investigation, Driving Base activity, or Inspection Detection Engineering Challenge. Reinforce that engineers continuously evaluate their work, learn from setbacks, and improve their designs through collaboration and evidence-based decision making. Celebrate thoughtful reflection and problem-solving just as much as successful engineering outcomes.

Differentiation

Support: Provide sentence stems such as *"One thing I learned today was..."*, *"The evidence that helped me understand..."*, or *"If I redesigned my project, I would..."* to guide student responses.

Extension: Ask students to develop an engineering recommendation for improving a railway system based on one concept they explored during the day. Students should explain their recommendation using evidence from the investigations and describe how their proposed improvement could increase safety, efficiency, or reliability.

Day 4: Full Steam Ahead: The Final Freight Challenge

Day Overview

On the final day of camp, students bring together the scientific concepts, engineering practices, and robotics skills developed throughout the week to solve authentic railway engineering challenges. Students begin by strengthening teamwork and communication, then explore real-world railway engineering through a High Bay engineering tour. They investigate Newton's Third Law using a Balloon Racer Engineering Investigation before applying the Engineering Design Process to design, build, program, and test a LEGO® Education SPIKE™ Prime robotic system. Throughout the day, students collaborate in engineering teams to solve transportation challenges involving railway safety, obstacle detection, cargo movement, and rural railroad crossings while demonstrating creativity, critical thinking, and evidence-based problem solving.



Lesson Objectives:

By the end of Day 4, students will be able to:

- Apply the Engineering Design Process to solve authentic railway engineering challenges.
- Investigate how Newton's Third Law explains the motion of trains, robots, and balloon-powered systems.
- Design, build, program, test, and improve robotic systems that model real-world railway operations.
- Analyze how sensors, automation, and engineering design improve railway safety.
- Demonstrate effective communication, collaboration, and leadership while working as engineering teams.
- Evaluate engineering solutions using evidence collected during testing and redesign.

Essential Questions

- How do engineers combine science, technology, and teamwork to solve transportation problems?
- How does Newton's Third Law help explain how trains and robots move?
- How do sensors and automated systems improve railway safety?
- Why is testing and redesign an important part of the Engineering Design Process?
- How can engineering solutions make railroad crossings safer for people and communities?

Day 4 at a Glance

Time Frame	Activity	Focus / Goal
10–15 min	Engineering Design Process Recap	Review the Engineering Design Process and connect the concepts from Days 1–3 to the final engineering challenges of the camp.
15–20 min	Activity 1: Good Listener Engineering Team Builder	Strengthen active listening, communication, teamwork, and situational awareness while preparing students for collaborative engineering challenges.
30–45 min	Activity 2: High Bay Engineering Tour	Observe real-world engineering facilities, equipment, and careers while connecting classroom investigations to authentic transportation and railway engineering.



45–60 min	Activity 3: Balloon Racer Engineering Investigation	Investigate Newton's Third Law by designing, testing, and improving a balloon-powered racer while exploring force, motion, and transportation engineering.
35–45 min	Activity 4: Smart Railway Safety Systems Investigation	Examine railroad crossings, sensors, warning systems, and automated technologies to understand how engineers improve railway safety through integrated systems.
60–75 min	Activity 5: Smart Railway Safety System Challenge	Design, build, program, test, and refine a LEGO® Education SPIKE™ Prime Forklift to complete a simulated railway safety mission using the Engineering Design Process.
20–30 min	Activity 6: Engineering Reflection, Awards & Final Debrief	Reflect on engineering growth, evaluate design solutions, celebrate accomplishments, and connect the week's learning to future STEM and engineering careers.

Day 4 Vocabulary

Students should review the following vocabulary before beginning the Day 4 activities. These terms will be used throughout the day during discussions about listening, motion, rural crossings, sensors, signals, and the final freight mission.

Term	Student-Friendly Definition	Day 4 Connection
Newton's Third Law of Motion	For every action, there is an equal and opposite reaction.	Students investigate action-reaction forces during the Balloon Racer Engineering Investigation and connect the concept to transportation systems.
Action Force	The force one object exerts on another during an interaction.	Students observe how air rushing out of the balloon creates the action force that moves the balloon racer.
Reaction Force	The equal and opposite force produced in response to an action force.	Students explain how the reaction force propels the balloon racer forward and compare it to how vehicles move.



