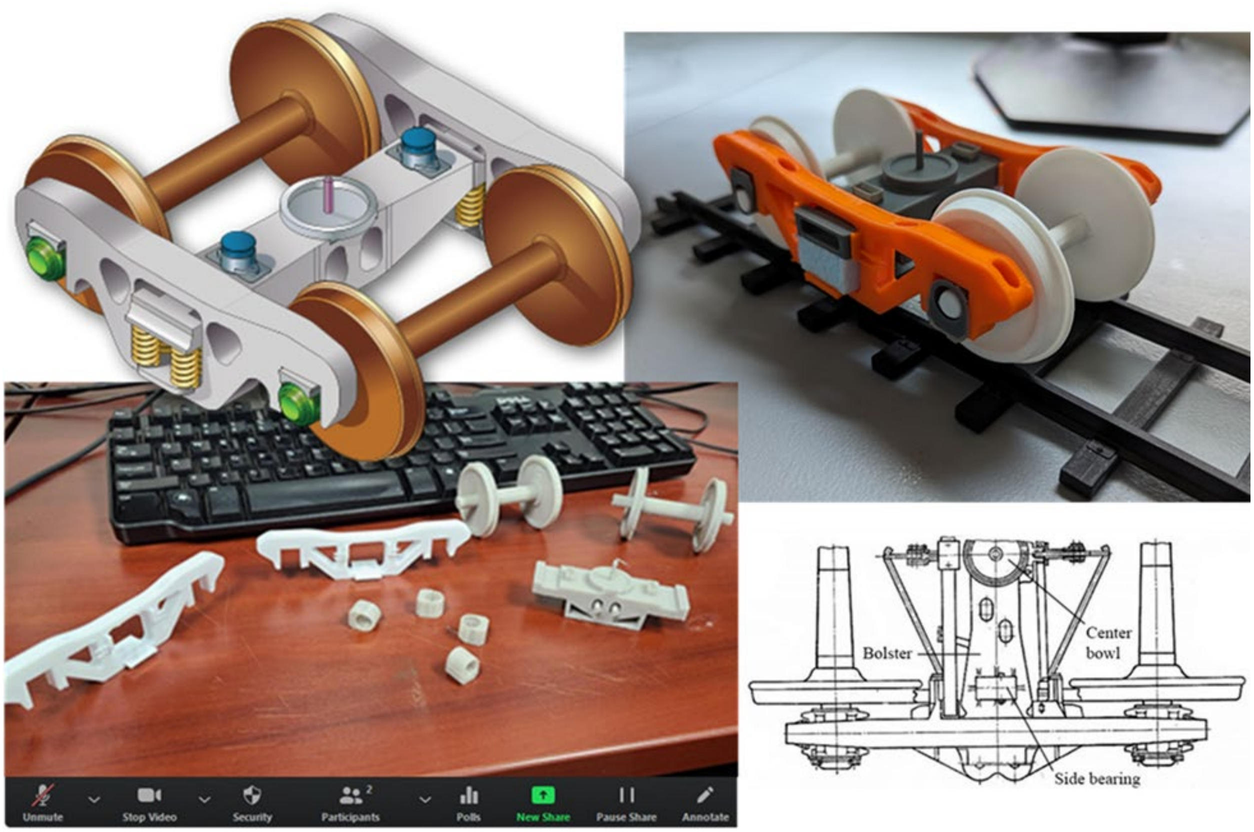
U.S. Department
of Transportation

Federal Railroad
Administration

Office of Research,
Development and Technology
Washington, DC 20590

Guidebook for Railway-Themed K–12 STEM Distance Learning Activities



DOT/FRA/ORD-26/13

Final Report | August 2026

REPORT DOCUMENTATION PAGE		*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
19 Aug. 2026	Technical Report	January 2024 to March 2024

4. TITLE AND SUBTITLE

Guidebook for Railway-Themed K–12 STEM Distance Learning Activities

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

C. Tyler Dick, ORCID: 0000-0002-2527-1320

Pasi T. Lautala, ORCID: 0000-0001-5552-5590

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
The University of Texas at Austin
110 Inner Campus Drive
Austin, TX 78712

8. PERFORMING ORGANIZATION REPORT NUMBER

If Any

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Department of Transportation
Federal Railroad Administration
1200 New Jersey Avenue, SE
Washington, DC 20590

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
DOT/FRA/ORD-26/13

12. DISTRIBUTION/AVAILABILITY STATEMENT
This document is available to the public through the FRA website.

13. SUPPLEMENTARY NOTES
COR: Michael Jones

14. ABSTRACT
Rail-themed outreach to K–12 students introduces those students to the railroad industry and can encourage them to pursue engineering and transportation education programs. This project will develop new rail-themed K–12 STEM distance learning activities, adapt current in-person activities to remote use, enhance activities with 3D printing and computer "gamification" code, and document existing online activities in a distance learning activity guidebook. This interim technical report summarizes the results of the first stage of the project that reviewed and identified potential rail-themed K–12 distance learning activities for inclusion in the guidebook and recognizes best practices in developing distance learning and self-study activities from in-person STEM activities.

15. SUBJECT TERMS
K-12 STEM, STEM, distance learning, guidebook, railroad self-study, railroad STEM activities

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**		35	Michael Jones
					19b. TELEPHONE NUMBER *(Include area code)*

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

Acknowledgments

The project team thanks the collaborating railway academic programs and the broader railway academic community for their assistance in identifying and/or developing several of the rail-themed K–12 STEM outreach activities described in this report.

Contents

Illustrations

Tables

Executive Summary

The objective of this project is to develop new, rail-themed K–12 STEM (science, technology, engineering, and mathematics) distance learning activities, adapt existing, in-person rail camp and open house activities to remote use, enhance specific existing activities with 3D printing and online computer game experiences, and document new, modified, enhanced, and existing online activities in a distance learning guidebook. The resulting guidebook to rail-themed K–12 STEM distance learning activities will be distributed online for use by educators, industry practitioners and others interested in conducting rail-focused STEM activities as part of classroom or community outreach programs via distance learning or independent study at home. Through these activities, the guidebook will help fulfill the objective of informing a broader K–12 student audience about future railroad workforce.

The first stage of the project reviewed and identified potential rail-themed K–12 distance learning activities for inclusion in the guidebook and recognized best practices in developing distance learning and self-study activities from in-person STEM activities. The review included engineering disciplines and those specific to transportation and revealed that most activities are designed for in-person delivery. However, there is a growing body of best practices and lessons learned in converting in-person STEM outreach activities to distance learning delivery modes. The project team will consider these best practices and the requirements of integrating K–12 STEM outreach activities into a classroom curriculum in preparing the guidebook.

The project team identified a list of 14 activities for inclusion in the guidebook. The activities cover different facets of railway transportation and include a mixture of digital activities and hands-on desktop activities that can be conducted synchronously or asynchronously. Next, the team worked to document each of these 14 activities and create activity descriptions that can be compiled into the guidebook.

1. Introduction

The objective of this project is to develop, adapt, enhance, and document rail-themed K–12 STEM (science, technology, engineering, and mathematics) distance learning activities. For each activity, the project team will create a guidebook to describe the activity, including required resources, a script for conducting the activity, and key learning points that tie railway transportation to broader STEM concepts. The guidebook will be distributed online for use by educators and individuals interested in incorporating rail-focused STEM activities into their classroom or community outreach programs via distance learning or independent study at home. These activities will help raise K–12 student awareness of railway transportation careers.

1.1 Background

Demand for graduates with rail transportation expertise remains strong in North America, particularly in engineering, construction, and related technical fields. Railway courses are now offered at two dozen universities in the United States, and, for the first time in decades, several universities offer specific degrees in railway engineering. Despite this progress, challenges remain, such as raising student awareness of rail industry career paths and having quality education materials available for instructors interested in providing rail-related curriculum.

Since most railway engineering courses at universities are senior-level electives, many students are already committed to other engineering disciplines before they are exposed to railway concepts. To raise student interest in rail courses and satisfy industry demands for interns and graduates to fill rail industry positions, students must be introduced to railway concepts before they decide on the direction of their studies. The few existing pre-college experiences in railroading are often focused on railway history at railroad museums or scenic railroads. To counter any potential impressions of railroads as outdated and obsolete, the rail industry must develop a pre-college program that can introduce K–12 students to modern railroading and the many high-tech applications and jobs available.

