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Guidebook for Railway-themed K-12 STEM Outreach Activities

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Introduction

Welcome to the *Guidebook for Railway-themed K-12 STEM Outreach Activities*! Inside, you will find descriptions of educational activities designed to introduce students to the railroad transportation mode through the lens of STEM (Science, Technology, Engineering, and Mathematics) concepts.

Railroads have been a critical part of the global economy since the 1830s. Today, railroads haul more ton-miles of intercity freight (one ton of freight moved one mile) than any other mode of transportation in the United States. While the railroad industry is the leader in long-haul freight transportation, recruiting students to leadership roles in the industry is challenging. With many railroad employees approaching retirement age, the need to raise student awareness of railway industry career opportunities has never been greater.

The activities in this guidebook cover a wide variety of railroad topics. The activities are intended to be hands-on to provide students with knowledge through experiential learning that also increases their awareness of railway transportation technology. Although the following chapters provide a step-by-step guide to each activity, we encourage you to experiment with modifications to each activity and to create your own activities on other facets of the railroad industry and STEM topics.

We hope you find the activities in this guidebook to be informative and entertaining!

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Locomotive and Train Simulators

This activity allows participants a chance to experience the challenge of operating a train through a computer simulation.

Number of Participants: 1 **Recommended Age:** 3+

Setup Time: 20 minutes **Activity Time:** 5-20 minutes

STEM Concepts:

- *Science: long train braking distances arise from the physics of high inertia and momentum*
- *Technology: modern locomotives are highly engineered with advanced technology on board*
- *Engineering: long train braking distances are reflected in design of track and signal systems*
- *Mathematics: calculating the braking distance of a train is critical to safe operation*

Key Learning Points

1. **Trains usually require a long distance to stop, typically farther than the locomotive engineer can see ahead. Thus, stay off the tracks since trains will not be able to stop for an obstruction.**
2. **Trains do not accelerate as quickly as automobiles.**
3. **The slow acceleration and deceleration characteristics of trains are directly related to its relatively large mass. Because trains are heavy, they have substantial amounts of inertia and thus it takes a lot of accelerating force or braking effort to start and stop.**

Figure 1: Student operates a virtual locomotive in Run8 Train Simulator with a RailDriver controller

Background

Becoming a locomotive engineer has been the dream of many children since the inception of the railroad. While many never get a chance to operate a locomotive in real life, locomotive simulators can provide a similar experience. It takes skill and practice for a locomotive engineer to learn how to properly handle a train up a steep mountain pass without stalling, or to know when to begin braking a higher-speed passenger train to make an exact stop at the platform of an upcoming passenger station. Train crews must spend time running a simulator and making multiple trips over a particular route with an instructor before they are allowed to operate a train over that same route on their own. If they need to operate a train over a different route, they must go through the same training process again with an instructor experienced on the unique requirements of that route.

A locomotive simulator also provides an avenue for educating students on how the physics of mass, acceleration, force, power and momentum pose a challenge for the train crew. When operating a heavy train at high speeds, the train crew does not have the ability to stop quickly. In most cases, the distance required for the train to stop exceeds how far the train crew can see along the track ahead. By the time the train crews sees an obstruction on the track ahead, it is too late to stop the train before reaching it. Besides having implications for the engineering of the railway signal system that controls the movement of trains, demonstrating the time and distance required to stop a train can reinforce the message of railway safety. Because a train cannot stop quickly, trespassing on the railroad or not obeying signs and signals at highway-rail grade crossings will often have fatal consequences.

Several locomotive simulator software programs (more commonly known as train simulators) are available for purchase and are a popular activity for students at rail-focused camps and outreach events.

Materials List and Setup

- Simulator of your choice
    - Microsoft Train Simulator
    - Train Sim World
    - Train Simulator
    - Trainz
    - Run8 Train Simulator
- RailDriver Desktop Train Cab Controller (optional, but highly recommended)

Each of the simulators listed above has its advantages and disadvantages, briefly summarized below.

Microsoft Train Simulator (MSTS) is well known but relatively old (released in 2001), so the graphics are somewhat dated compared to other locomotive simulation software. It is still possible to find MSTS in CD-ROM format through various outlets on the internet and it has the advantage of often being relatively inexpensive. However, MSTS is not supported on operating systems newer than Windows XP.

Train Sim World (TSW) is the latest train simulator on the market. TSW is produced by Dovetail Games and features the ability for the user to get out of the locomotive and walk around. Nearly every switch and button is functional in the world of the computer model. Because this is a relatively new product, the content selection is somewhat small and more expensive than other options listed here.

Train Simulator (formerly known as **Railworks**) produced by Dovetail Games has been updated regularly since 2009. It has a large content base available, although some of the add-ons are relatively expensive. The RailDriver controller is compatible with Train Simulator.

Figure 2: Screenshot from Train Simulator inside a GE ES44AC

Trainz was released in 2001 but new versions have been frequently rereleased since then with updated graphics and additional modeled routes and railway equipment. Trainz is a solid middle-ground option that is not too expensive but lacks some finer simulation details of other options on this list.

Figure 3: Screenshot from Trainz

Run8 Train Simulator is the most technically advanced simulator on this list. The price is comparable to Train Simulator or TSW. However, the geographic route content included with the base game is less than most of the other options on this list. Additionally, the simulator can be too accurate in the sense that it can require some advanced knowledge of locomotive operation and proper train handling to use without triggering an emergency brake application that consumes considerable time to recover from.