Automation	The use of technology to perform tasks with little or no human assistance.	Students investigate how automated systems improve railway safety before programming their LEGO® SPIKE™ Prime Forklift.
Sensor	A device that detects information from its surroundings and sends it to a computer or robot.	Students use sensors to help their robotic system detect crossings, obstacles, and stopping points during the final engineering challenge.
Railway Crossing	A location where a road crosses railroad tracks.	Students compare different crossing designs and analyze how engineers improve crossing safety using warning systems and automation.
Warning System	Devices such as lights, gates, bells, or signals that alert people to approaching trains or hazards.	Students investigate how warning systems reduce accidents and are incorporated into modern railway safety systems.
Systems Engineering	A branch of engineering that combines many technologies and components into one complete working system.	Students learn how mechanical systems, electrical systems, sensors, and programming work together to improve railway safety.
Prototype	An early model built to test and improve a design before it is finalized.	Students build and refine robotic solutions while completing the Smart Railway Safety System Challenge.
Optimization	Making a design or system work as efficiently and effectively as possible.	Students improve their robotic programs through testing and redesign to complete the engineering mission more successfully.
Iteration	The process of repeatedly testing, evaluating, and improving a design.	Students modify and retest their robotic systems while applying the Engineering Design Process during the final challenge.
Engineering Design Process	A series of steps engineers use to identify problems, develop solutions, test ideas, and improve designs.	Students apply every step of the Engineering Design Process during the culminating Smart Railway Safety System Challenge.



Activity #1: Good Listener Engineering Team Builder

Activity Overview

Students begin the final day by participating in the Good Listener Engineering Team Builder, a fast-paced activity that develops active listening, communication, reaction time, and teamwork. Working with a partner, students must carefully listen for verbal cues and react quickly when prompted to retrieve an object. Following the activity, students reflect on how attention, communication, and quick decision-making contribute to safe engineering practices and railway operations. The lesson reinforces that successful engineers and transportation professionals depend on effective communication and situational awareness to prevent accidents and ensure public safety.

Estimated Time: 15–20 minutes

Learning Objectives

The students will be able to:

- Demonstrate active listening and quick decision-making during a collaborative engineering challenge.
- Apply communication, focus, and teamwork skills while following verbal instructions.
- Explain how effective communication and situational awareness contribute to railway safety and engineering success.

Science TEKS:

- MS.1(A) Ask questions and identify strategies for solving engineering challenges through collaboration.
- MS.1(B) Apply scientific and engineering practices while working effectively in teams.
- MS.1(G) Communicate observations and reflect on how teamwork contributes to successful engineering solutions.

Math TEKS:

- 6.1(B) Apply a problem-solving process by analyzing information, selecting strategies, and communicating reasoning during collaborative activities.

NGSS:

- MS-ETS1-1 Define the criteria and constraints of an engineering challenge while collaborating to solve problems.

Materials Needed:

- Plastic cup (or similar object) for each pair
- Open floor space



- Timer (optional)
- Reflection questions
- Whiteboard or chart paper

Teacher Preparation

Arrange an open space where students can safely face a partner with a cup placed between them. Review the activity rules and emphasize that the objective is not simply to react quickly, but to practice careful listening, focus, and respectful competition. Before beginning, explain that communication and attention to detail are essential skills for engineers, conductors, and railway workers responsible for keeping transportation systems safe. The reflection questions provided in the presentation should be used to connect the activity to engineering and railway safety.

Facilitation Guide

1. Divide students into pairs and have partners stand facing one another.
2. Place a cup or other object between each pair.
3. Explain that students should touch the body part called out by the instructor (head, shoulders, knees, toes, etc.).
4. When the instructor calls "Cup!", students must quickly grab the cup.
5. Winners advance to compete against other winners until a final champion is determined.
6. Facilitate a class discussion using the reflection questions to connect the activity to engineering communication and railway safety.

Reflection & Discussion

- What happened when you lost focus during the activity?
- How did careful listening improve your performance?
- How did you demonstrate good sportsmanship while competing?
- Why is communication an essential skill for engineers and railway workers?
- How can quick reactions and effective communication help prevent accidents near railroad crossings?