One approach to showing the modern side of the industry and directing more rail-aware students into engineering programs is rail-themed outreach to K–12 students. Railways still hold a fascination for many young people as complex, multidisciplinary systems, and numerous interesting STEM concepts can be demonstrated through the lens of railway transportation.

Interactive, hands-on rail-themed classroom activities can illustrate STEM topics while highlighting rail career opportunities and reinforcing railway transportation. Ideally, such activities should be conducted by visiting industry experts or qualified educators face-to-face with multiple student participants in a classroom, group, or camp environment. As such, the project team and partners have previously focused on developing rail-themed STEM outreach activities with strong interactive and hands-on components, delivering them through summer camps, public open houses, and other on-campus events, or in-person visits to local classrooms.

To reach wider audiences, there is a need to adapt and develop new rail-themed K–12 STEM distance learning activities that are highly flexible in their delivery. Such activities can include purely online digital activities or smaller-scale hands-on desktop activities, be guided or self-study, and involve a single student or small groups of students in the home or classroom environment. This project proposes to further develop, adapt, and consolidate information about these activities into a single guidebook that can serve as a convenient and critical resource for educators and individuals interested in incorporating rail-themed curriculum elements.

1.2 Objectives

The objective of this project is to develop new rail-themed K–12 STEM distance learning activities, adapt in-person activities used by the project partners and other collaborating railway academic programs to remote use, and document existing online activities in a distance learning guidebook. The guidebook created through this project will be distributed through various online channels for use by educators, industry practitioners and other individuals interested in incorporating rail-focused STEM activities into their classroom lesson plans or community outreach programs via distance learning or independent study at home. The wider objective of developing and documenting activities that can be delivered remotely is to help inform a broader K–12 student audience of rail transportation careers.

1.3 Overall Approach

This project builds upon the successful *Guidebook for Railway-themed K–12 STEM Outreach Activities* (Dick & Evans, 2020) that focused on developing and documenting activities with strong, hands-on interactivity and provided directions for delivering the activities in classroom, summer camp, or open house settings. Since its online release in December 2020, activity descriptions from the guidebook have been distributed and implemented by multiple K–12 educators and volunteers at railway museums across the country.

The project team reviewed and identified rail-themed K–12 distance learning activities for potential inclusion in the guidebook and/or further development. This review included examining in-person activities for potential adaptation to the online environment, and distance learning activities from other transportation and STEM fields that could be adapted into a new online activity with a rail focus. This report summarizes the results review , including a list of activities to include in the guidebook, consisting of existing distance learning activities that require documentation, in-person activities to adapt and further develop for distance learning, and new original activities to completely develop and document.

1.4 Scope

The scope of this project is limited to activities that can be conducted by a facilitator remotely online or can be completed by a participant independently, at any time, and at their own pace. This will avoid duplicating previous efforts focused on rail-focused STEM outreach activities conducted in-person by a facilitator with groups of students or one-on-one.

To maintain a focus on promoting future careers in railway transportation, the scope of activities selected for inclusion in the final guidebook is limited to those with a direct connection to some aspect of railway transportation planning, infrastructure, rolling stock, operations, or safety. However, the project also includes a limited review of distance learning activities from other transportation and STEM fields to stimulate ideas that could be adapted to rail transportation and developed into a new online activity. The project team also conducted a literature review to identify best practices in adapting in-person STEM outreach activities to the online distance learning and self-study environment.

1.5 Organization of the Report

This report summarizes the review and identification of potential rail-themed K–12 distance learning activities. The report is divided into two main sections. Section 2 broadly reviews literature and resources describing distance learning activities from transportation and other related STEM fields and best practices in developing distance learning and self-study activities from in-person STEM activities. Section 3 describes the identified existing and potential railway-themed K–12 distance learning activities and outlines the plans for their documentation and enhancement.

2. Broader STEM Distance Learning and Transportation Activities

To provide a context for and inform the development of the rail-themed STEM distance learning activities to be included in the guidebook, the project team reviewed literature describing distance learning resources and activities from transportation and other related STEM fields. A key part of the review was identifying best practices in developing distance learning and self-study activities from in-person STEM activities typically delivered in a camp or open house format.

2.1 STEM Distance Learning Modes

K–12 classrooms are increasingly equipped with smartboards, touchscreens, tablets, and other technology allowing online access to distance learning modules. K–12 students regularly engage in STEM lessons and activities through Google Classroom, Kahn Academy, and Prodigy, and educators often use YouTube videos or Zoom to host virtual classroom visits from working professionals. Railway industry and academic professionals routinely receive inquiries to participate in such virtual classroom visits in conjunction with K–12 STEM class modules taught through the lens of various railway transportation and civil engineering topics.

Self-guided online STEM enrichment programs for individual student study at home are offered by entities such as Brain Chase and Black Rocket. Google Summer Camp and entities such as the Chicago Museum of Science and Industry regularly organize virtual online visits with internationally recognized scientists and engineers who provide live STEM demonstrations with interactive question and answer sessions. Popular immersive sandbox platforms such as Minecraft and Roblox facilitate open-ended and game-based STEM exploration on personal computers and other portable electronic devices. In some cases, these platforms are increasingly incorporating augmented reality to merge and enhance an actual view of the physical surroundings with artificial computer graphics to create additional interactivity. Such technology can allow students to virtually explore and see inside objects and processes that are physically present but otherwise static or inaccessible in the real world due to practical considerations and/or potential safety concerns.

This landscape of STEM-focused distance learning options can be broadly categorized in two dimensions:

- Learning Method
  - Digital Activities primarily use interactive webpages, maps, videos, animations, live demonstrations, games, and other resources accessible via a computer, tablet or smartphone.
  - Desktop Activities allow students to step away from the screen and engage in small-scale, hands-on activities that demonstrate various STEM concepts using common household items or pre-packaged kits mailed to participants in advance. The advent of 3D printing facilitates the design and manufacture of small batches of custom components for participants to assemble into working models or mechanisms.

- Delivery Approach

- Asynchronous activities can be completed by a participant independently, at any time, and at their own pace. These activities include online instructions and/or feedback and evaluation, and thus do not require the real-time participation of an online facilitator.
- Synchronous activities involve an online facilitator, either via a video conference or real-time chat, to guide participants through the activity or demonstrate concepts. The activities may also require the students to collaborate with other remote participants in small groups. These activities require students and the facilitator to be available at scheduled times.

Of the four possible combinations of learning method and delivery approach described above, certain combinations may be better suited to self-study in classroom environments, while others may be best facilitated by an industry practitioner in a virtual camp or classroom event. To reach the broadest cross-section of students, the rail-themed activities in the guidebook should effectively cover a range of delivery and learning approaches.

2.2 Broader STEM Activity Resources

To potentially identify existing STEM activities that could be adapted to rail transportation and stimulate ideas for new enhancements to existing rail-themed online activities, the project team conducted a limited review of resources and activities from broader STEM fields and other transportation modes with a focus on distance learning.

2.2.1 General Engineering Resources

With the popularity of STEM topics for classroom demonstrations, camps, and open house events, there are countless STEM resources available online. Given that railway transportation has a strong connection to engineering and technology, the project team placed a specific focus on identifying resources in those fields (Table 1). Each of these sites provides documentation and descriptions for dozens of STEM activities covering a wide range of engineering topics. CoBuild at Home is notable for its focus on activities that can be conducted at home and thus potentially fit the distance learning scope of this project.

Table 1. STEM Resources on General Engineering Topics

Organization	**URL**
American Society of Engineering Education	http://teachers.egfi-k12.org/
Teach Engineering	https://www.teachengineering.org/
CoBuild at Home	https://cobuildathome.com/

2.2.2 Transportation Resources

Since the review of general engineering STEM resources yielded many potential activities, additional emphasis was placed on identifying transportation-themed STEM resources that either directly involve railway concepts or offer ideas that can be adapted to the railway transportation and engineering scope of this project (Table 2). Each of the listed sites documents various STEM activities across a range of transportation modes.

