Royal Academy of Engineering

Employer Engagement Challenge

Payload

How can coding support front line medical supplies to those in need?

Ariennir gan Lywodraeth Cymru
Funded by Welsh Government

THIS IS ENGINEERING

Pupil comments

"I know more about coding now and used CAD to create a design for our robot car."

"I didn't know much about engineering before the project, but it is actually a lot more fun than I thought."

Teacher comments

"The pupils enjoyed and engaged with the challenge and learnt about perseverance and the value of a failure to then change a design to get it to work."

"The pupils had insight into a real-world engineering challenge and were able to experience a range of STEM-based skills to complete the task."

Employer comment

"It's been great to support schools to embed engineering skills and see the confidence of the students grow as they participate in each activity."

Acknowledgements

The Royal Academy of Engineering thank Tredegar Comprehensive School and General Dynamics for developing this challenge resource.

They have helped to raise awareness of engineering among young people, improve STEM teaching in schools and created new career opportunities for STEM learners.

General Dynamics

General Dynamics is a multinational company that develops cutting-edge defence and security solutions for the UK Armed Forces and the Ministry of Defence.

One of its major projects in Wales is the production of the AJAX armoured vehicle, which plays an important role in safeguarding the UK and supporting operations in emergency response missions.

The challenge

Autonomous vehicles are increasingly being used in disaster response missions because they can be deployed in hazardous environments, reducing the risk to life. They can navigate through challenging terrains and obstacles that might be difficult for traditional vehicles to overcome, collecting valuable data about disaster-affected areas along the way.

This challenge asks students to collaborate in teams to design, build and program an autonomous vehicle capable of delivering front-line medical supplies (the payload) promptly, safely and intact. Students will need to construct the vehicle and a container to carry the emergency medical supplies, intended for delivery to a pre-set destination where the victims of the natural disaster are located.

Prior to deployment, the autonomous vehicle will undergo several tests by navigating its way through inhospitable landscapes, overcoming multiple obstacles along the route before delivering much-needed medical supplies. The medical supplies will be secured to the vehicle in a container and will need to return to the depot to collect more supplies for the next mission.

This challenge is designed to support practitioners to follow Curriculum for Wales' careers and work-related experience guidance. It is supported by a set of videos that give an inside look at how engineers at General Dynamic work, and introduces first-hand how the challenge is delivered in school.

The challenge is recommended for secondary school pupils and can be adjusted to match different age groups and abilities.

Here are some of the learning opportunities that the challenge provides:

- **Collaborative teamwork**
- **Problem finding and solving**
- **Programming and physical computing**
- **Design and building**
- **Environment and social considerations**

Challenge overview

Setting the class challenge

Design, build and program an autonomous vehicle engineered to deliver essential front-line medical supplies (the payload).

Welcome to Operation Payload! Your mission is to build a cutting-edge autonomous vehicle equipped to tackle the most challenging of terrains, and safely and swiftly transport essential medical supplies to those affected by adversity in the midst of a natural disaster.

Your vehicle will carry a specially designed container with life-saving emergency medical supplies. These supplies are to be delivered to

a predetermined drop-off point located in the disaster area. Your vehicle's success in delivering aid hinges on its ability to overcome obstacles that conventional vehicles would find difficult to navigate.

After drop-off, your vehicle must return to the designated depot. There, it will reload with additional medical supplies, preparing for future missions.

By participating in this challenge, young learners will develop the skills and practices that engineers use every day in their professional lives.

Asking questions, imagining and planning ideas, creating and refining outcomes, while continuously reflecting on how things could be improved, are all 'Engineering Habits of Mind' as demonstrated in 'the Progressing to be an Engineer' cycle.

The Progressing to be an Engineer cycle

Learning opportunities	Core skills
■ Collaborative teamwork ■ Problem finding and solving ■ Programming and physical computing ■ Design and building ■ Environment and social considerations	**Literacy:** Reading and technical vocabulary. Selective research. Writing and reporting. Presenting and communication. **Numeracy:** Data collection and analysis. Pattern spotting. Measurements and calculation. **Scientific:** Problem-solving and experimenting. Visual and special awareness. **Technical:** Systems thinking and problem-solving. Communication and teamwork.

