EPIC ENGINEERS

HS2

ARE YOU EPIC?

TEACHERS' GUIDE

The HS2 Secondary School Programme supports secondary students aged 11-14 years in developing their knowledge and skills in Science, Technology, Engineering and Maths (STEM), with real world examples from the railway and transport infrastructure industries.

These resources support teachers to deliver high quality and effective learning activities around the theme of careers in transport infrastructure. This suite of resources is based on the secondary education STEM workshops delivered by HS2 along the route between London, Birmingham, Leeds and Manchester. You can select to use some of the materials or modify them to meet the learning objectives in your classroom.

The objectives of the programme are to help students:

- Describe the STEM careers available in transport infrastructure.
- Describe the skills useful in a STEM working environment.
- Understand how railway infrastructure is developed to satisfy present and future needs.

How to use these materials

The materials are designed to be used in a flexible way. You may want to run these activities as a complete day-long event, or run some activities as part of other lessons.

These resources have been written to include five learning activities. The first sets the scene for all the activities, providing a wider context for the design and engineering involved in railway construction, and the final activity prompts reflection on what has been learned.

If the learning activities are spread over several lessons, it may be suitable for you to run activities one and five at the start and the end of each of those other activities to introduce them and consolidate key learning points at the end.

Each learning activity is outlined in this document, including:

- Suggested timing
- Overview
- Details of activities
- Assets

In some cases, the assets may need some preparation. There may be alternative options for these depending on time and budget.

There are also slide decks with presenters' notes available to provide a structure to the activities. The notes offer additional guidance as to the use of the slides.

Curriculum links

Maths

KS3

Students should learn to:

- Select and use appropriate calculation strategies to solve increasingly complex problems.
- Extend and formalise their knowledge of ratio and proportion in working with measures and geometry, and in formulating proportional relations algebraically.
- Make and test conjectures about patterns and relationships; look for proofs or counter-examples.
- Begin to reason deductively in geometry, number and algebra, including using geometrical constructions.
- Develop their mathematical knowledge, in part through solving problems and evaluating the outcomes, including multi-step problems.
- Select appropriate concepts, methods and techniques to apply to unfamiliar and non-routine problems.

KS4

Students should learn to:

- Apply appropriate reasoning strategies and degrees of accuracy to increasingly complex problems.
- Use technology to represent and interpret functions.
- Increasingly evaluate situations based on the underlying mathematical properties rather than on surface features.
- Develop mathematical knowledge, in part through problem solving and evaluating the outcomes.

Science

KS3

Working scientifically

Students should learn to:

- Evaluate risks.
- Use appropriate techniques, apparatus, and materials during fieldwork and laboratory work, paying attention to health and safety.
- Make and record observations and measurements using a range of methods for different investigations; and evaluate the reliability of methods and suggest possible improvements.
- Interpret observations and data, including identifying patterns and using observations, measurements and data to draw conclusions.
- Identify further questions arising from their results.

Forces

Students should learn about:

- Forces: associated with deforming objects; stretching and squashing – springs; with rubbing and friction between surfaces, with pushing things out of the way; resistance to motion of air and water.
- Forces measured in newtons, measurements of stretch or compression as force is changed.

KS4

Students should learn to:

- Plan experiments to make observations, test hypotheses or explore phenomena.
- Apply a knowledge of techniques, apparatus, and materials to select those appropriate to the experiment and use them appropriately, having due regard to health and safety considerations.
- Apply a knowledge of sampling techniques to ensure any samples collected are representative of the whole population.

- Make and record observations and measurements using a range of methods.
- Apply the cycle of collecting, presenting and analysing data, including interpret observations and data, including identifying patterns and trends, make inferences and draw conclusions.

Technology

KS3

Design

Students should learn to:

- Develop specifications to inform the design of innovative, functional, appealing products that respond to needs in a variety of situations.
- Use a variety of approaches [for example, biomimicry and user-centred design], to generate creative ideas and avoid stereotypical responses.
- Develop and communicate design ideas using annotated sketches, detailed plans, 3-D and mathematical modelling, oral and digital presentations and computer-based tools.