Teacher Tips

Keep the pace energetic while emphasizing that success depends on listening rather than speed alone. During the debrief, connect the activity to real railway operations by discussing how engineers, conductors, dispatchers, and maintenance crews must communicate clearly and respond quickly to changing conditions. Reinforce that even small lapses in communication can have significant consequences in transportation systems.



Differentiation

Support: Begin with slower practice rounds so students become familiar with the instructions before increasing the pace. Pair students strategically to encourage confidence and collaboration.

Extension: Challenge students to explain how communication failures could affect railway operations. Have engineering teams develop a short list of communication strategies that could improve safety during engineering projects and transportation operations.

Activity #2: High Bay Engineering Tour

Activity Overview

Students participate in a guided tour of the High Bay engineering facility to observe how engineers design, build, test, and maintain transportation systems and other large-scale engineering projects. Throughout the tour, students examine engineering equipment, manufacturing processes, testing facilities, and safety procedures while identifying how science, mathematics, technology, and teamwork are applied in real-world engineering careers. Students are encouraged to ask questions, make observations, and connect the concepts explored throughout the camp to authentic engineering environments.

Estimated Time: 30–45 minutes

Learning Objectives

The students will be able to:

- Observe how engineers apply the Engineering Design Process in real-world engineering environments.
- Identify engineering careers and describe how engineers use science, mathematics, and technology to solve transportation challenges.
- Explain how engineering facilities support the design, testing, and improvement of transportation systems.

Science TEKS:

- MS.1(A) Ask questions and define engineering problems through observations of real-world engineering systems.
- MS.1(B) Apply scientific and engineering practices by making observations and identifying how engineers develop solutions.
- MS.1(G) Communicate observations and explain how engineering practices improve transportation systems and public safety.

**Math TEKS:**

- 6.1(A) Apply mathematical reasoning while interpreting engineering processes and system designs.
- 6.1(B) Analyze observations, identify patterns, and communicate conclusions using evidence gathered during the tour.

NGSS:

- MS-ETS1-1 Define engineering problems by identifying criteria and constraints observed in real-world engineering systems.
- MS-ETS1-2 Evaluate how engineering solutions are designed to meet performance, safety, and operational requirements.

Materials Needed:

- Student observation sheet or engineering journal
- Clipboard (optional)
- Pencil
- Safety glasses or personal protective equipment (if required by the facility)

Teacher Preparation

Coordinate with the High Bay staff to determine the tour route, safety expectations, and areas students will be permitted to visit. Prepare an observation guide that encourages students to identify examples of the Engineering Design Process, engineering careers, safety features, robotics, transportation technologies, and problem-solving strategies. Review facility expectations with students before entering the High Bay and emphasize the importance of following all safety procedures throughout the visit.

Facilitation Guide

1. Review safety expectations and explain the purpose of the engineering tour.
2. Distribute observation sheets and encourage students to record engineering practices, equipment, and technologies they observe.
3. Guide students through the facility while highlighting examples of engineering design, testing, manufacturing, robotics, and transportation systems.
4. Encourage students to ask questions about engineering careers, equipment, and design processes.
5. After the tour, facilitate a discussion connecting the observations to the concepts explored during the previous three days of camp.
6. Have students identify one engineering innovation that they found most interesting and explain how it improves transportation or public safety.



Reflection & Discussion

- What engineering technologies or equipment stood out to you during the tour?
- How did engineers use the Engineering Design Process in the projects you observed?
- Which engineering career interested you the most? Why?
- How did the High Bay demonstrate the importance of teamwork in engineering?
- How did today's tour connect to the engineering concepts you have learned throughout the week?

Teacher Tips

Encourage students to become active observers rather than passive participants. Prompt them to look for examples of forces and motion, electrical systems, robotics, mechanical engineering, testing, safety features, and teamwork that connect directly to the camp activities. After the tour, allow time for students to compare observations and discuss how classroom engineering challenges relate to professional engineering practice.

Differentiation

Support: Provide students with a guided observation checklist that includes prompts such as "Find an example of a machine that moves," "Identify a safety feature," or "Observe an engineer using technology to solve a problem."