Engineering design process		Activity	Success will look like
0–1 hour	Research the challenge	**Watch the challenge videos** – engineers films	Understand the aims and requirements of the challenge, as well as how engineering concepts relate to it. Gather relevant information and have a clear and comprehensive understanding of the challenge.
1–2 hours	Ask	**Time to problem solve and calculate** – budgeting for medical supplies **Time to present** – budget proposal **Time to question** – systems thinking	Identify problems and ask questions to understand how to resolve them. Explain how systems work while identifying ways they can be improved.
2–6 hours	Imagine Plan Create	**Time to imagine, plan and create** 1. Introduction and kit familiarisation 2. Building the chassis and container 3. Programming fundamentals 4. Obstacle avoidance 5. Autonomous navigation 6. Pay load handling 7. Final testing and refinement 8. Demonstration	Understand the basic components of the robotics kit, such as sensors and micro-controllers, and how these components work together to build a robot. Write simple programs using the programming language chosen for the project and understand basic programming concepts like variables, loops and conditional statements. Use knowledge of how systems and components work and interact to create a product that achieves a specific purpose. Evaluate the product's fitness for purpose and look to find ways to refine this based on observation and improvement.
6–7 hours	Improve	**Time to reflect** – on experiences in relation to each stage of the challenge	Test the outcome for quality using a logical approach gathering evidence to make an informed decision. Evaluate how the product is working, identifying areas for improvement and describe possible changes that can enhance the design.
7–8 hours	Present the challenge	**Time to present** – highlight the success of the challenge	Communicate ideas effectively and with confidence, making complex concepts understandable to the audience. Engaging interactions and making a lasting impression.

Research the challenge

Ask

Imagine

Plan

Create

Improve

Present the challenge

Time to start

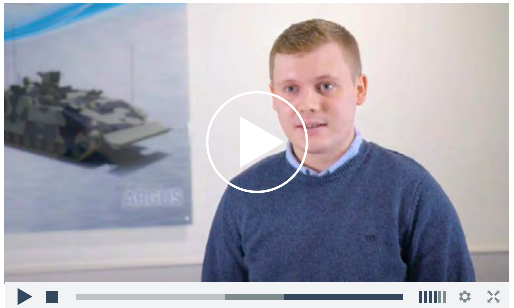
Begin by showing the class the set of three engineer videos that showcase the diverse range of engineering roles within the company. Each video is approximately three minutes long.

Go to **raeng.org.uk/wvep** or scan the QR code to watch the videos.

Jonathan: Software engineer

Olivia: Engineer apprentice

Rob: Graduate engineer



Time to calculate

The aim of this first activity is to allocate a budget or medical supplies intended for delivery to a disaster response area.

Begin by explaining that a major landslide has occurred, isolating individuals within a remote rural area. Roads and bridges have become impassable, while adverse weather conditions mean an airdrop is not possible.

Residents need medical supplies to help those affected by the landslide. The only way to deliver these essential provisions is through the deployment of an autonomous vehicle. This approach ensures the safety of those involved in the mission and eliminates the risk to their lives.

Coordinating efforts in a flood defence zone


University of Chichester

Time to problem solve

Divide students into teams of three or four and give them a list of medical items.

Each team has a total budget of £150 allocated for buying medical supplies. It is estimated that there are currently 20 people with various unknown injuries.

Teams must decide which items to buy and how much to spend on each. Multiple items can be bought, but teams cannot go over budget. Record the number of items and costs on a spreadsheet.