Table 2. STEM Resources on Transportation Topics

Organization	URL
PBS Kids	https://www.pbs.org/parents/things-that-go
American Society of Civil Engineers (ASCE)	Pre-College Outreach | ASCE
Institute of Transportation Engineers	https://www.ite.org/councils/transportation-education-council/science-technology-engineering-and-math-stem-resources/
American Association of State Highway and Transportation Officials (AASHTO)	https://transportation.org/stem-outreach-solutions/
State Departments of Transportation (DOTs)	Example from the Minnesota DOT: https://www.dot.state.mn.us/stem/resources.html
University Transportation Centers (UTCs)	Example from a Regional UTC: https://www.cts.umn.edu/education/K–12
University Research Centers	Example from the University of Illinois: https://railtec.illinois.edu/academics/other-educational-activities/k-12-stem-outreach/?highlight=K%2012%20STEM%20outreach
Individual Faculty	Example from a faculty member at the University of Illinois: https://trafficvis.com/

Although dominated by roadway transportation, the list represents aviation, marine, and rail modes, as well. The activities cover a range of transportation disciplines, such as urban planning, geometry, vehicle design, and operations.

Many of the transportation-specific STEM resources are distributed by transportation industry and professional organizations, typically for free, to increase student awareness of the importance of transportation and related career opportunities. However, AASHTO requires registration and charges a fee to access its STEM resources and curriculum.

The American Railway Engineering and Maintenance-of-Way Association (AREMA) features a web page with links to various K–12 STEM resources developed and hosted by others. Previously, the Association of American Railroads (AAR) had an active education and outreach division that produced and distributed teaching materials focused on the nation's railroads, along with comic books to introduce youth to railway operations, rolling stock, technology, and careers. However, while the current AAR website contains much useful information on railway traffic and technology, it does not feature specific K–12 education materials except for links to Operation Lifesaver and its railway safety-focused message.

Beyond industry organizations, individual State Departments of Transportation (DOTs) often have K–12 education and STEM resources posted or linked from their websites. The activities may focus on local transportation issues that are particularly important to a region (such as agricultural transportation, movement of trees and logs etc.) or align with research and education programs offered by local university transportation programs.

As part of their overall mission, National, Regional, and Tier 1 University Transportation Centers (UTCs) designated and funded by the U.S. DOT must have a workforce development and outreach component. For many UTCs, developing and distributing transportation-focused K–12 outreach activities forms a central part of these workforce development and outreach initiatives. Such was the case for the National University Rail Center Tier 1 UTC that developed the original *Guidebook for Railway-themed K–12 STEM Outreach Activities* (Dick & Evans, 2020) with a focus on in-person events and camps. Outside of the formal UTC structure, many other university research groups and individual faculty also post materials documenting STEM activities.

2.2.3 Specific Transportation Topics for Potential Development

The STEM resources listed in the previous sections focus on activities to be conducted in-person or in the classroom. The principal exception is CoBuild at Home, which was developed during the initial stages of the COVID-19 pandemic in direct response to the need for STEM activities that could be conducted remotely. However, as a general STEM resource, CoBuild at Home only has a limited selection of activities related to transportation. Overall, across general and transportation-focused resources, only a small subset of transportation-focused activities is designed for online delivery.

The documented transportation-focused STEM activities designed for distance learning via online delivery or self-study tend to fall into one of three broad thematic categories:

Building wheeled vehicles or airplanes with household items

Constructing simple models of vehicles and aircrafts can demonstrate many fundamental physics concepts related to rolling motion, aerodynamics, and forces such as propulsion, friction, lift, and drag. Concepts such as pushing and pulling forces and power-to-weight ratios are easily extended and demonstrated through building simple models of rail vehicles and linking them together into trains. While such desktop activities are ideal for self-study and promote development of many hands-on making and crafting skills, they can also suffer from a lack of equity and inconsistency of student experience due to availability of materials and tools, as discussed in Section 2.3.

Comparing travel and transit times of different modes

The review identified several digital activities that teach students about the strengths and limitations of different transportation modes while emphasizing mathematics and the concepts of distance, speed, and time. Students are usually required to select the appropriate transportation mode for different passengers or freight commodities over various travel or shipment distances. The decisions are usually based on calculated travel time, such as in the data table worksheet (Figure 1) used for the Let's Get It There Fast! activity on the Teach Engineering website. However, for passenger transportation, the activities are sometimes extended to factor in the number of people travelling together and cost, requiring students to research the cost of tickets for different trips and modes using online resources. For freight transportation, the comparisons may require students to consider the size of the shipment, the value of the goods, and if the freight is perishable.

Distance 1: ___________________

Cargo	Mode of Transportation	Time to Arrive at Destination	Why?
Shoes			
Medicine			
Cars			
Lumber			
People on Vacation			
Produce			
Fresh fish			
Mail			

Figure 1. Let's Get It There Fast! Student Worksheet

Driving games and routing puzzles

Moving vehicles and transportation networks naturally lend themselves to interactive digital activities that involve driving or racing vehicles or solving puzzles related to routing vehicles between different points in a network. These activities typically take on a game format, with student users competing against each other, the clock, or their own high score. These games are good examples of asynchronous digital activities that students can explore at their own pace. However, these types of activities can also be integrated into a synchronous online event with a facilitator who leads the students to participate in the games and report their scores as part of a competition to promote engagement.

An example of a driving and racing activity applicable to the rail domain is the Rail Rally hosted on the PBS Kids website. The game allows a student to choose from different locomotive types, each with their own strengths, such as speed on level track, ability to climb hills (gradients) and range before refueling is required. The selected locomotive is then raced against the clock and other computer-controlled locomotives across a side-scrolling course (Figure 2). A routing aspect is introduced to the game by allowing the student to throw turnouts that direct their locomotive on different tracks featuring their own vertical alignment and grade profile. The locomotives decelerate significantly on steep uphill sections and accelerate quickly on downhills, while maintaining a relatively constant speed on level track, mirroring the physics of actual train performance.

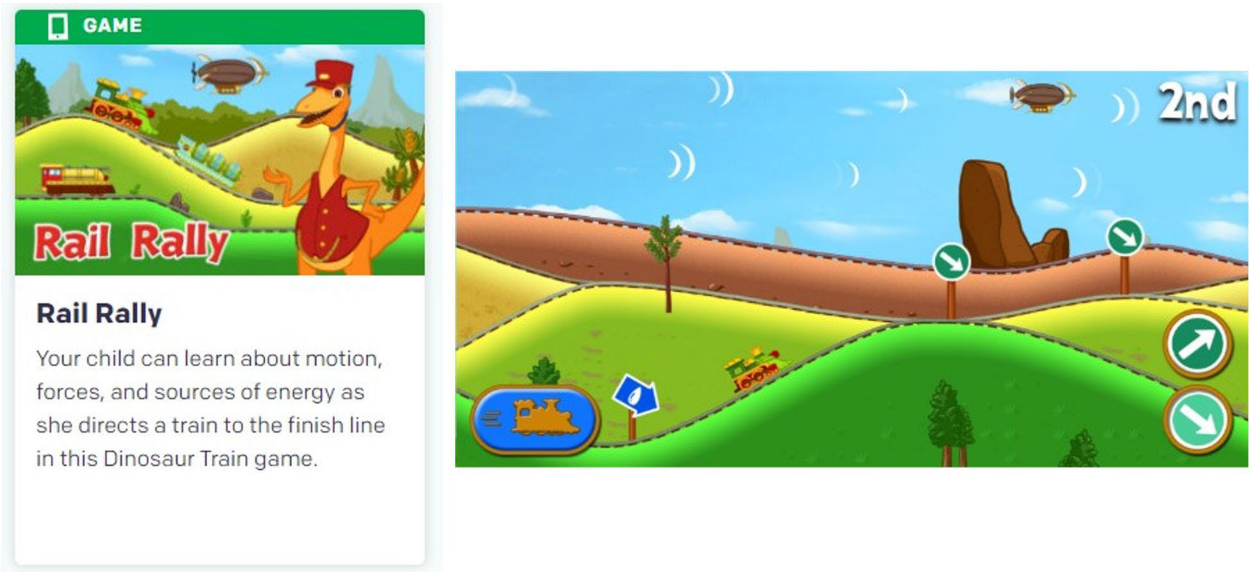


Figure 2. Rail Rally Locomotive Racing and Routing Game from PBS Kids

An example of a puzzle game outside the railway domain is Gridlock Buster from the Center for Transportation Studies at the University of Minnesota. This game-based activity is designed to teach students about the complexities of controlling traffic to avoid congestion in urban areas while reinforcing concepts of distance, speed, time, and geometry and developing critical thinking and problem-solving skills. Students assume the role of a traffic control center in charge of setting the "green time" by direction at individual intersections within an urban street network under varying traffic demands (Figure 3). Vehicles that encounter green proceed signals without stopping score points while vehicles that encounter red stop signals accumulate delay time until the signal clears, leading to increasing driver frustration. If the amount of driver frustration reaches a critical level, the game stops and the student must try the level again with a new strategy. If the student succeeds in managing the traffic effectively for a specified period, they complete the game level and unlock a new, more challenging level featuring a more complicated street grid and increased traffic volumes.

