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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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Railroad Track Construction

This activity allows participants to build their own section of railroad track from the subgrade to the rails.

Number of Participants: 2 or more **Recommended Age:** 3+

Setup Time: 30 minutes **Activity Time:** 15 minutes

STEM Concepts:
- *Science: pressure is the amount of force applied over a given area*
- *Technology: track is a structure designed to support the weight of railway rolling stock*
- *Engineering: track components reduce pressure by distributing forces over a greater area*
- *Mathematics: use averages of multiple trials to obtain a representative measured value*

Key Learning Points

1. **Understand the basic components of railroad track (rail, ties, ballast) and their purpose.**
2. **Track components take very high forces and gradually spread them out over a large area.**
3. **Track ballast is effective at resisting lateral and longitudinal forces.**

Background

Railroad track is designed to support the weight of heavy locomotives and railcars moving at speed. The components of the track structure must be able to resist large forces created by trains in both the vertical and lateral directions:
- Rails guide the train wheels and transfer their weight across multiple crossties (also simply called "ties").
- Crossties support the rails, hold them the proper distance apart, and distribute the weight of the train over a larger area, reducing pressure on the ground below.
- Ballast, the crushed rock gravel that is underneath and between the crossties, supports the crossties, and provides resistance to the forces created by the train. Ballast also facilitates drainage of water away from the track structure.

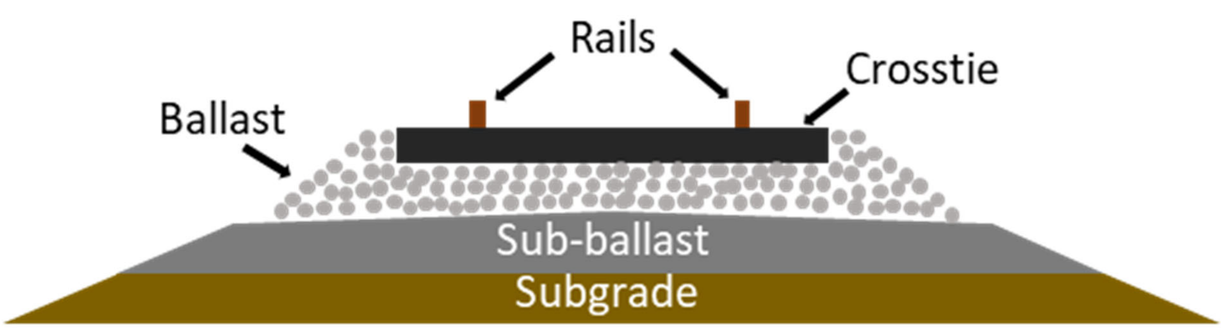

Figure 1: Typical railroad track cross-section showing the main components of the track structure.

This activity demonstrates the effectiveness of ballast at restraining the track and helps the participants understand the different components of track and their purposes.

<u>Materials List and Setup</u>

Materials to construct one 18-inch track section:

- Cookie sheet, approx. 18 inches in one dimension (with sides to keep materials from spilling)
- Approximately ten balsa wood “crossties”, each 3.5” x 0.5” x 0.5”
    - A 36” length of ½” square balsa wood strip commonly sold in craft stores can be cut into the ten crossties required for this length of track
- Two metal rails removed from G-scale model railroad track sections
    - The rails from one straight track section 18” to 24” in length work well
- 40 “Map-Style” push pins with 1/8” round head (approximately 1/2" to 3/5” overall length)
- Sand
- Aquarium gravel
- Spring scales (2.5 N/250g and 5N/500g capacity, we bought from https://sciencekitstore.com/)
- Sieve (to separate gravel and sand for storage after completion of the activity)
- Small hand saw (to cut ties to length from the balsa wood strip)
- G scale wheelset or railcar (optional)

Figure 2: Some of the materials required for this activity.

Script

In this activity, the participants will construct a short section of railroad track. The track will be built as skeleton track (no ballast) and will be gradually built up from individual track components. We recommend building the track on a cookie sheet with sides to prevent the sand and aquarium gravel from spilling. The lateral and longitudinal resistance of the track will be measured using a spring scale at various times during the activity.