	Medical items	Cost
1	x1 Blood pressure monitor	**£10.00**
2	x1 Burn care kit	**£10.00**
3	x1 First aid kit	**£5.00**
4	x1 Hygiene product pack	**£2.00**
5	x1 Medication pack	**£5.00**
6	x1 Medical instruments pack	**£7.50**
7	x1 Mobile phone	**£15.00**
8	x1 Personal protective clothing	**£1.00**
9	x1 Respirator kit	**£20.00**
10	x1 Wound care kit	**£7.50**

Time to present

Ask each team to present their budget proposal to the class, explaining the reasoning behind the prioritising and allocation of funds based on necessity and impact.

Emphasise the importance of involving each team member in some aspect of the presentation.

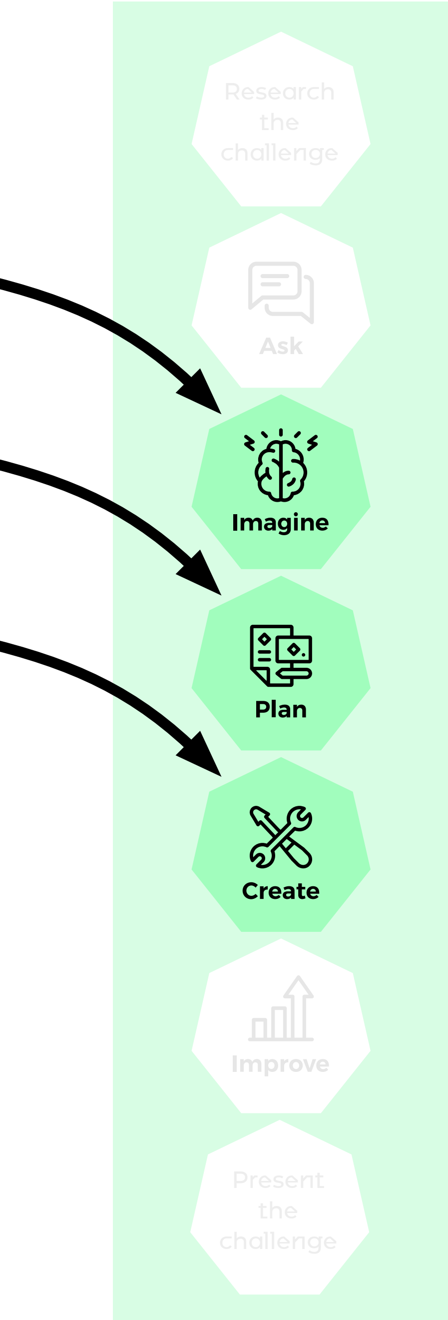
Time to question

Systems thinking is “explaining how things work together and why each part is there”.

The questions below encourage students to think about the design and programming of the autonomous vehicle, considering its various components, interactions and implications.

Discuss these questions as a group and facilitate the conversations in class.

	Systems thinking questions
1	How might the design of the autonomous vehicle affect its ability to navigate challenging terrains?
2	How might the design of the medical supply container influence the vehicle's overall performance?
3	What might happen if the vehicle's programming encounters an unexpected obstacle and doesn't know how to handle it?
4	How could the vehicle be designed to adapt to unexpected changes in the disaster environment and still complete its mission successfully?
5	What could be the environmental, social and economic consequences of widespread use of autonomous vehicles?



Time to question

The aim of this activity is to gain hands-on experience in building and programming an autonomous vehicle for a disaster response mission.

Students will learn about robotics, programming, problem-solving, teamwork and the real-world applications of technology in emergency situations.

It is recommended that this stage of the challenge be supported by a member of staff from the IT or computing department.

