Royal Academy of Engineering

Employer Engagement Challenge

Bionic Barbie

Can you re-engineer the human body?

Ariennir gan Lywodraeth Cymru
Funded by Welsh Government

THIS IS ENGINEERING

Acknowledgements

The Royal Academy of Engineering thank Willowtown Community Primary School and Zimmer Biomet 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.

Pupil comments

"I now know more about the different jobs in engineering and it is interesting."

Teacher comments

"The challenge was easily integrated into the current topic that the school was doing. This flexibility created more cross-curricular links."

"The activities in this challenge embed core engineering skills, such as problem-solving, testing and retesting, plus designing and trialling."

Employer comment

"This project has helped to make the primary school children think and challenge themselves to solve an engineering problem. I have really enjoyed seeing the development of the children who start off thinking they can't do it and then succeeding"

Zimmer Biomet

Zimmer Biomet manufacture medical devices to assist individuals with issues related to their bones, muscles and ligaments.

They produce implants, robotics and materials to aid people with various conditions, including arthritis, trauma and sports injuries. Implants are artificial parts designed to replace damaged bones or joints, while their robotics assist in building artificial tendons and aid surgeons in operating on muscles and ligaments.

Zimmer Biomet invites schools to take part in the bionic Barbie challenge, an engaging and educational project aimed at exploring the world of biomedical engineering and bionic enhancements.

The aim of this challenge is to encourage teams of pupils to learn about the human body and explore the skeleton. They will gain an understanding of joint mechanics and experiment with various material enhancements suitable for use on the human body. The goal will be to design a bendable knee for Barbie, while developing their creativity and problem-solving skills.

The bionic Barbie challenge offers an exciting opportunity for pupils to discover the links between biomedical engineering, material science and human biology. Through hands-on experimentation, teamwork and ethical discussions, they will develop valuable skills that extend beyond the classroom.

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 Zimmer Biomet work, and introduces first-hand how the challenge is delivered in school.

The challenge is recommended for primary 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**
- **Creativity and design**
- **Material testing and selection**
- **Problem finding and solving**
- **Ethical and social considerations**

Challenge overview

Setting the class challenge

Welcome to the bionic Barbie challenge. Prepare to explore the world of biomechanics and bionic enhancement.

Get ready to learn how how engineering and biology are used to improve people's lives.

In this challenge, you will become real-life scientists and engineers, designing a revolutionary bendable part for Barbie or another doll that's similar.

You'll design a special part for Barbie that lets her move her legs just like humans do. Think about how your knees work when you bend and straighten your legs. We would like Barbie to be able to do the same thing. We want her to move realistically, just like real people do. That means we need to understand how our knees and ligaments work in our bodies.

During this challenge, you will learn about how our bodies work and how we can use technology to make our lives more comfortable. Plus, you'll get to see how scientists and engineers help people in the real world, like making implants for those who need them.

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
■ Real-world relevance ■ Collaboration and teamwork ■ Innovation design and making ■ Material exploration ■ Testing and analysis	**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 **Time to play** – the human skeleton **Time to investigate** – bone strength	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 find** – movement, measurements and maths **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.
2–4 hours	Imagine Plan	**Time to imagine** – design and visualise implant ideas **Time to present** – showcase design ideas to the class **Time to plan** – plan the steps to construction	Draw and label multiple design ideas, effectively communicating fitness for purpose and why certain ideas are better than others. Use simple annotated sketches to turn ideas into words and drawings. Plan a design that aims to solve a problem or task for a specific user, by transforming one idea into a better one.
4–6 hours	Create	**Time to create** – build the bionic Barbie	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 improve 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 benefits and potential drawbacks of the bionic knee parts	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

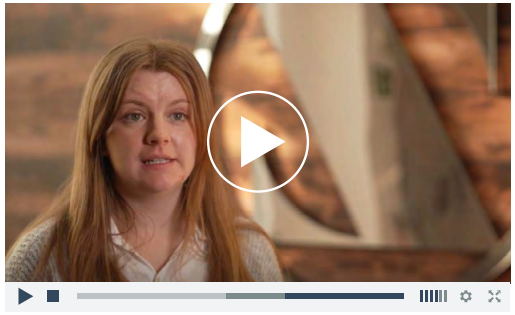
Time to start

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.