Evaluate

Students should learn to:

- Analyse the work of past and present professionals and others to develop and broaden their understanding.
- Investigate new and emerging technologies.
- Test, evaluate and refine their ideas and products against a specification, taking into account the views of intended users and other interested groups.
- Understand developments in design and technology, its impact on individuals, society and the environment, and the responsibilities of designers, engineers and technologists.

Technical knowledge

Students should learn to:

- Understand and use the properties of materials and the performance of structural elements to achieve functioning solutions
- Understand how more advanced mechanical systems used in their products enable changes in movement and force.

KS4

Students should learn to:

- Understand that all design and technological practice takes place within contexts which inform outcomes.
- Investigate factors, such as environmental, social and economic challenges, in order to identify opportunities and constraints that influence the processes of designing and making.
- Explore and develop their ideas, testing, critically analysing and evaluating their work in order to inform and refine their design decisions thus achieving improved outcomes.
- Use different design strategies, such as collaboration, user-centred design and systems thinking, to generate initial ideas and avoid design fixation.
- Develop, communicate, record and justify design ideas, applying suitable techniques, for example: formal and informal 2D and 3D drawing; system and schematic diagrams; annotated sketches; exploded diagrams; models; presentations; written notes; working drawings; schedules; audio and visual recordings; mathematical modelling; computer-based tools.

Using the HS2 Project for students to gain CREST Awards

You can use these resources to support students in working towards CREST Awards. The Bronze, Silver and Gold Awards require more hours than the duration of the HS2 sessions, encouraging students to partake in self-initiated projects. The sessions may provide a starting point and can stimulate and enthuse students into starting projects they subsequently follow up.

These Awards recognise the development of skills that are closely aligned with the *STEMPowers* in the resources. The CREST Discovery Award requires students to demonstrate skills including problem solving, self-management, organisation, teamwork, and communication. By using the full suite of HS2 sessions (incorporating maths, design and technology and science), it would then be possible to enter students for an Award. To reward, you should confirm on your CREST account that each student has:

- Completed around 5 hours of work.
- Made a positive contribution to their team effort.
- Reflected on their learning using a CREST Discovery Passport.

Below is a more detailed table for assessing Discovery Awards.

	Discovery
Self-management	Students demonstrate readiness to accept responsibility; flexibility; effective time management; motivation to improve own performance; confidence when tackling tasks. Students describe their plan for how to complete the project and why they chose that approach e.g. division of tasks according to skills in the team.
Teamworking	Students are set a challenge and demonstrate that they can break down their overall aim into smaller tasks, with support where necessary, recording this in their CREST Passport. Students respect each other's work and views; working collaboratively; negotiating/ persuading; contributing positively to discussions.
Problem solving	Students apply creative (imaginative) approaches in developing solutions.
Research	Students acquire new knowledge relevant to the task and apply it appropriately. Students identify some different approaches to completing the project before selecting one.
Communication	Students follow written and verbal instructions (the brief); talking and listening to other team members; producing a structured presentation which relates to the original brief and which reflects the creativity applied by the group during the day.
Reflective practice	Students demonstrate the ability to recognise: what knowledge and skills have been gained; where they could have worked more effectively; where they achieved/exceeded expectations.

For more information or to register interest, go to: **help.crestawards.org/portal/home**

Classroom Activity 1 – approx. duration 30 mins

Welcome to the Team

Purpose: Students self-examine and reflect on their skills and attributes and understand how these can be used as *STEMPowers*.

Activity overview: The HS2 introduction film provides an overview of the diversity of job roles on the HS2 Project. Students learn about transport infrastructure careers and gain wider context of the Project.

Detail of activity:

After introducing the HS2 Project using the film, you should explain the purpose of the activities to the students. Ask them to discuss and reflect on their *STEMPowers* to identify and explore employability behaviours and skills. They should rate and give examples of when they have used them. The seven *STEMPowers* are:

- Creativity
- Teamwork
- Communication
- Problem solving
- Investigation
- Determination
- Respect

Ask students to consider which of these they feel they have and which they would like to improve.

Assets:

- HS2 film
- Welcome to the Team slide deck
- Welcome to the Team worksheet

Classroom Activity 2 – approx. duration 1 hr

Joining the Team: Stations of the Future

Purpose: Students assume STEM career roles and create aspects of a proposal for a station of the future.