1. Introduction and kit familiarisation

1.1 Setting the scene – ‘Operation Payload’. Introduction of the disaster response programming challenge and robot kit.

1.2 Divide the class into teams of three or four students and designate roles and responsibility within the team.

1.3 Each team familiarises themselves with the 2WD Robot Smart Car Chassis DIY Kit components.

2. Building the chassis and container

2.1 Teams assemble their robot chassis with step-by-step guidance from the teacher.

2.2 Introduction to the container design for carrying medical supplies: size, material and attachment mechanism.

2.3 Teams brainstorm ideas for their container designs.

2.4 Each group presents their design and justifies their choices.

3. Programming fundamentals

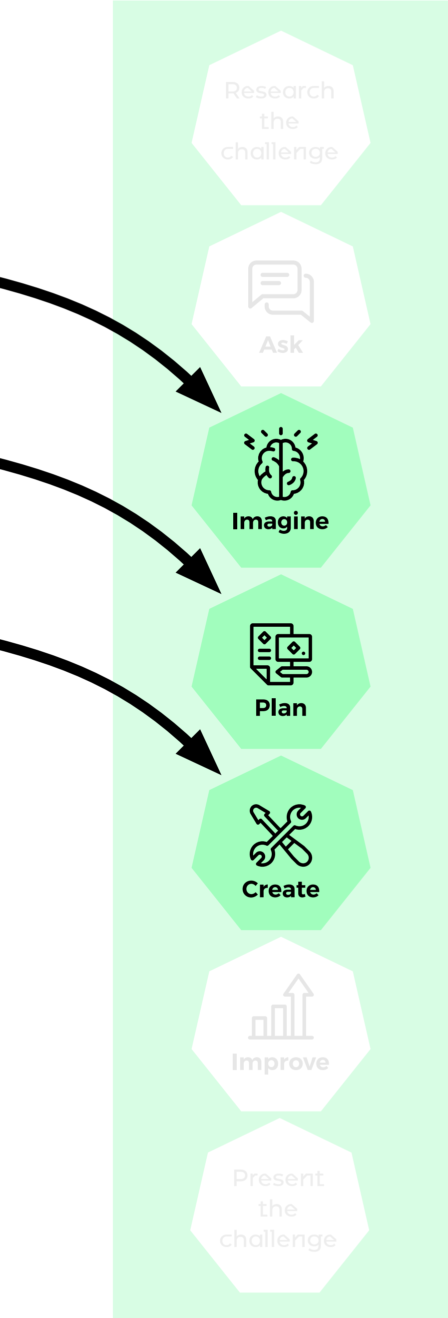
3.1 Introduction to programming and its role in autonomous vehicles.

3.2 Explanation of basic programming concepts: commands, loops and conditions.

3.3 Hands-on practice with block-based programming tools suitable for beginners.

3.4 Writing a simple program to make the robot move forward and turn.

1 **2WD Robot Smart Car Chassis DIY Kits**



4. Obstacle avoidance

4.1 Introduction to sensors (ultrasonic sensors) and their role in navigating around obstacles.

4.2 Explanation of the concept of conditional statements for decision-making when avoiding obstacles.

4.3 Guided practice: writing a program for obstacle detection and avoidance.

4.4 Testing the robot's obstacle avoidance capabilities in a controlled environment.

5. Autonomous navigation

5.1 Introduction to mapping and pathfinding concepts to navigate the robot autonomously.

5.2 Hands-on practice: Writing a program to follow a predefined path.

5.3 Team activity: creating a basic map of the disaster scenario and planning routes.

5.4 Testing the robot's ability to follow the programmed path accurately.

6. Payload handling

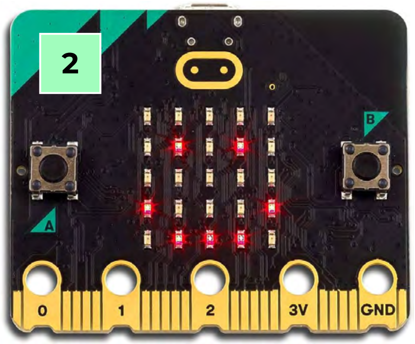
6.1 Introduction to the concept of payload and how to attach and detach the container carrying medical supplies.

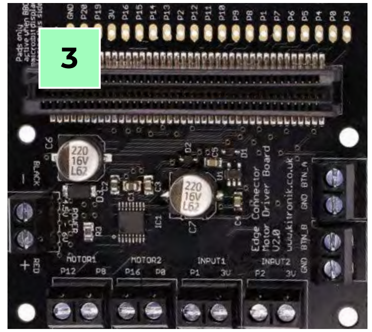
6.2 Discussion on payload stability during movement.