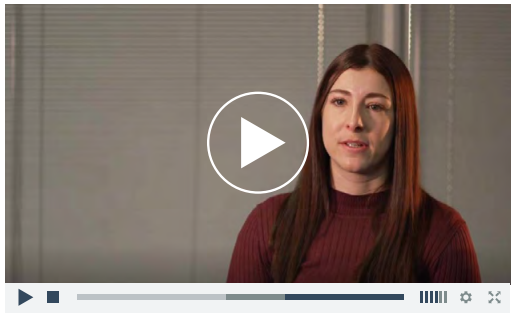
Go to **raeng.org.uk/wvep** or scan the QR code to watch the videos.

Leigh: Development engineer

Jess: Regulatory affairs specialist



Leah: Senior development engineer



Time to play

The aim of the first activity is to identify and label major parts of the human skeleton while creating a 3D model of the skeleton using card, split pins and labels.

Ask pupils to draw and cut out the major parts of the human skeleton from card. These parts will include the skull, spine (vertebrae), ribcage, arm bones, leg bones, and hand and foot bones.

Printed skeleton sheets can be used for those who prefer not to draw.

Ensure that the parts are proportionate to the size of the card, keeping in mind that the pieces will be attached with split pins to create a movable skeleton.

Once all the parts are cut out, demonstrate how to attach these using split pins at the joints, e.g. shoulders, elbows and knees.

Encourage pupils to label each part. If needed, provide pre-made labels and they can glue them onto the corresponding bones.

Materials

- White card paper (A4 size)
- Printed body or skeleton parts sheet downloaded from the internet
- Scissors and split pins
- Labels with the names of skeleton parts (optional – can be handwritten)

Time to play – *continued*

The aim of this activity is to introduce the structure and function of the spine and its importance in supporting the body.

Divide the class into small groups of two to three pupils.

Cut the string to approximately 90 centimetres long. In groups, thread the string through each cotton reel from one end to the other. Secure the cotton reels to the string at each end.

Materials

- Cotton reels and string
- Scissors, craft glue or adhesive tape
- Printed diagrams or pictures of the human spine (optional)

This mirrors the flexible movement and curvature of the spine. Facilitate a class discussion on what they have learnt.

Here are some 'systems thinking' style questions to help.

Topic titles	
1	Why do you think it's important for the spine to be bendable?
2	How can we keep our spines flexible and healthy?
3	Why is the spine important for supporting our body?
4	Can you think of any tools or structures that are like the spine in providing support?
5	Why do you think the spine has curves instead of being completely straight?

Time to investigate

The aim of this activity is to investigate the strength of bones through hands-on experimenting using sheets of rolled up newspaper.

Bones need to be strong enough to support our bodies and withstand different forces.

Divide the class into small groups and distribute sheets of newspaper.

Ask the teams to roll the sheets of paper tightly to create paper rolls of the same size. They can use glue or tape to secure the rolls.

Apply pressure to the paper roll by balancing a book or heavy weighted object on the top. Note if the roll is able to withstand the pressure or if it snaps.

Discuss what they have learnt about the strength of the paper rolls during the experiment. Guide teams to present the results to the class and have each group share their findings. Analyse factors that might have affected the strength, such as the tightness of the roll or the force applied during testing.

Help the class draw conclusions about bone strength based on the similarities between the paper roll experiment and the bones in our bodies.

Emphasise that our bones, like the paper rolls, need to be strong to support our bodies and resist different forces.

Materials

- Sheets of newspaper
- Safety scissors
- Glue or tape

Research the challenge

Ask

Imagine

Plan

Create

Improve

Present the challenge

Time to problem find

The aim of this activity is to understand the importance of limbs, their length and their role in our daily activities.

Divide the class into small groups and have them stand on one leg while attempting to open their school bags with one arm. Afterward, encourage them to discuss how it felt and the challenges they faced while performing the task using only one leg and one arm.