Activity overview: Students develop and present ideas for a station of the future, discussing, exploring and planning what it might look like.

Detail of activity:

In this session, each student must assume the role of one of four STEM careers. The careers identified and provided are:

- Civil Engineer
- Customer Experience (CX) Designer
- Environmental Advisor
- Building Information Modelling (BIM) Technician

Brief students on each role using the job descriptions sheet provided. They can either choose roles themselves or you can allocate roles. There will need to be a balance within each team.

STEM career	Nature of role
Civil Engineer	Civil Engineers are creative problem solvers. They design and construct tunnels, bridges, airports, stations and motorways, taking responsibility for the use of materials and building structures.
Environmental Advisor	Respecting wildlife, sustainability and the environment, Environmental Advisors investigate and minimise the impact of engineering projects on the natural environment.
Building Information Modelling (BIM) Technician	BIM Technicians are great communicators, bringing information from different teams to life through drawings and models.
Customer Experience (CX) Designer	From the interior design to how customers purchase their tickets, Customer Experience Designers are dynamic trend spotters who ensure that stations keep up with the latest trends and work well for everybody.

Ask students to create a design proposal. They should develop initial ideas within their team, paying particular notice to their roles and ensuring they have explored their aspects of the project.

You should then instruct students to develop a presentation. The prime function of this is to help communicate their ideas to others, so it needs to do this effectively.

Emphasise to students that the idea is not to simply replicate what stations are like at present, but rather to explore new aspects and features. Possibilities include:

- Automation and digitisation
- Changing mobility patterns
- Digital communication
- Sustainable architecture
- Leisure and food

Ask students to evaluate their proposal, consider their personal contribution to the work of the team, and identify which attributes they have developed.

Assets:

- Stations of the Future slide deck
- Joining the EPIC Team worksheet
- Job descriptions sheet
- Materials to develop and present design proposals

Classroom Activity 3 – approx. duration 1 hr 40 mins

Engineering Challenge: Tunnel Structures

Purpose: Students apply their *STEMPowers* to solve real-world design and make problems.

Activity overview: This activity is about tunnel building. Students build a train tunnel structure and test its stability with a sandbag, undertaking a full design and make challenge, exploring design and modelling and its effect on modern engineering practice.

Encourage students to take on the roles identified on the job descriptions sheet and collaborate through an iterative design process to design and construct a scale model of an element of rail infrastructure. You should also judge their innovation, collaboration and technical skills. Students should then evaluate their designs, learning and STEM career skills.

Materials used should be recyclable or reused, and tunnel structure models should be modest in size and resource usage. Students should not use trial and error but a guided design process, with room for variation and approach to outcomes informed not just by STEM knowledge but their wider transferable skills as *STEMPowers*.

Detail of activity:

Brief the students on tunnel structures using the slide deck. In their groups, students should use a selection of scrap materials to build a structure able to withstand ground pressure in a simulation jig.

Students should plan and build their proposals for destructive testing on a central testing rig, using a sandbag to mimic the ground pressure.

Encourage students to use all of the *STEMPowers* in this challenge, especially investigation, teamwork and problem solving. You should commend them for different aspects of their contribution according to these powers.

Advise students to take varied but informed design approaches, considering different types of structure to resist the forces of compression and tension acting upon their tunnel using different types of material.

Students should compare the different kinds of prototyping, assessing the advantages and disadvantages of each as a plenary, as well as reflecting upon the success or failure of their own design solution and their use of *STEMPowers*.

The first challenge is to consider the forces a tunnel structure has to withstand and to start developing ideas about the kind of structure that might be best.

The second challenge is to develop this design using an isometric grid into a prototype structure. Students should consider weight as well as strength. Feedback on their efforts should focus upon the attributes of investigation, teamwork and problem solving.

The third challenge is to reflect upon the test results. Students should consider how well their structure did, how it could be improved, what the challenges were and how sustainable their solution was. Individuals should also consider their personal development.