Figure 3. Gridlock Buster Traffic Control Game from the University of Minnesota

The list of activities identified for development and inclusion in the guidebook (presented in the next section) include activities comparing the travel and transit time of rail to different modes and a game-based activity that incorporates driving and routing in the form of a railcar switching (shunting) puzzle.

2.3 Converting In-Person STEM Activities to Distance Learning

As mentioned previously, most resources describing STEM activities emphasize experiences that can be conducted in-person within a classroom or open house environment. Thus, in addition to creating original activities for the online environment, when creating a STEM outreach program based on distance learning, it is logical to attempt to adapt existing in-person activities to online delivery or self-study at home. This transition was critical during the early stages of the COVID-19 pandemic, when classroom activities and summer camps were forced into the distance learning environment. During this transition, two challenges gained widespread recognition. The first is the challenge of avoiding "Zoom fatigue" in students spending hours online with headphones straining to hear and see their instructors (García-Bullé, 2020). The primary strategy for addressing this problem is to decrease lesson lengths, insert additional breaks, and make frequent changes in the content format, including using interactive content to recapture some of the personal in-classroom engagement lost online. The second is the need for parents to take an active role in helping students engage in STEM activities offered online, particularly those in elementary grades (Paul, et al., 2023).

However, this period revealed much about the feasibility of converting in-person STEM outreach activities to online delivery (Kitch, et al., 2021), and experiences and best practices are now being documented in the academic literature (Maltese, et al., 2022). Some important lessons that must be considered in identifying, developing, and documenting the rail-focused distance learning STEM activities for the guidebook include the following:

Technological Barriers

Reliable internet with sufficient bandwidth to handle consistent streaming audio and video remains a challenge for many students. This can be a particular challenge in homes with multiple children who are using separate computers and devices to attend multiple different online camp or outreach activities at the same time. Desktop or asynchronous self-study activities that can be conducted without the need for a live facilitator can allow a student to continue with an activity at their own pace and lessen the need for a constant, high-bandwidth internet connection for the duration of the outreach event.

Multitasking between a live Zoom session and the windows required for other activities, such as viewing a common document in a breakout room or searching for information in a web browser can be a challenge and a skill possessed only by the most computer-literate students. While straightforward on a desktop computer or laptop, staying connected to Zoom while multitasking may be difficult, if not impossible, on tablets, phones, or other electronic devices. Thus, it can often be difficult for the facilitator to help students through any challenges, particularly if the student loses the Zoom window and effectively becomes disconnected from the outreach activity.

File handling is another skill that can vary greatly between students. While some older students are comfortable downloading, editing, and sharing files, this can be a struggle for others. Facilitators also cannot assume that all students will have access to programs such as Word and Excel that are considered standard in the academic and office environments. It is often more productive to create templates in Google Docs that can easily be shared via URL links, and having all students or groups work on separate pages within one master document instead of handling multiple documents.

Access to Tools and Materials

Different households and students may not have the same materials available. This is a downfall of activities that suggest students build working models from available household items. As children spend more time with digital activities and less time on arts and crafts, and busy parents have less time to engage in hobbies at home, it is less likely that they will have a supply of construction paper, pipe cleaners, wooden spools, paper towel tubes, or wooden dowels that make excellent model-building materials. Students without access to suitable materials are unlikely to have a positive experience when engaging in such a desktop activity, resulting in an inequity in the engagement and effectiveness of activities that rely on household materials.

Different households and students may also not have the same tools available. A facilitator may wrongly assume all students have access to resources such as scissors, tape, and glue. The availability of tools can be a critical challenge for students that are traveling or staying away from home during the summer or breaks from classes when many outreach activities are conducted. Even if the materials required for an activity are mailed to a student in advance, a list of the necessary tools to cut-out or assemble the different parts and pieces should also be communicated in advance. This information will allow parents and students to ensure that required tools are made available in advance. Mail-out activities should also be designed to simplify assembly with a minimum of tools and additional materials like glue, tape, paper clips, staples, etc.

The cost of producing and delivering these kits can be another challenge to desktop activities conducted via distance learning. While mailing out required materials and equipment is one way to improve the equity of a STEM distance learning activity by providing all students with a common starting point, materials can prove costly to acquire, produce, and ship. These costs are a particular challenge for free programs, and user fees to offset these costs may work against the goal of using these programs to reach students from disadvantaged communities. Careful design of materials to ship flat in envelopes can help minimize costs. Creative use of 3D printing can avoid the cost of acquiring or manufacturing unique model components. However, this technology does introduce its own material costs plus the cost of a technician to supervise the time-consuming printing process. This approach can be particularly time-consuming and inefficient if only a small number of parts and components can be printed simultaneously.

Timing and Troubleshooting

Longer durations are required for activities when they are converted from in-person to online delivery. There are many reasons for this, including the natural time delay in talking back and forth to answer questions when not face-to-face and each party needs to find an unmute button, unfamiliarity with the online technology and how to create, manage, and navigate breakout rooms; the difficulties in multitasking and handling files described previously, an inability to hear audio, forgetting to un-mute or getting dropped due to internet connectivity issues, and the overall awkwardness of interacting and collaborating with strangers that students have not met in person. Since it is difficult to eliminate many of these causing factors, the best mitigation strategy is for facilitators to simply allow more time for online activities and not expect to progress through the same schedule used for an on-campus camp.

Problem intervention is more difficult with online activities as the facilitator often lacks the ability to see problems developing. With groups working in-person, the facilitator can often see, hear, or tell when a group is getting off topic, is stuck on a particular step, or otherwise not working effectively. The facilitator often lacks this type of visibility into individual group breakout rooms online unless the students use the raise hand feature to draw attention. Also, an in-person group can easily ask questions, and facilitators can observe and then casually approach an in-person group to take a corrective action and get the group back on track with all students involved. In an online breakout room, a group can feel isolated and may not understand how to ask questions or seek attention from the facilitator. Also, when a facilitator drops in unannounced to check on a breakout room, it can be disruptive to the group and make them feel like they are doing something wrong or are in trouble even if they are progressing normally. Having multiple facilitators such that the ratio of groups-to-facilitators is low enough that ample time can be spent with each breakout group can help mitigate this situation. Another advantage of using one consolidated Google doc for students to work in is that the facilitator can observe the progress of all groups in one document to see if certain groups might be experiencing problems.

A final lesson learned from conducting online STEM activities is to expect a high attrition rate, particularly for free, organized online activities (Maltese, et al., 2022). As reported by Maltese, et al., on average, only two-thirds of students registered for an organized online STEM outreach program actually begin any of the activities, and only one-third of the students actually complete the main activity.

2.4 Implementation Considerations

Many K–12 STEM outreach activities are ideally suited for summer camps or open houses centered on a specific STEM theme and conducted by faculty or industry practitioners who are familiar with the topics and concepts being introduced. While such events can be converted to online delivery and are effective at reaching students, they have the drawback of primarily reaching students that are already aware of, or already have a potential interest in, a particular STEM field. To reach the goal of attracting students to careers in railway transportation and engineering, rail-focused STEM activities must reach a wider audience of students than those who already have an interest in transportation, engineering, and/or railroads.

2.4.1 Integration of K–12 Curriculum

One way to increase the size of the audience reached by STEM outreach activities in a particular field is to have the activities integrated into the regular classroom curriculum for K–12 students. In this manner, the activities will reach students who may not have been familiar with a particular STEM field, such as railway transportation and engineering, and possibly spark their interest. However, integrating these activities into regular K–12 curriculum goes beyond creating an activity description, list of materials, step-by-step instructions, and a script for executing the activity (Douglas, et al., 2004). Inclusion in curriculum requires the activity to be placed into a broader context that more strongly connects it to a particular fundamental STEM topic or to be expanded and developed into a full course module on the STEM field complete with additional resources such as background material, homework assignments, and quiz questions to complement the main activity or activities.