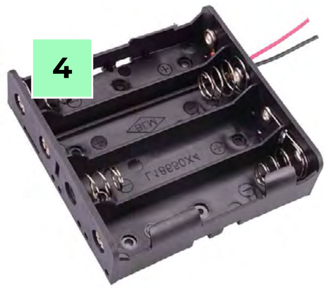
6.3 Guided practice: programming the robot to pick up and drop off the container.

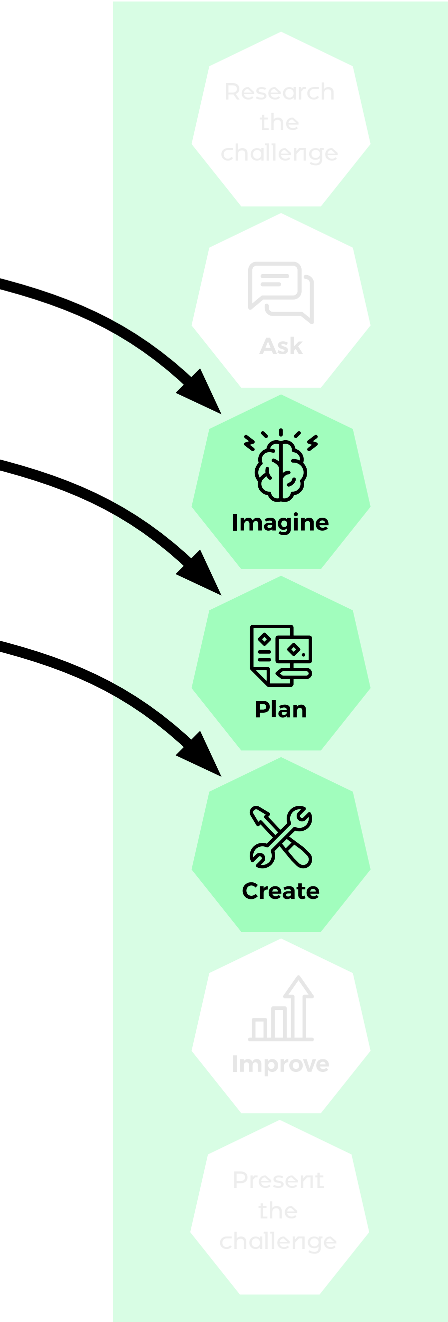
6.4 Multiple trial runs to ensure the container's stability during movement.

Materials based on a class size of 30 students	
1	x7 2WD Robot Smart Car Chassis DIY Kits
2	x7 Micro:Bit V2
3	x7 Motor Driver Board V2 for the BBC Micro:Bit
4	x7 5V Battery holder
5	x7 Ultrasonic distance sensor
6	x1 Dupont cables (pack of 120)
7	x7 Micro USB cables









7. Final testing and refinement

7.1 Full-system integration: combining obstacle avoidance, navigation and payload handling to test the complete system and make necessary adjustments.

7.2 Multiple test runs on a mock disaster scenario map.

7.3 Identifying issues and refining the programming for smoother operation, through teamwork and collaboration to solve challenges together.

The obstacle course

The obstacle course is a 3 x 3 metre grid, containing 10 x 30 cm squares in each direction.

This can be created easily with masking tape on a smooth surface rather than a carpeted area or outside on rough tarmac.

During the trial runs, students can use this area to gauge distance travelled before recalibrating and refining.

Note: to use the bridge, the robot will need to stop at the gate for five seconds before moving across. This will provide the opportunity to use the sensors to stop the vehicle.

8. Demonstration

8.1 Final autonomous vehicle demonstration by each group.

8.2 Peer evaluations: students assess other groups' vehicles based on functionality and creativity.

8.3 Reflective discussion on what they've learned about robotics, programming and teamwork.

Teachers: pplease note that alternative robot kits with supporting software and hardware are available for use with this challenge and work equally as effectively.