Extension: Challenge students to select one piece of equipment or engineering system observed during the tour and explain how it demonstrates the Engineering Design Process. Students should identify the problem being solved, the design solution, and how testing or improvement contributes to the final product.

Activity #3: Balloon Racer Engineering Investigation

Activity Overview

Students investigate Newton's Third Law of Motion by designing, constructing, and testing a balloon-powered racer. Working in engineering teams, students observe how action and reaction forces create motion and analyze how design choices influence the performance of their vehicle. Through repeated testing and redesign, students apply the Engineering Design Process to improve speed, stability, and distance traveled. Students conclude the investigation by connecting Newton's Third Law to the movement of trains, railway equipment, and other transportation systems.

Estimated Time: 45–60 minutes

Learning Objectives



The students will be able to:

- Investigate how Newton's Third Law of Motion explains the movement of a balloon-powered vehicle.
- Apply the Engineering Design Process to design, test, and improve a balloon racer.
- Analyze how design modifications affect the speed, distance, and stability of a moving vehicle.

Science TEKS:

- MS.1(A) Ask questions and define engineering problems related to force, motion, and transportation systems.
- MS.1(B) Apply scientific and engineering practices to design, test, and improve a transportation prototype.
- MS.1(C) Collect, organize, and analyze observations gathered during engineering investigations.
- MS.1(G) Develop explanations and communicate scientific reasoning supported by evidence.

Math TEKS:

- 6.1(A) Apply mathematical reasoning to compare the performance of engineering designs.
- 6.1(B) Analyze observations, identify patterns, and communicate conclusions using evidence collected during testing.

NGSS:

- MS-PS2-2 Plan an investigation to provide evidence that changes in an object's motion depend on the sum of the forces acting on the object.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- MS-ETS1-3 Analyze data from tests to identify characteristics of the most effective design solution.

Materials Needed:

- Balloons
- Drinking straws
- String or fishing line
- Tape
- Binder clips or clothespins
- Measuring tape or meter stick
- Stopwatch (optional)
- Student engineering journal or data sheet



Teacher Preparation

Prepare one balloon racer kit for each engineering team and set up testing lanes using string stretched tightly between two supports. Review Newton's Third Law using the presentation and demonstrate how releasing air from the balloon produces an equal and opposite reaction that propels the racer forward. Encourage students to think like engineers by considering how design choices, such as balloon size, alignment, and friction, may influence performance.

Facilitation Guide

1. Review Newton's Third Law of Motion using examples from the Day 4 presentation.
2. Demonstrate how a balloon racer moves by applying action and reaction forces.
3. Divide students into engineering teams and present the Balloon Racer Engineering Challenge.
4. Have students design and construct their balloon racer.
5. Test each design and record observations such as speed, distance, and stability.
6. Encourage teams to identify one design variable to modify and repeat the investigation.
7. Compare class results and discuss how engineering redesign improved vehicle performance.
8. Conclude by connecting the investigation to the movement of trains, rockets, and other transportation systems that rely on balanced and unbalanced forces.

Reflection & Discussion

- How did Newton's Third Law explain the movement of your balloon racer?
- Which design modification had the greatest impact on your vehicle's performance?
- Why is testing and redesign an important part of engineering?
- How do engineers use knowledge of forces and motion when designing transportation systems?
- How is the motion of your balloon racer similar to the movement of trains or other vehicles?

Teacher Tips

Encourage students to change only one design variable at a time so they can clearly determine which modification improves performance. Ask students to support their conclusions with observations collected during testing rather than relying on guesses. Reinforce that engineers use repeated testing and evidence-based decision making to develop more efficient transportation systems.

Differentiation

Support: Provide students with a sample balloon racer design and discuss the relationship between action and reaction before construction begins. Encourage teams to sketch their design and predict how it will perform before testing.

Extension: Challenge teams to optimize their balloon racer by maximizing travel distance or improving speed while using the same materials. Have students justify each design modification using evidence



from testing and explain how engineers use similar investigations to improve the efficiency of transportation systems.