Assets:

- Tunnel Structures slide deck
- Engineering Challenge worksheet
- Job descriptions sheet
- Testing jig (i.e. a box with holes at each end), sandbag (or another way of applying weight) and scrap materials:
  - 40 x 400mm paper straws
  - Scissors
  - Masking tape
  - Scrap paper

Classroom Activity 4 – approx. duration 1 hr

Rail Rush! Board Game

Purpose: Students apply their understanding of *STEMPowers* to grow and manage a rail network.

Activity overview: Exploring the issues of costs, construction, sustainability, community and technical developments, students partake in a multi-player board game, using skills to build competing high speed rail routes, hubs and terminals, connecting with the wider transport infrastructure networks. Students must use their *STEMPowers* and the information learned to make strategic, ethical and cost decisions, working in collaboration to make the best network for Britain.

Detail of activity:

Rail Rush! is a turn-based board game activity for two to four players. To play, each player competes to build the best rail network, balancing their responsibilities as service providers between expanding their service as well as meeting the needs of the environment and local communities.

The aim of the game is to be the player who has collected the most points whilst growing their rail network.

The downloadable and printable game components will consist of:

- 1 x game board (in 4 A4 sections, to make up A2 map)
- 1 x deck of game cards, consisting of community, environment, service, construction and rule cards
- Printable sets of counters and track lozenges in four player colours
- Rail Rush! worksheet with scorecard and rules

Game board: A map of Great Britain with cities separated by rail marker templates. Airports and ports are also shown to highlight key destinations. Template areas for in-play action cards are included, as well as templates for community, environment, service and construction cards.

Counters and track: Alternatively, students can use drywipe markers in four colours on a laminated board. This will make stock easier to maintain and replace.

Each player will need:		
6 x station discs	15 x track lozenges	1 x scorecard

How to set up:

- Separate the game cards into community, service, environment and construction decks. The rule cards should be distributed and hidden in each of these decks. Place each deck face down on its marked position. Each player chooses one coloured set of counters. The youngest player goes first.

Playing the game:

- Each player starts the game by placing their two starting stations anywhere on the board, along with two lengths of track. Starting stations may be built anywhere there is a station circle. These stations are the start of players' lines. Tracks and additional stations must join to one of these starting stations.
- For each turn, players choose to take the number of cards from the decks equalling their number of stations (e.g. a player with two stations may take two cards per turn). Players can take any combination of cards from the community, service, environment or construction decks. There are points to be gained on these cards.
- Each player must read their cards out to the team, state and record any points that they have earned, or build track or stations if their cards instruct them to.

How to win:

- The game ends when the first player has used all of their track. At the end of the game, the player with the most points wins the game.
- Point scores are a combination of each player's community, service and environment points, as well as the points players earned for building track and any bonus points available.

How to get bonus points:

- Players can win bonus points by following the instructions on the rule cards, which appear at random in the other decks. These will change the rules of the game, and are placed on one of the three rule card positions on the board. The player who picks a fourth rule card must replace one of the rule cards already in play.

Examples of rule cards include:

- Bonus points for having stations on ports or airports.
- Bonus points for having the longest continuous track.
- Restricted building on national parks.

Players should use the scorecards in the worksheets to keep track of their points throughout the game. Players can earn a maximum of 5 service, community, and environment points and may build up to 15 tracks, worth one point each. Stations do not win any points.

Assets:

- Rail Rush! slide deck
- Rail Rush! worksheet with scorecard and rules
- Game board and associated assets:
  - Game cards
  - Counters
  - Track lozenges

Classroom Activity 5 – approx. duration 15 mins

Reflection

Purpose: Students reflect on how their *STEMPowers* have grown and decide on the next steps for a STEM career.

Activity overview: Ask students 'What have you learned?' and challenge them to evaluate and reflect on their progress, identify new skills learned and consider how they could embark on a STEM career. This activity will link to the 'Welcome to the Team' session and the development of students' *STEMPowers*, as they connect skills learned to career pathways.

The reflection worksheet asks students to:

- Consider the *STEMPowers* they have improved.
- Consider the *STEMPowers* they found most important.
- Think about whether they would consider a future in a STEM career.
- Identify particular progress.

Assets:

- Reflection slide deck
- Reflection worksheet