As an example, the Gridlock Buster traffic game described earlier was integrated into a series of lessons developed for high school science classrooms (Liao, et al., 2010). The curriculum development phase extended over multiple years as the lesson plans were tested and evaluated on high school students attending STEM summer camps before being released for broader K–12 implementation. Another example is a curriculum of six modules of lectures and hands-on projects designed to provide high school students with a fundamental understanding of basic concepts in transportation logistics and relate classroom theories with real-time examples that highlight career opportunities (Sarder, 2013).

An unconventional option for high school students is to introduce transportation-related STEM concepts via a service-learning project that addresses local transportation issues such as pedestrian access to rail transit. Studies of service-learning projects have shown that students are more attracted to, and are more likely to persist in, fields in which they can make a difference in the world, improve the lives of others, and better the natural environment (Hernandez & Ritchie, 2015). Service-learning projects also provide an ideal avenue to introduce students to non-traditional facets of the transportation field, such as the multimodal, environmental, and public service aspects of transportation projects, as opposed to simply focusing on automobile travel.

In all cases, implementation of these materials requires the support and cooperation of local school administration to allocate the required time within an already busy school year during which K–12 educators already struggle to cover the mandated curriculum, required evaluations, and standardized tests.

2.4.2 Training Educators

One challenge in implementing a specialized curriculum on a specific STEM field such as transportation is the ability of K–12 educators who lack a professional or educational background in the area to deliver the material and adequately answer student questions while fostering their interest in the field. While K–12 educators may bring in outside experts to speak to a class on a specific topic, these interactions are typically limited in duration such as a one-hour remote visit via Zoom projected on a smartboard, or possibly a day-long visit as part of a career day or special event focused on a particular STEM field (such as a Transportation Day). Thus, these outside experts cannot be expected to cover a curriculum extending over multiple class periods.

To equip K–12 educators with the background knowledge required to deliver the transportation logistics curriculum described in the previous section, a critical component of developing the curriculum was hosting a teach the teacher event (Sarder, 2013). The three-day training program was attended by 75 high school teachers from the area where the transportation logistics program was being implemented.

Using educational programs developed by AASHTO, several state DOTs are involved in organizing teacher training sessions designed to equip K–12 educators with tools to incorporate transportation and STEM applications and examples in their classrooms throughout the school year (Subramanian & Clark, 2016). A typical format for a three-day, transportation-based summer academy for teachers includes brief in-class overviews of transportation systems, logistics and supply chain management, followed by two days of site/field visits to a variety of real-life settings such a state DOT Traffic Management Center, an air-traffic control tower, a commercial airport and airfield, a traffic signal systems laboratory, a crash-reconstruction study site, and a driving simulator (Nambisan & Richards, 2015). Based on these experiences, the facilitators work with the teachers to develop corresponding case-based transportation lesson plans and related materials for use in the K–12 classroom.

2.4.3 Peer Connections

-A final consideration is that studies of STEM programs have shown that it is not enough to simply have tangible connections between a course concept and professional aspects of transportation engineering, but that students are more likely to be positively influenced by transportation STEM outreach activities if they are conducted by a near-peer facilitator who is involved in transportation (Nezamuddin, Pande, & Nuworsoo, 2014). The term near-peer includes connections between the student and facilitator in several ways such as age, ethnicity, gender, interests, etc. In this manner, undergraduate students specializing in transportation are ideal near-peers for high school students as they have recently been through the K–12 system. The experience of the project team in conducting various rail-focused STEM outreach activities with undergraduate members of AREMA Student Chapters is consistent with these ideas. The undergraduate students can form different types of connections with high school students and provide a different perspective in answering questions and offering advice compared to faculty facilitators.

Near-peer teaching is one technique that can help connect students to the field of transportation and the career opportunities it offers. Exploring these topics and issues can help students from different backgrounds develop a positive impression of the diversity and inclusiveness of the transportation field.

2.4.4 Guidebook Considerations

While the primary focus of this project is documenting rail-focused STEM outreach activities for distance learning via online delivery or self-study, it is important to consider how these materials may also be used in the classroom by K–12 educators. Where possible, the project team will strive to develop activity descriptions that provide appropriate background and ideas for follow-on work and assignment questions. While curriculum development and teach the teacher programs are beyond the scope of this project, such efforts could be the subject of follow-on programs to leverage the material developed through this effort and expand its reach.

3. Rail-Focused

This section describes the identified existing and potential railway-themed K–12 distance learning activities and outlines plans for their documentation and enhancement via 3D printing and digital online game development.

3.1 Previous Development

The University of Illinois (under the supervision of the project PI, now at the University of Texas at Austin) and Michigan Technological University have been working on K–12 outreach programs and education curricula for over a decade. However, the primary focus has been on developing rail-focused, hands-on STEM activities for in-person delivery (Dick, et al., 2019). The distance learning environment imposed by the COVID-19 pandemic during the 2020–2021 academic year unexpectedly forced the project team to adapt many classroom activities and demonstrations to alternative learning techniques via online delivery. STEM summer camps and other outreach events were similarly shifted to synchronous or asynchronous online delivery. In adapting to this new educational paradigm, the project team essentially created the foundation of an online, rail-focused STEM curriculum that can reach a wide audience of students through distance learning. However, due to the dynamic nature of the pandemic, many activities were hastily converted to online delivery. This project will revisit and further develop these distance learning activities with a more polished and professional appearance and delivery and develop new types of activities that build upon these earlier experiences.

The project team for the FRA-funded project entitled “Expanding Summer Youth Programs in Rail through Virtual learning and a National Campus Network” have already taken steps to leverage this new distance learning capability. This project developed and marketed a hybrid online and in-person summer camp for high school students named “Tracks to the Future: Railroad Transportation and Engineering”, and hosted it simultaneously at the University of Illinois, Michigan Tech, and Penn State Altoona in July 2022. In summer 2023, the camp was expanded to include the University of South Carolina, University of New Mexico, and Fresno State University. The camp included a two-day online component with newly developed activities designed to highlight recent technological advances in operations, motive power, and signaling, including positive train control, and aspects of the industry intended to engage students with the variety and breadth of career opportunities available. The guidebook will further develop and formally document these activities and describe how they can be adapted for other age groups, time slots, and settings so they can be shared with other educators and industry volunteers.

3.2 Review of Rail-Themed STEM Distance Learning Activities

The project team worked with Tracks to the Future collaborating institutions to identify existing and potential railway-themed K–12 STEM distance learning activities for inclusion in the guidebook. Many of these activities are based on in-person activities related to classroom demonstrations, summer camps, open houses, and other interactions with K–12 students that have been shared at the AREMA Railway Engineering Education Symposium (REES) and American Public Transportation Association (APTA) Passenger REES events. Activities that could potentially be adapted to the online, distance learning, or self-study environment were selected for inclusion in the guidebook, along with several new original activities developed especially for this delivery mode.

3.2.1 Rail-Themed Activities Proposed for the Guidebook

The list of activities proposed for inclusion in the guidebook is summarized in Table 3, along with the basic characteristics of each activity. Note that some activities can be adapted to synchronous delivery with a facilitator or used asynchronously for student self-study. Similarly, some activities can be enhanced by optional 3D printing, but the activity may also be conducted with more basic materials that are less costly to produce and ship or that can be downloaded online and printed by the student. Each activity is briefly described in the following paragraphs.