Activity #4: Smart Railway Safety Systems Investigation

Activity Overview

Students investigate how engineers use sensors, warning signals, communication systems, and automated technologies to improve railway safety. Through guided discussions, demonstrations, and collaborative investigations, students examine the differences between passive and active railroad crossings, explore the unique challenges of rural railroad crossings, and analyze how smart technologies detect hazards and prevent accidents. Students conclude the lesson by evaluating how multiple engineering systems work together to create safer transportation networks, preparing them for the final robotics challenge.

Estimated Time: 35–45 minutes

Learning Objectives

The students will be able to:

- Compare passive and active railway safety systems and explain how each contributes to public safety.
- Analyze how sensors, warning devices, and automated technologies help detect hazards and prevent railroad accidents.
- Explain how engineers integrate multiple systems to create safer and more efficient railway transportation networks.

Science TEKS:

- MS.1(A) Ask questions and define engineering problems related to railway safety and transportation systems.
- MS.1(B) Apply scientific and engineering practices to analyze how multiple engineering systems work together to solve transportation challenges.
- MS.1(G) Develop explanations and communicate engineering solutions supported by evidence.

Math TEKS:

- 6.1(A) Apply mathematical reasoning to analyze engineering systems and transportation data.
- 6.1(B) Analyze information, identify patterns, and communicate conclusions using evidence gathered during investigations.



NGSS:

- MS-ETS1-1 Define the criteria and constraints of an engineering problem involving transportation safety.
- MS-ETS1-2 Evaluate engineering solutions based on how well they improve safety, reliability, and efficiency.

Materials Needed:

- Day 4 PowerPoint
- Images or diagrams of passive and active railroad crossings
- Railroad crossing case studies (optional)
- Student observation sheet
- Whiteboard or chart paper

Teacher Preparation

Review the presentation sections on railway safety systems, rural railroad crossings, trackside safety, sensors, and automated warning systems. Prepare visual examples of different railroad crossings and safety technologies. Develop discussion prompts that encourage students to evaluate why engineers select different safety systems for different environments. Emphasize that railway safety depends on multiple engineering disciplines working together to reduce risk and protect communities.

Facilitation Guide

1. Introduce the concept of smart railway safety systems and explain how engineers design transportation systems to reduce accidents.
2. Compare passive and active railroad crossings using images and examples from the presentation.
3. Discuss the unique challenges associated with rural railroad crossings and why additional engineering solutions may be necessary.
4. Explore how sensors, warning signals, gates, cameras, and communication systems detect hazards and improve railway safety.
5. Have engineering teams analyze different crossing scenarios and recommend the most appropriate safety systems for each location.
6. Facilitate a class discussion comparing team recommendations and the engineering reasoning behind each decision.
7. Conclude by explaining that students will apply these concepts during the Smart Railway Safety System Challenge in the next activity.

Reflection & Discussion

- Why are active railroad crossings used in some locations but not others?
- How do sensors and warning systems improve railway safety?
- What challenges make rural railroad crossings different from crossings in urban areas?



- Why must engineers consider the environment when designing transportation systems?
- How do multiple engineering systems work together to reduce accidents and protect communities?

Teacher Tips

Encourage students to justify every recommendation using evidence rather than opinion. Prompt them to consider factors such as traffic volume, train frequency, visibility, road conditions, nearby schools or neighborhoods, and cost when evaluating different crossing designs. Reinforce that engineers rarely rely on a single safety feature; instead, they integrate multiple systems to create a safer transportation network.

Differentiation

Support: Provide students with comparison charts illustrating passive and active railroad crossings, common warning devices, and examples of sensor technologies. Allow teams to discuss each scenario before presenting their recommendations.

Extension: Challenge students to design an improved railway crossing for a rural community using concepts from the lesson. Students should identify the hazards present, recommend appropriate safety technologies, and justify their design decisions using engineering principles and evidence from the investigation.

Activity #5: Smart Railway Safety System Challenge

Activity Overview

Students participate in the culminating engineering challenge of the camp by designing, building, programming, and testing a LEGO® Education SPIKE™ Prime Forklift capable of completing a simulated railway safety mission. Working in engineering teams, students apply the Engineering Design Process to create an automated system that travels along a railway, detects a designated crossing, safely stops, sounds a warning signal, retrieves a wheel-and-axle component from the track, transports it to a repair station, and completes the mission by parking at the depot. Throughout the challenge, students analyze robot performance, troubleshoot programming and mechanical issues, and refine their solutions using evidence collected during repeated testing. This activity integrates science, engineering, robotics, and teamwork while modeling how engineers develop technologies that improve railway safety and transportation efficiency.