	D								
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		b					o		
		b					o		
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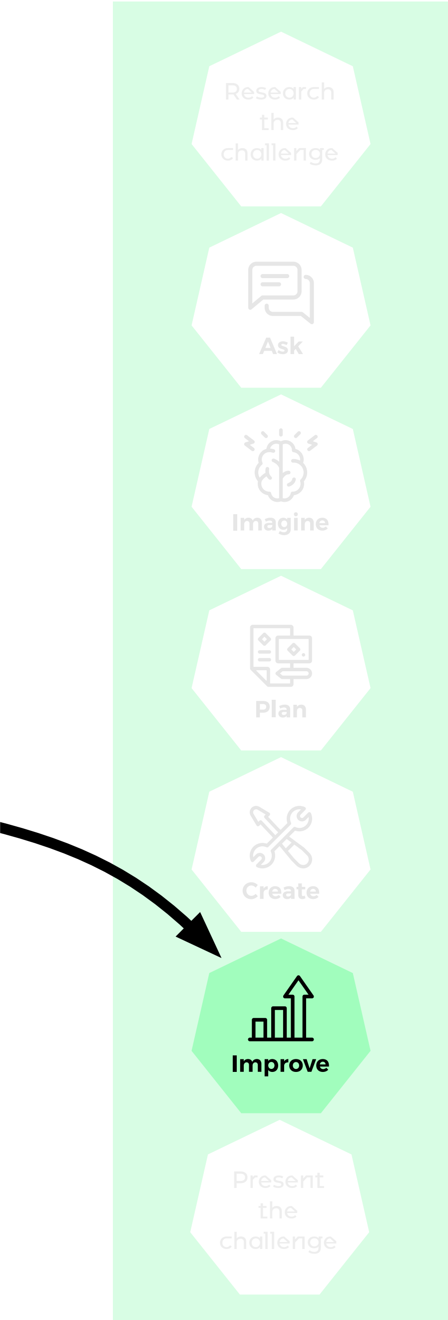
								X	

Key

Red – Obstacles
B – Draw bridge
D – Depot start/end point
X – Destination point



Time to reflect

Success can be based on the skills students develop and the practices they acquire throughout each stage of the challenge.

These include the ability to ask questions, imagine and plan ideas, create and refine outcomes, while continuously reflecting on how things could be improved.

Engineers also demonstrate the following practices as part of their day-to-day activities.

- Problem finding and creative problem-solving
- Systems thinking and visualising
- Adapting and improving
- Teamwork and collaboration
- Project and time management

At the end of the challenge, gather teams for a post-challenge debrief.

Encourage them to reflect on their experiences and assess their personal growth in relation to the skills they have developed and practised throughout the challenge.