Table 3. Identified Rail-Themed Distance Learning Activities

Activity	Synchronous Online Interaction	Asynchronous Self-Study	Game/Competition	Digital Activity	Hands-On/Desktop	3D Printing
Kahoot Quizzes (5 Different Topics)	●		●	●		
Locomotive Puzzle	●	●			●	●*
3D Virtual Rolling Stock	●	●		●		
Wheel-Rail Dynamics	●	●			●	●
Railway Trucks/Bogies	●	●			●	●
Train Energy and Fuel Consumption	●	●		●		
Freight Rail State-to-State	●	●		●		
Networks: Trucks vs. Trains	●				●	
Yard and Terminal Scavenger Hunt	●	●	●	●		
Classification Yard Railcar Sorting	●				●	
Moving with Different Modes	●	●	●	●		
High-Speed Rail (HSR) Around the World	●		●	●		
Transit and Passenger Scavenger Hunt	●	●	●	●		
Railcar Switching Puzzle	●	●	●	●		

*Optional

Kahoot Quizzes

Kahoot Quizzes are a popular way to promote student engagement during distance learning sessions. There are several platforms available to host online quizzes, but Kahoot is commonly used by educational institutions at the K–12 and post-secondary levels and is thus familiar to many students, teachers, and faculty. Kahoot allows students to compete against each other in answering a series of multiple-choice questions that can include text and images. Questions have four possible answers and may include a follow-up slide that allows the facilitator to provide additional information and explanation of the answer. Students are awarded points based on correctly answering the questions as fast as possible, and Kahoot automatically keeps track of the standings after each question and declares a champion at the end of a round. Besides fostering a sense of competition and engaging students with the material, using a Kahoot quiz at the beginning of an online learning module can allow the facilitator to estimate student familiarity with the topic and to adjust subsequent material and activities accordingly. The project team has previously developed quizzes on five different railway topics:

- Railroad history, including important dates in development of railroads and related technology
- Public rail transit, for which students are shown pictures of different rail transit systems and must identify the city where the system is located, or the type of rail transit system (i.e., commuter rail, subway, light-rail, streetcar, etc.)
- Locomotives, including locomotive components, braking, and fuel/energy use
- Railway operations, including statistics on tons of freight shipped by rail, average shipment distances, railcars per train, tons of freight per train, and number of freight trains operated per day
- High-speed rail, including the basics of what makes high-speed rail different from freight and conventional intercity passenger rail

Locomotive Puzzle

Locomotive Puzzle is a hands-on desktop activity that introduces students to the major components of a diesel-electric locomotive. The students are provided with individual locomotive components such as the diesel prime mover, alternator, traction motors, trucks/wheels, frame, cab, radiator hood, etc., either as paper cut-outs or 3D printed plastic models. The students must then correctly assemble the components to form a diesel-electric locomotive while learning about the function of each component and how it works with other parts of the locomotive to turn fuel into energy and the force to propel a train.

3D Virtual Rolling Stock

3D Virtual Rolling Stock is a digital activity that uses online, 3D-rendered models of various freight cars to introduce students to different rolling stock components such as the bogie/truck, hand brake, A and B railcar ends, brake hoses, and couplers. After giving students time to explore several 3D computer models of different freight car types, this activity can be structured as a matching game between a list of components and labels placed on the freight car renderings.

Wheel-Rail Dynamics

Wheel-Rail Dynamics is a hands-on desktop activity that uses a kit of parts mailed in advance to introduce students to the ways geometry and physics influence the behavior of railway wheelsets traveling on straight and curved track. The kit includes model sections of straight and curved track, plus 3D printed cylindrical and tapered wheelset models. Students observe how the different wheelsets perform when rolled down each of the two track sections and relate their observations to the geometry of the wheelset and the concepts of rolling radius, diameter, and circumference. The discussion of wheelset geometry can be extended to explain the physics of how wheelsets steer rolling stock around curves and negotiate straight tangent track sections and its relationship to the gentle swaying motion felt when riding a train.

Railway Trucks/Bogies

Railway Trucks/Bogies is a hands-on desktop activity that leverages 3D printing to teach students how a three-piece railcar truck (bogie) carries the heavy load of a freight car. Students are provided with 3D printed truck components such as the side frames, bolster, and wheelsets. The students must correctly assemble these parts to form a working model of the truck while learning about the load path from the center plate/bowl down through the truck to the contact patch at the wheel-rail interface.

Train Energy and Fuel Consumption

Train Energy and Fuel Consumption is a digital activity that leverages one of several web-based train performance calculators to introduce students to freight train fuel consumption and energy efficiency. Students can build trains with different numbers of locomotives, loaded freight cars and empty freight cars, and simulate their fuel consumption and running time performance over different rail corridors. The results allow students to make comparisons between different train sizes, train weights, and route topography (i.e., mountainous versus flatter routes). The tools can also allow students to explore the potential of new technologies such as Battery Electric Locomotives.

Freight Rail State-to-State

Freight Rail State-to-State is a digital activity where students explore the amount and types of freight commodities moving by rail between different pairs of states. The activity leverages web-based data from AAR on the most common types of freight originating and terminating in each state by rail, and Bureau of Transportation Statistics data on traffic volumes between each pair of states. Students receive a list of specific origin-destination state pairs that offer contrasts in the types of freight movements or have some local connection to where the students are from. The activity can be further enhanced by providing students with an online rail network map and asking them to identify a possible rail routing between a major city in the assigned origin state and a city in the destination state.

Networks: Trucks vs. Trains

Networks: Trucks vs. Trains is a hands-on desktop activity that explains how railroads achieve economies of scale compared to trucks in moving freight from multiple origins to multiple destinations. Students receive a network sheet illustrating three freight origins, three color-coded freight destinations and nine colored bingo chip markers (three matching each destination color).

Students use different strategies to move the freight from origin destination in the manner of trucks, dedicated direct trains, and manifest trains with a single sorting (classification) yard.

Yard and Terminal Scavenger Hunt

Yard and Terminal Scavenger Hunt is a digital activity that introduces students to the locations and types of major yard and terminal facilities on the North American rail network. Students are provided with a list of latitude and longitude coordinates and instructions on how to search those locations in Google Maps using a web browser. Based on the aerial image at each provided locations, students must identify the type of railway facility, including classification yards, intermodal terminals, mine loading loops, and port facilities. With groups of students, the activity can be structured as a competition to correctly identify the most terminals, or to be the first to collect a complete set of different terminal types.

Classification Yard Railcar Sorting

Classification Yard Railcar Sorting is a hands-on desktop activity that explains how railroad yards sort railcars by destination. Students are provided with a yard track layout and a set of railcar cutouts. The railcar cutouts illustrate different types of freight cars and are lettered and color coded by their assigned destination blocks. Students place the railcars on the yard lead and slide them into their assigned tracks. This process is repeated several times to demonstrate processes such as triangular and matrix sorting that allow railroads to make the same number of blocks using fewer tracks.

Moving with Different Modes

Moving with Different Modes is a digital activity that allows students to explore the travel time and cost of different passenger transportation modes between specified city pairs reflecting different trip lengths. Students use online resources to determine the cost and travel time of air, bus, and rail modes. They also calculate the cost and time of automobile travel based on average travel speeds, fuel efficiency, and fuel costs. The students then recommend the best mode for travel between each city pair.

HSR Around the World

HSR Around the World is a digital activity where students explore the types of trains and corresponding train speeds in different countries using online resources. The activity culminates in students producing a comparison between an HSR corridor in China and the Northeast Corridor in the United States in terms of train speed, travel time, and number and frequency of train departures.

Transit and Passenger Scavenger Hunt

Transit and Passenger Scavenger Hunt is a digital activity where students must collect different types of passenger rail and transit systems by identifying a North American city that hosts each type of system. The activity is extended by discussing the properties of each type of system and how they correspond to the size and travel demand in their corresponding host cities or locations (such as airports).

Train Shunting Puzzle

Train Shunting Puzzle is a digital game activity where students use a locomotive to switch railcars to assigned locations on a track network with various turnouts. The students can control the direction of locomotive travel, couple and uncouple railcars, and line turnouts as needed to sort the railcars into the required order to reach their specified destinations. As students solve each puzzle, they progress to levels of increasing complexity based on the number of railcars, tracks, turnouts, and movements required to correctly position the railcars. This digital game is under development.

Desktop materials for some of the hands-on activities listed above are illustrated in Figure 4, which depicts the mail-ahead kit developed for the Tracks to the Future hybrid rail camp. Items include the track layout and railcar cutouts for classification yard sorting, the network sheet and bingo chip markers for Trucks vs. Trains, track segments (curved and tangent) and wheelset models for wheel-rail dynamics, 3D printed parts for trucks/bogies and locomotives, and a copy of the latest Railroad Facts book courtesy of AAR.