Estimated Time: 60-75 min.



Learning Objectives

The students will be able to:

- Apply the Engineering Design Process to design, build, test, and improve an automated railway safety system.
- Program a LEGO® Education SPIKE™ Prime Forklift to complete a multi-step transportation and safety challenge.
- Evaluate engineering solutions using evidence gathered through testing and redesign while working collaboratively in engineering teams.

Science TEKS:

- MS.1(A) Ask questions and define engineering problems by identifying the criteria and constraints of an automated railway safety challenge.
- MS.1(B) Apply scientific and engineering practices to design, construct, test, and improve a robotic engineering solution.
- MS.1(C) Collect, organize, and analyze qualitative observations to evaluate system performance.
- MS.1(G) Develop explanations and communicate engineering solutions supported by evidence gathered during testing.

Math TEKS:

- 6.1(A) Apply mathematical reasoning to solve robotics and engineering design challenges.
- 6.1(B) Analyze results, evaluate programming solutions, and communicate reasoning using evidence collected throughout the investigation.

NGSS:

- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet established criteria and constraints.
- MS-ETS1-3 Analyze data from tests to determine similarities and differences among design solutions and identify characteristics of the most effective solution.

Materials Needed:

- LEGO® Education SPIKE™ Prime Kit
- SPIKE™ Prime Hub
- Medium Motor
- Tablet or computer with the SPIKE™ Prime App
- Challenge mat or railway course
- Wheel-and-axle object
- Designated repair station
- Depot/finish line



- Student engineering journal or data sheet
- Stopwatch (optional)

Teacher Preparation

Assemble the challenge course before class by creating a simulated railway that includes a crossing, a wheel-and-axle obstacle, a designated repair station, and a final depot. Ensure each engineering team has a functioning SPIKE™ Prime robot equipped with the forklift attachment and access to the SPIKE™ Prime App. Review the engineering roles presented in the lesson (Lead Engineer, Systems Engineer, Mechanical Engineer, and Mechatronics Engineer) and encourage each team member to contribute throughout the challenge. Explain that engineers rarely succeed on their first attempt and that testing, troubleshooting, and redesign are expected parts of the Engineering Design Process.

Facilitation Guide

1. Introduce the Final Freight Mission and review the engineering criteria and constraints.
2. Assign engineering roles within each team.
3. Review the mission objectives:
 - a. Travel along the railway.
 - b. Detect the railroad crossing.
 - c. Stop safely and activate a warning signal.
 - d. Pick up the wheel-and-axle component.
 - e. Deliver the component to the repair station.
 - f. Continue to the depot and park safely.
4. Allow teams time to build, program, and test their forklift system.
5. Encourage students to troubleshoot programming and mechanical issues, modifying one variable at a time.
6. Conduct multiple testing rounds and allow teams to refine their solutions using evidence gathered during each trial.
7. Conclude with a showcase in which teams demonstrate their final engineering solutions and explain how their robot addresses the railway safety challenge.

Reflection & Discussion

- Which part of the engineering challenge was the most difficult? Why?
- How did your team use the Engineering Design Process to improve your robot?
- Which programming or mechanical changes had the greatest impact on performance?
- How did teamwork contribute to the success of your engineering solution?
- How does your robotic system model the technologies engineers use to improve railway safety?



Teacher Tips

Encourage students to assign responsibilities based on the engineering roles introduced in the presentation and remind them that successful engineering projects rely on communication and collaboration. During testing, prompt students to change only one programming or mechanical variable at a time so they can identify which modifications improve performance. Celebrate persistence and thoughtful problem-solving as much as successful task completion, reinforcing that engineering is an iterative process.

Differentiation

Support: Provide teams with a programming checklist or flowchart that breaks the mission into smaller tasks, allowing students to test each section of the program before combining them into a complete solution. Offer guiding questions that help students troubleshoot rather than supplying direct answers.

Extension: Challenge teams to optimize their robotic system by improving efficiency, reducing completion time, increasing accuracy, or incorporating additional programmed behaviors such as multiple warning signals or smoother cargo transport. Have students present their final solution and justify each programming or design decision using evidence gathered during testing.