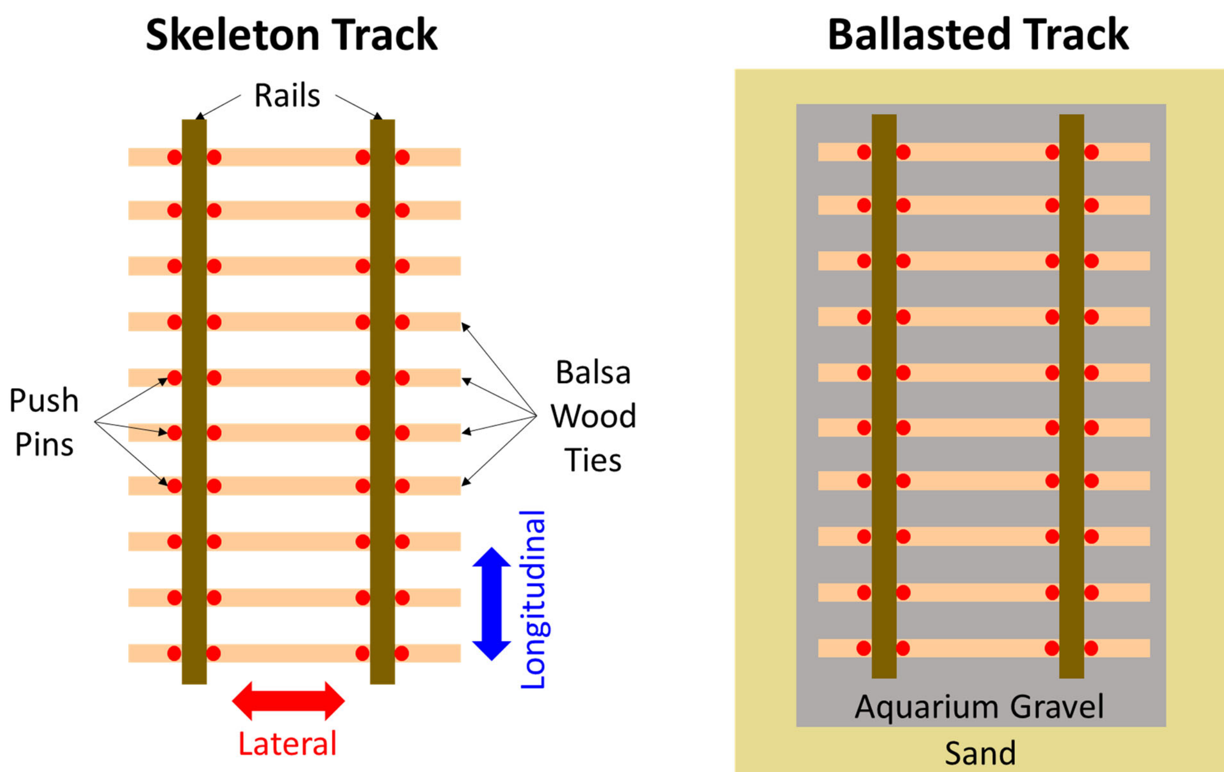

Figure 3: Schematic of skeleton track and ballasted track.

1. Construct the skeleton track by spacing out the balsa wood ties and laying the rails on top of them. For best results, construct at least 12” to 18” of track with approximately 1.5” of spacing between each crosstie. (If the ½” square balsa wood strip has yet to be cut into ties, you may either have the students perform this task or prepare the ties yourself prior to starting the activity. Each tie should each be around 3.5” long, although this dimension does not need to be precise as long as it is reasonably to scale.

2. Use push pins to secure one of the rails to the ties, approximately ¾” to 7/8” from the ends of the ties. Then position the second rail such that the distance between the rails is approximately 1 ¾“ and secure with push pins. A distance of 1.75 inches between the rails is the proper “track gage” for G scale track, allowing the track to be tested with a G scale wheelset or railcar, if available. Each rail should be held to each crosstie by two push pins, one on each side of the rail, for a total of four push pins per crosstie as shown in Figure 3 above.

3. Once the skeleton track is assembled, use a spring scale to measure the lateral resistance of the track (perpendicular to the rails). Clip the spring scale to one of the rails and gently pull on the skeleton track perpendicular to the rails until the track starts to move. Also test the longitudinal resistance of the track by pulling on it parallel to the rails. From the spring scale reading in Newtons or grams, record the force resisted by the in each direction on the activity worksheet (found in the appendix). We recommend making three measurements and taking the average of the three. Without ballast, it will not require much force to move the track. This is not ideal for real track since movement of the track could cause a derailment!