Figure 4. Desktop Materials for Rail-Themed, Hands-On Activities

3.2.2 Guidebook Development

The guidebook developed through this project will use text, diagrams, and images to document each of the above activities. The documentation will contain enough information for an outside educator or railway engineering professional to incorporate the activity into their distance learning curriculum or remotely conducted community outreach program. At a minimum, activity documentation will include the following:

- Activity name and main aspect of railway transportation and STEM field
- Appropriate age, group size, setting, and duration of the activity
- Key learning points related to STEM topics and to railway transportation
- List of required resources, materials, and equipment
- Instructions and diagrams for creating or assembling equipment or preparing pre-packaged kits
- Instructions and/or script for executing the activity, including images of it being conducted
- Copies of relevant handouts, data collection sheets, 3D printing files, etc.
- Ideas for altering the activity to shorten or lengthen the time duration and adjust for group size
- References and a list of resources for additional learning

The above list may be adjusted based on the exact scope and setting of each activity and its specific learning objectives.

3.3 Enhancement with 3D Printing

As previously described, several of the identified activities already leverage 3D printing. The project team has previously identified or developed the 3D model and printing files required to create the truck/bogie assemblies (Figure 5), the major components of the Locomotive Puzzle breakdown model (Figure 6), and the different shaped wheelset models for the wheel-rail dynamics activity (Figure 7).

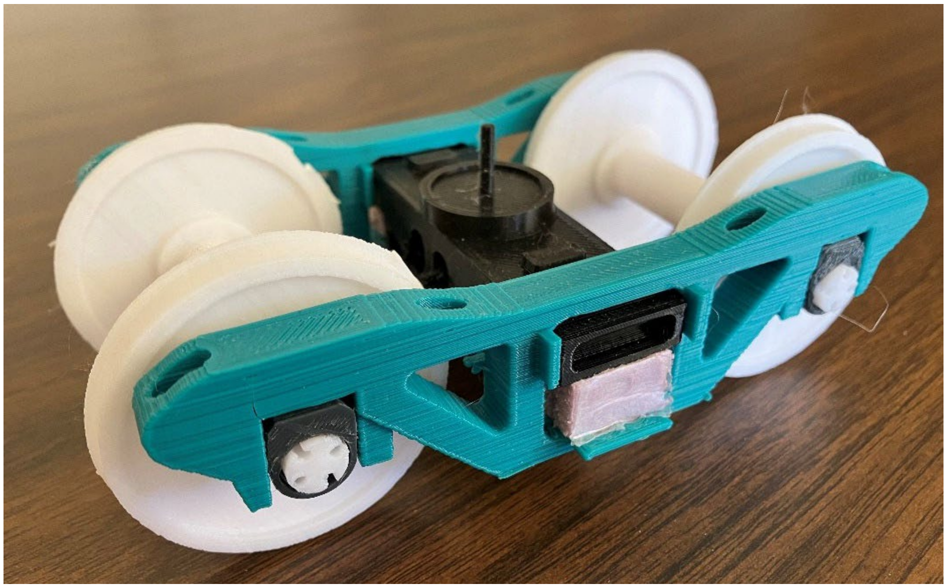


Figure 5. Assembled 3D Printed Railway Truck/Bogie Model

Figure 6. 3D Printed Locomotive Puzzle Breakdown Model

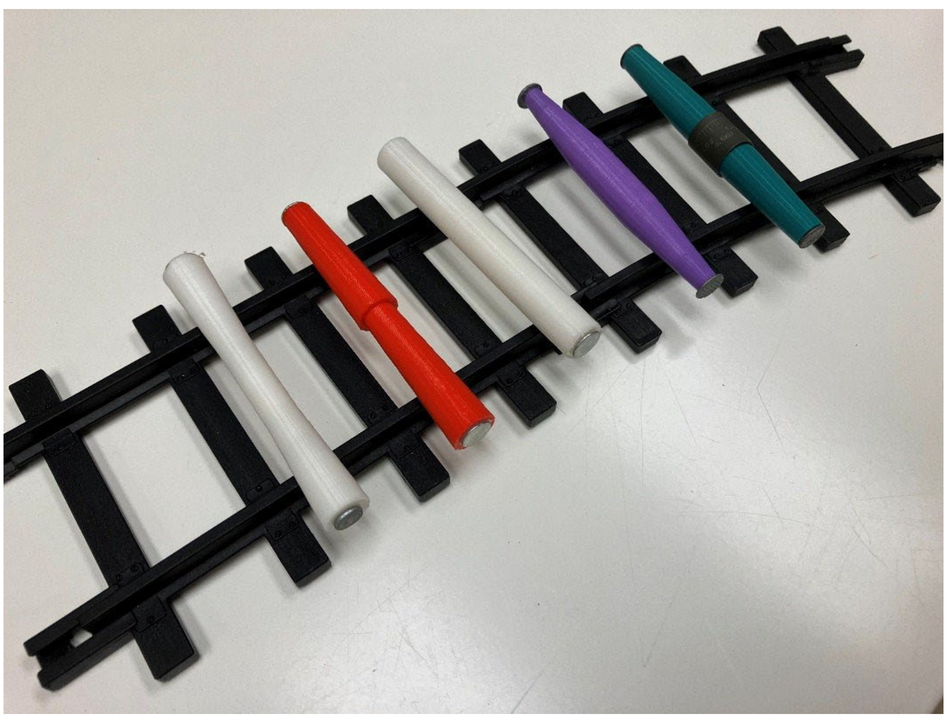


Figure 7. 3D Printed Wheelset Models for Wheel-Rail Dynamics Activity

In using this technology to support distance learning activities during summer 2023 and 2024, the project team gained valuable insight into its strengths and limitations. One major hurdle with 3D printing is the time required to print all the parts for various kits, even when multiple items can be printed simultaneously (Figure 8). The parts can also be brittle or subject to warping and shrinking, making them difficult to assemble and easily broken if parts with a tight fit are forced together. However, the flexibility in designing custom parts and the wide variety of rail-related 3D printing files available online make this technology critical to supporting desktop activities conducted remotely via distance learning.

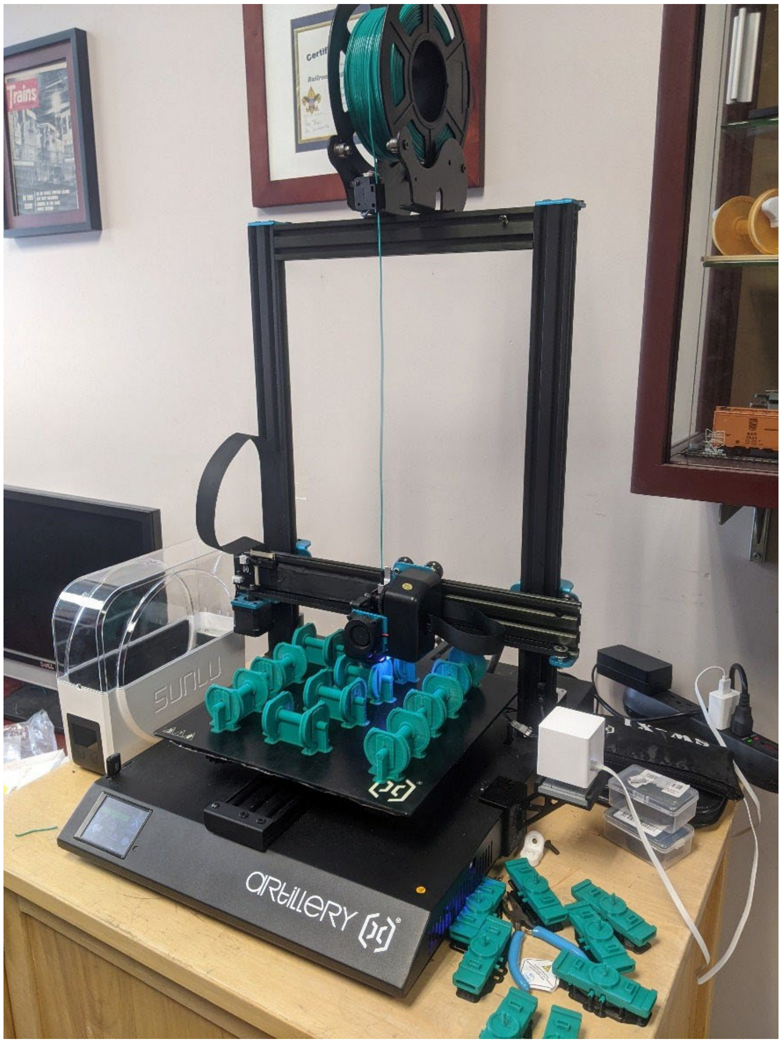


Figure 8. 3D Printing Truck/Bogie Model Components

3.3.1 Future Development

Additional applications of 3D printing to potential hands-on rail-themed STEM distance learning activities include models of a partial knuckle coupler, wayside block signal heads, track components (rails, ties, etc.), and a tank car model/puzzle consisting of its major components.