Research the challenge

Ask

Imagine

Plan

Create

Improve

Present the challenge

Present the challenge

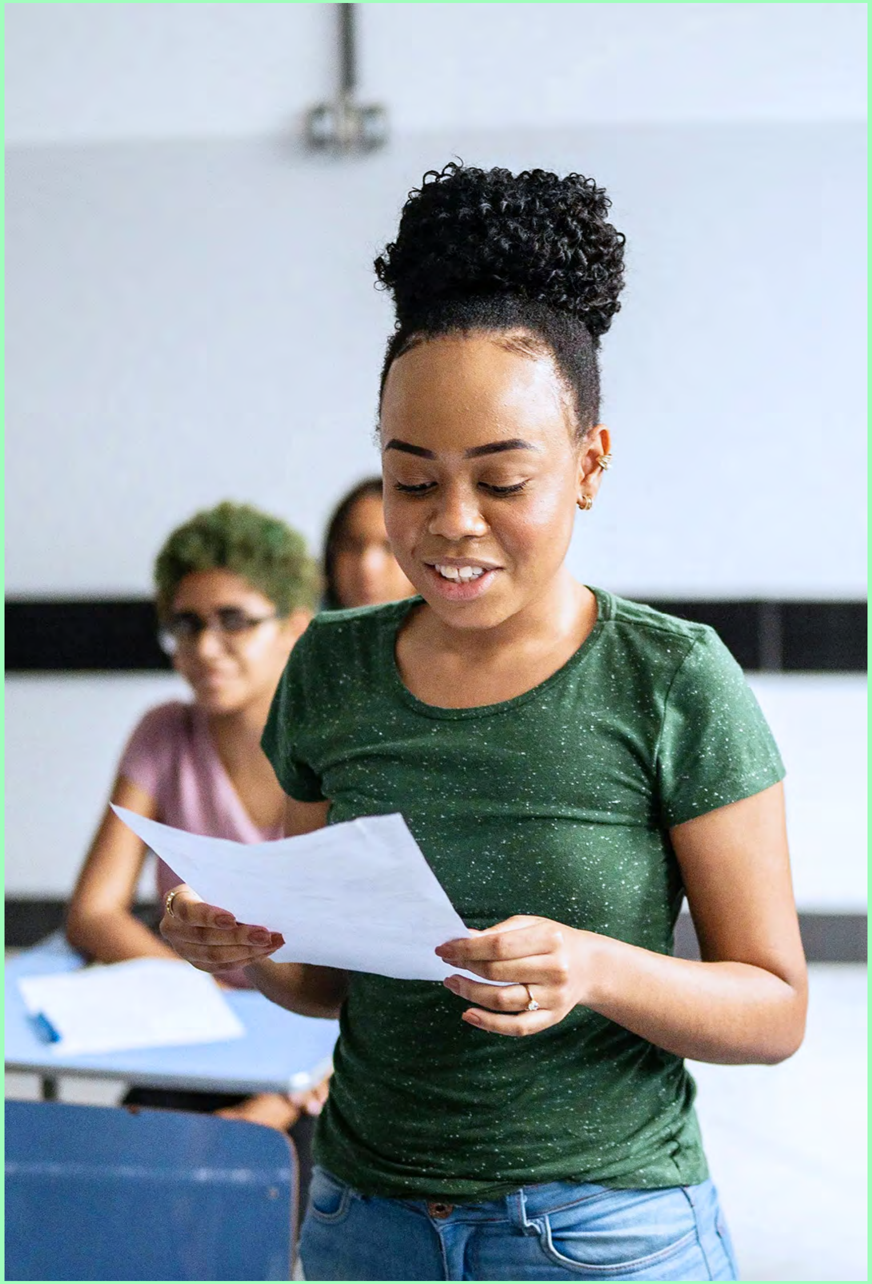
Time to present

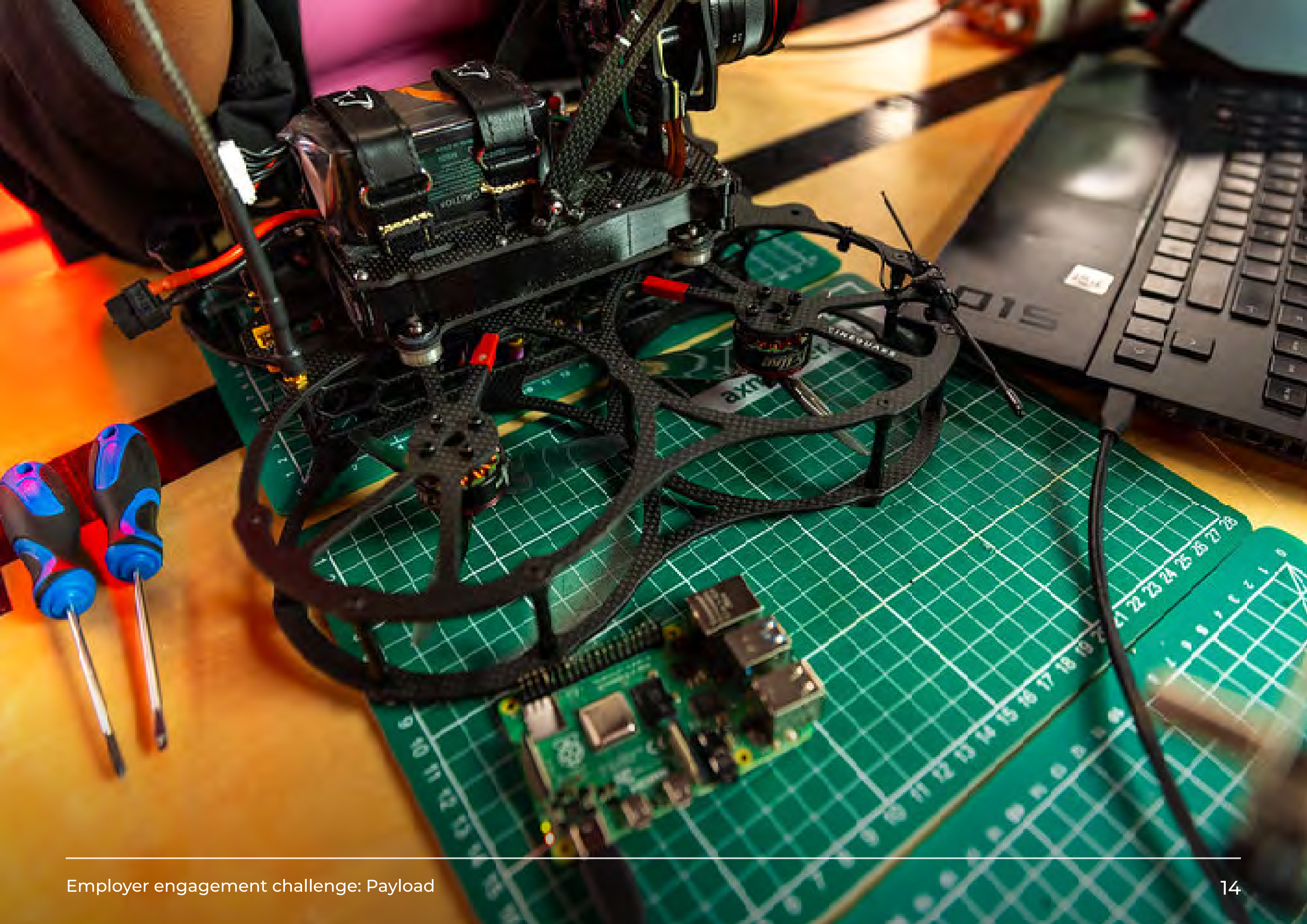
The aim of this final activity is to present outcomes, explain choices throughout the challenge and highlight what went well and what could be improved.

This should be a group task where every member of the team contributes to the presentation in some way.

The presentation can be divided into the following sections:

1. A summary of the final outcome and its features.
2. What went well during the build and programming process.
3. What challenges they faced and how they overcame these.
4. How the outcome could be improved or enhanced.





Royal Academy of Engineering

The Royal Academy of Engineering is harnessing the power of engineering to build a sustainable society and an inclusive economy that works for everyone.

In collaboration with our Fellows and partners, we're growing talent and developing skills for the future, driving innovation and building global partnerships, and influencing policy and engaging the public.

Together we're working to tackle the greatest challenges of our age.

What we do

Talent & diversity

We're growing talent by training, supporting, mentoring and funding the most talented and creative researchers, innovators and leaders from across the engineering profession.

We're developing skills for the future by identifying the challenges of an ever-changing world and developing the skills and approaches we need to build a resilient and diverse engineering profession.

Innovation

We're driving innovation by investing in some of the country's most creative and exciting engineering ideas and businesses.

We're building global partnerships that bring the world's best engineers from industry, entrepreneurship and academia together to collaborate on creative innovations that address the greatest global challenges of our age.

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We're influencing policy through the National Engineering Policy Centre – providing independent expert support to policymakers on issues of importance.

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