Activity #6: Engineering Reflection, Awards & Final Debrief

Activity Overview

Students conclude the Railway Safety Engineering Camp by reflecting on the knowledge, skills, and engineering practices they developed throughout the week. Working individually and with their engineering teams, students evaluate their final robotic designs, discuss how the Engineering Design Process guided their work, and explain how teamwork, communication, and evidence-based problem solving contributed to their success. Students complete a final engineering reflection and exit ticket before participating in the recognition of outstanding engineering teams and individuals. The activity reinforces that successful engineers continuously reflect, improve, and collaborate to solve real-world problems.

Estimated Time: 20–30 minutes

Learning Objectives

The students will be able to:

- Evaluate the effectiveness of their engineering solutions using evidence gathered throughout the camp.



- Reflect on how teamwork, communication, and the Engineering Design Process contributed to successful engineering outcomes.
- Communicate how science, technology, engineering, and mathematics work together to improve railway safety and transportation systems.

Science TEKS:

- MS.1(G) Develop and communicate explanations and engineering solutions supported by evidence gathered during investigations.

Math TEKS:

- 6.1(B) Analyze information, evaluate engineering solutions, and communicate reasoning using evidence collected during investigations.

NGSS:

- MS-ETS1-3 Analyze data from engineering investigations and use evidence to evaluate and improve design solutions.

Materials Needed:

- Student engineering journal
- Exit ticket
- Reflection questions
- Team evaluation sheet (optional)
- Certificates or awards (optional)

Teacher Preparation

Prepare the reflection prompts, exit tickets, and recognition materials before class. Review the engineering challenges completed throughout the week and identify examples of perseverance, collaboration, creativity, and effective problem-solving that can be highlighted during the closing discussion. Create an environment that celebrates both successful designs and the learning that occurred through testing, redesign, and teamwork. The PowerPoint also includes recognition for winning teams, the Conductor Award, and information about the closing ceremony, which can be incorporated into the wrap-up.

Facilitation Guide

1. Ask students to complete an individual engineering reflection and exit ticket.
2. Have engineering teams discuss what they learned from the week's investigations and identify how their designs improved through testing and redesign.
3. Facilitate a whole-class discussion connecting the Engineering Design Process to the final robotics challenge and the real work of railway engineers.



4. Invite teams to briefly share their engineering solution and explain one improvement they made during the design process.
5. Recognize student accomplishments by celebrating teamwork, perseverance, creativity, and engineering thinking. Present awards or acknowledge outstanding engineering teams as appropriate.
6. Conclude the camp by encouraging students to continue exploring engineering, robotics, and STEM careers.

Reflection & Discussion

- Which engineering challenge helped you learn the most throughout the week? Why?
- How did the Engineering Design Process help improve your final solution?
- Which engineering skill do you think grew the most during camp?
- How did teamwork contribute to your success?
- How can engineers use science, technology, and innovation to improve railway safety in the future?

Teacher Tips

Encourage students to celebrate both successes and challenges by emphasizing that every redesign contributed to a better engineering solution. During the discussion, help students connect each day's investigations, from forces and motion to electricity, robotics, and transportation engineering, to the final freight challenge. Recognize perseverance, creativity, communication, and collaboration alongside technical achievement so that every student leaves feeling valued for their contributions.

Differentiation

Support: Provide sentence starters such as "One engineering skill I improved was...", "The biggest challenge my team faced was...", or "One thing I would change next time is..." to guide student reflections.

Extension: Challenge students to write a brief engineering proposal describing one improvement they would make to a real railway system based on what they learned during camp. Students should explain the problem, propose a solution, and support their recommendation using evidence from the week's investigations.



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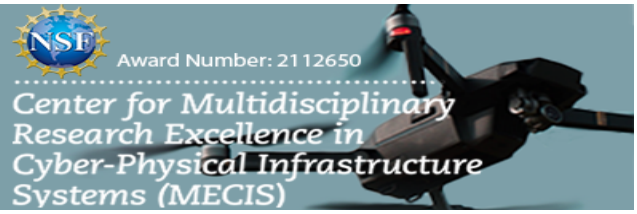
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