The ability to support 3D printing these models and different sets of components and parts is determined by the time required to develop an original 3D computer model or the availability of an appropriate 3D computer model file posted online. A challenge with many railroad-related

3D printing resources available online is that they are often geared towards parts compatible with scale model railroad trains or LEGO trains, with necessary compromises in geometry and how the parts are designed to fit together. Thus, many of the 3D model files for rolling stock and locomotive components available online are not true to the actual details and dimensions of full-size equipment. However, the educational impact of these compromises must be balanced against the expediency of using an existing model file compared to developing a higher-fidelity model file from scratch using Computer-Aided Drafting (CAD). Also, even if a new model is developed with more accurate details and dimensions, the printing files and dimensions usually need to be adjusted for the part to print properly or be shipped and handled without breaking.

3.4 Online Digital Game Development

An additional activity that is not within the scope of the first project task is the redevelopment of a Train Shunting Puzzle (described in Section 3.2.1) as an online digital game. The original version of the train shunting puzzle was an online Flash game that was used for many years as part of the Michigan Tech Summer Youth Program in Rail and Intermodal Transportation conducted as an in-person camp (Figure 9).

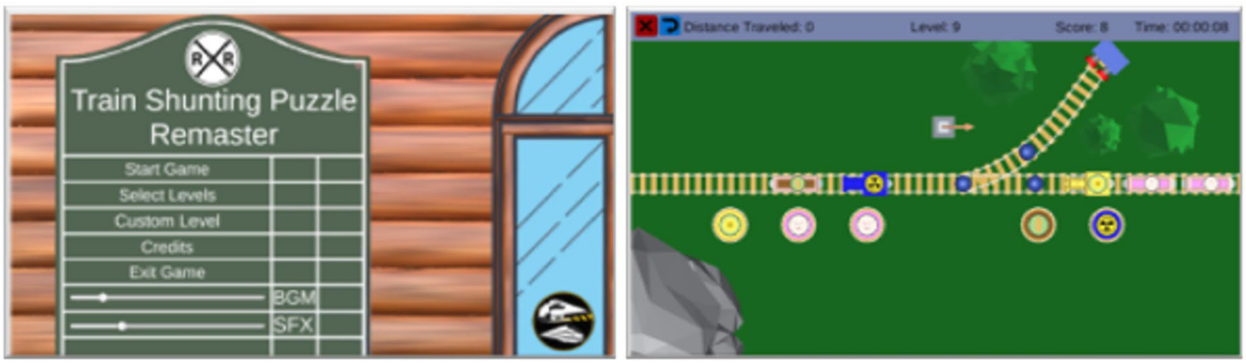


Figure 9. Current Screenshots from the In-Development Train Shunting Puzzle Game

The current version of the game can be played through the Michigan Tech Husky Game Development website. Besides recreating the basic game framework, the development team has been able to implement many features within the current version of the game, including:

- Players control how touching railcars connect
- Disconnect (uncouple) cars by left-clicking railcars
- Players can switch tracks by clicking the turnout switch stand
- Points sum the distance each locomotive was moved and the time it takes to complete each level
- Crash screen when turnout switches are not properly lined for a trailing point movement
- Stations recognize when their correct railcar is in close proximity

4. Conclusion

The review of both broader K–12 STEM outreach activities across all engineering disciplines and those specific to the transportation field revealed that most activities are designed for in-person delivery, rather than online distance learning or remote self-study. However, partially due to the impacts of the COVID-19 pandemic, there is a growing body of best practices and lessons learned in converting in-person STEM outreach activities to distance learning delivery modes. The project team will consider these best practices, and the requirements of integrating K–12 STEM outreach activities into a classroom curriculum, in preparing the guidebook to rail-themed K–12 STEM distance learning activities.

The project team identified a list of 14 different activities for inclusion in the guidebook. The activities cover different facets of railway transportation and include a mixture of digital activities and hands-on desktop activities that can be conducted synchronously or asynchronously

5. References

Dick, C. & Evans, L. (2020). *Guidebook for Railway-themed K-12 STEM Outreach Activities*. National University Rail Center. NURail2014-UIUC-E09.

Dick, C., Lautala, P., & Schlake, B. (2019). STEM K–12 Outreach as the Root of Transportation Education: Experiences from the Railway Engineering Field. *Transportation Research Record: Journal of the Transportation Research Board, 2673*(12): 558-569. https://doi.org/10.1177/0361198119841564

Douglas, J., Iversen, E., & Kalyandurg, C. (2004). *Engineering in the K–12 Classroom. An Analysis of Current Practices & Guidelines for the Future.* American Society for Engineering Education (ASEE) Engineering K–12 Center.

García-Bullé, S. (2020). What is Zoom fatigue and how to avoid it in students? Institute for the Future of Education.

Hernandez, S. & Ritchie, S. G. (2015). "Motivating Students to Pursue Transportation Careers: Implementation of Service-Learning Project on Transit." *Transportation Research Record: Journal of the Transportation Research Board, 2480*, 30–37. https://doi.org/10.3141/2480-04

Kitch, W. A., Robledo, A. L., & Green, W. J. (2021). *A Model for Conducting K–12 STEM Summer Outreach Programs During the COVID-19 Pandemic.* 2021 ASEE Annual Conference & Exposition. http://dx.doi.org/10.18260/1-2--36593

Liao, C. F., Glick, D. B., Haag, S., & Baas, G. (2010). Development and Deployment of Traffic Control Game. *Transportation Research Record, 2199*(1), 28–36. http://dx.doi.org/10.3141/2199-04

Maltese, A. V., Paul, K., Simpson, A., & Zych, A. (2022). *Creating online supports for at home making and STEM projects during COVID-19.* 2022 ASEE Annual Conference & Exposition.

Nambisan, S., & Richards, J. (2015). *Transportation systems STEM summer academy for teachers.* Engineering Leaders Conference on Engineering Education. https://peer.asee.org/24941

Naz, F., Saha, T., & Hyun, K. (2023). Transportation Curriculum with Culturally Responsive Teaching: Lessons Learned from Pre-Service Teachers and Future Transportation Workforce. *Transportation Research Record: Journal of the Transportation Research Board, 2678*, 1–13. https://doi.org/10.1177/03611981231184233

Nezamuddin, N., Pande, A., & Nuworsoo, C. (2014). *Workforce of the Future: Ideas for Improving K–12 Outreach by Transportation Engineering Educators through Near-Peer Involvement and Leveraging Contextual Exposure.* 2014 ASEE Annual Conference & Exposition. https://peer.asee.org/22792

Paul, K., Penney, L., Maltese, A. V., Simpson, A., & Kim, J. (2023). *Caregivers' Roles in Supporting Children's Engagement in Engineering Activities at Home.* 2023 ASEE Annual Conference & Exposition. https://strategy.asee.org/43132

Sarder, M. (2013). *Designing STEM Curriculum for K12 Students.* 2013 ASEE Annual Conference & Exposition. Atlanta GA. http://dx.doi.org/10.18260/1-2--19395

Subramanian, R., & Clark, S. (2016). *The partnership of University, Industry and K-12 Schools to improve awareness of STEM fields.* 2016 ASEE Mid-Atlantic Section Conference. https://www.hofstra.edu/pdf/academics/colleges/seas/asee-fall-2016/asee-midatlantic-f2016-subramanian.pdf

Abbreviations and Acronyms

ACRONYM	DEFINITION
AAR	Association of American Railroads
AASHTO	American Association of State Highway and Transportation Officials
APTA	American Public Transportation Association
AREMA	American Railway Engineering and Maintenance-of-Way Association
ASCE	American Society of Civil Engineers
ASEE	American Society of Engineering Education
CAD	Computer-Aided Drafting
DOT	Department of Transportation
HSR	High-Speed Rail
REES	Railway Engineering Education Symposium
STEM	Science, Technology, Math, and Engineering
UTC	University Transportation Center