Figure 4: Students test the lateral resistance of skeleton track. The sand subgrade for step 4 is ready on the left.

4. Once the values for the resistance of the skeleton track have been recorded, set the skeleton track to the side. Using the cookie sheet as a base, pour a level sand layer to serve as the subgrade that will support the ballast and track. The sand layer can fill the cookie sheet, or if the cookie sheet is considerably larger than the track section, the sand layer should extend longitudinally and laterally at least an inch or two around all sides of the track. Use a ruler or straightedge to smooth the top of the sand layer.

5. Set the skeleton track on top of the sand and measure the resistance in the lateral and longitudinal directions by gently pulling on the track with the spring scale. Record the observed values in the worksheet. The observed averages should be higher than when the track was sitting on the table or bare cookie sheet but will still be relatively low. If the skeleton track drags across the top of the sand, be sure to re-level the sand layer between each measurement.

6. After the resistance values for the track on top of the sand subgrade have been recorded on the activity worksheet, add a layer of aquarium gravel on top of the sand subgrade. The layer should be approximately ½" thick and represents the ballast layer underneath the track. Test both resistances and record the values.

Figure 5: Students pour a layer of aquarium gravel on top of the sand subgrade during step 6.

7. Set the skeleton track section on top of the aquarium gravel ballast layer. Using the same approach as in Step 5, measure the lateral and longitudinal resistance of the track on the ballast layer by gently pulling on the spring scale. Record the values in the worksheet and compare to the previous observations at different stages in the track construction process.

8. Next, add aquarium gravel between the rail and ties (the area is known as the "crib") but not around the ends of each crosstie. Note that the tops of the ties should remain uncovered.

9. Measure the lateral and longitudinal resistance values for the track with ballast in the cribs only and record them on the worksheet. Pull gently to avoid pulling the track out of the ballast.

10. Finally, add aquarium gravel along the sides of the track around the ends of the ties. This gravel represents the shoulder ballast which is critical in resisting lateral movement of the track structure. The section of track structure is now complete (Figure 7)! Test with a G scale wheelset or railcar if one is available (Figure 8).

11. Measure the lateral and longitudinal resistance values for the track with full ballast and record them on the worksheet. Pull gently on the spring scale to avoid displacing the track.

12. Compare the results. The resistance values should progressively increase as ballast is added to the track. Longitudinal resistance should improve significantly after the addition of crib ballast, while lateral resistance should improve significantly after the addition of shoulder ballast.

Figure 6: Students fill in the crib with ballast for step 7.

Figure 7: A section of completed track including shoulder ballast.

Figure 8: Students test a G scale railcar on their completed track sections.

Questions to Stimulate Student Thought

1. What would happen if railroads ran trains at high speeds on skeleton track?
2. Why do we add ballast along the sides of the track?
3. Why do we take three measurements when determining each resistance?

Adjusting for Time and Participant Age

1. This activity can be set up in a display format by constructing both skeleton track and ballasted track adjacent to one another. Students can then try moving the track sections while discussing the purpose of ballast and other track components.
2. If there are many students participating in the activity, try dividing them into groups and having each group construct a track section. At the end of the activity, if the students carefully observed all track dimensions and layer thicknesses, all of the track sections can be aligned end-to-end and be tested with a railcar (Figure 8).
3. To reduce the time required for this activity and focus on the track construction aspect, the various steps involving measuring lateral and longitudinal resistance can be omitted or only performed for the base skeleton track and final fully ballasted track section.
4. Also try our edible version of this activity!

Railroad Track Construction Activity Worksheet

Skeleton Track on Top of Bare Table:

	Longitudinal Resistance	Lateral Resistance
Measurement 1		
Measurement 2		
Measurement 3		
Average		

Skeleton Track on Top of Sand Subgrade:

	Longitudinal Resistance	Lateral Resistance
Measurement 1		
Measurement 2		
Measurement 3		
Average		

Skeleton Track on Top of Gravel Ballast:

	Longitudinal Resistance	Lateral Resistance
Measurement 1		
Measurement 2		
Measurement 3		
Average		

Track with Ballast in Cribs Only:

	Longitudinal Resistance	Lateral Resistance
Measurement 1		
Measurement 2		
Measurement 3		
Average		

Fully Ballasted Track:

	Longitudinal Resistance	Lateral Resistance
Measurement 1		
Measurement 2		
Measurement 3		
Average		