Figure 4: Students learn about operating a locomotive in Run8 Train Simulator

The train simulator programs described here can all be operated using a standard computer keyboard and mouse interface. However, it can often be difficult to recall which key commands correspond to the various controls in the locomotive cab, particularly for a facilitator that does not use the train simulation software on a regular basis.

Using the **RailDriver Desktop Train Cab Controller** from P.I. Engineering to interface with a selected train simulator software can provide a more realistic locomotive simulator experience. The RailDriver controller provides throttle, brake and direction controls, plus switches for the locomotive horn, bell and headlights, all with a look, feel and action matching that of an actual locomotive cab. The RailDriver controller connects to Windows computers running a locomotive simulator via USB. By manipulating the RailDriver cab controls in a realistic way and observing the corresponding response of the locomotive simulator software, students can get a better feel for the true experience of a locomotive engineer handling a freight train, as opposed to feeling like they are just controlling a computer mouse and keyboard.

Script

If you are unfamiliar with the controls in a typical locomotive cab, most train simulators have a tutorial that will walk you through the basics of running a locomotive in the context of that particular simulator. However, most diesel-electric locomotive models have the same basic controls. A short list of the most important ones and their functions is provided below.

- Reverser – selects the direction in which the locomotive will move. This can be removed from the control stand on a real locomotive to prevent unauthorized use
- Throttle – changes the amount of power the locomotive is generating and delivering to the wheels to move the train forward (or backward). Usually has nine positions (idle plus eight "notches" each corresponding to a different power output). Higher notched produce more power and allow the train to pull a heavier load or achieve a faster speed.
- Automatic (train) brake – applies/releases the air brakes on the entire train (including locomotives)
- Independent brake – applies/releases the brakes on the locomotives only
- Horn – sounds the locomotive's horn
- Headlight switch – selects headlight brightness and direction

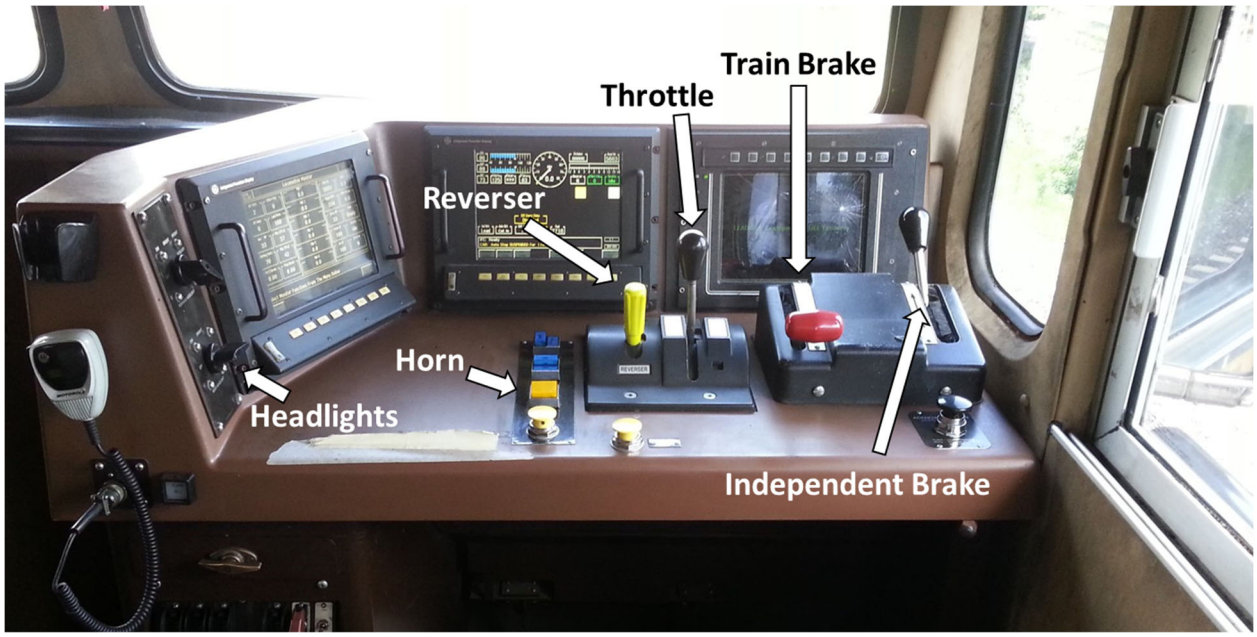

Figure 5: The control stand of a GE AC4400 freight locomotive. This control stand is similar to many other modern freight and passenger locomotives.

When conducting this activity, we recommend operating the train over a commuter line with frequent station stops or some other route that will require frequent starting and stopping. This keeps participants engaged with accelerating and braking the train by manipulating the throttle and brake controls. The stops also provide convenient places to swap participants. You will likely need to instruct each participant on the purpose and function of each of the locomotive cab controls, help them with starting/stopping the train, and with complying with posted speed limits.

Questions to Stimulate Student Thought

1. Why does it take so long for a train to stop?
2. How many of the controls in the cab can you name?

Adjusting for Time and Participant Age

1. The activity can be shortened or lengthened by allowing students to operate the simulator for longer or shorter periods of time as needed.
2. Younger students will likely need more direction while operating the simulator.
3. Older students could be introduced to signaling concepts with the simulator.

Railroad Simulation Software Package Websites

Train Sim World: https://live.dovetailgames.com/live/train-sim-world

Train Simulator (Railworks): https://live.dovetailgames.com/live/train-simulator

Trainz: https://www.trainzportal.com/

Run8: http://www.run8studios.com/

RailDriver Control Stand: http://raildriver.com/products/raildriver.php

Microsoft Train Simulator: No official website