Connect this exercise to the concept of limb length and how it influences our capabilities. Emphasise the importance of different limb lengths and how they enable us to perform various activities effectively.

Show the class various dolls with different leg lengths, including Barbie dolls and action figures. Place the dolls on a flat surface and simulate actions like walking, sitting and reaching. Observe how the leg length might affect movements and discuss the implications.

Now, divide the class into small groups and distribute rulers. Ask each group to measure the length of the legs of different dolls and record their findings.

Gather the class together and facilitate a discussion based on their observations and measurements. Encourage them to compare the leg lengths of the dolls and explore possible reasons for variations in their movements.

Materials

- Various dolls with different leg lengths (e.g. Barbie dolls, action figures and stuffed animals)
- Rulers or measuring tapes
- School bags or backpacks

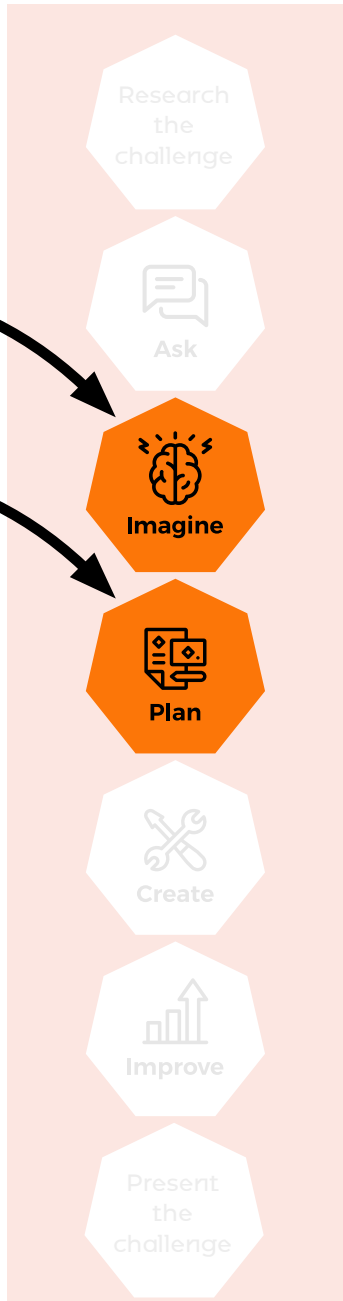
Time to question

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

Now the class has investigated the relationship between the body and implants, what questions should pupils be thinking about before they start to build their bionic Barbie?

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

Systems thinking questions	
1	How will the implant integrate with the doll's body and existing movement?
2	How might the design affect the doll's posture, balance, and overall mobility?
3	How would a implant be adjusted and adapted as a person's needs change over time?
4	Does a implant impact the person's self-esteem, body image, and emotional well-being?
5	Can the implant be recycled or disposed of responsibly at the end of its life cycle?



Time to imagine

The aim of this activity is to work together as a team to plan, visualise and present your ideas for a bionic Barbie.

Divide the class into small groups and explain that the design process goes beyond just the appearance of the implant; it also involves considering the physical and emotional needs of the person for whom it is being built.

As a team, ask pupils to draw and label several designs showing what the limb will look like and the materials it will be made from. Also, ask them to incorporate the length of the limbs into the designs based on the measurements calculated in the previous activity.

Encourage them to share ideas with each other, exploring their creativity and using colour to illustrate each design vividly.

Ask them to show how the limb will be constructed and explain its physical structure. Also, make sure they note the reasons for selecting the materials that will be used to build the bionic enhancement.

Throughout the design process, guide pupils to continuously think about how the limb will provide support and flexibility, enabling the user to move freely and comfortably.

Time to present

Allow each group to present their bionic limb design journey and assembly plans to the class.

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

Time to plan

The aim of this activity is to explore and select a range of suitable materials to construct a functional implant for Barbie.

Within the same groups, ask pupils to work collaboratively to brainstorm, plan and select the materials they would like to use for constructing their limb.

They should carefully consider the properties of each material when making their selections. For example, is it lightweight, flexible and durable as well as having load-bearing capacity.

Teams should be able to justify the reasons for their material choices, taking into account the specifics of their design ideas.

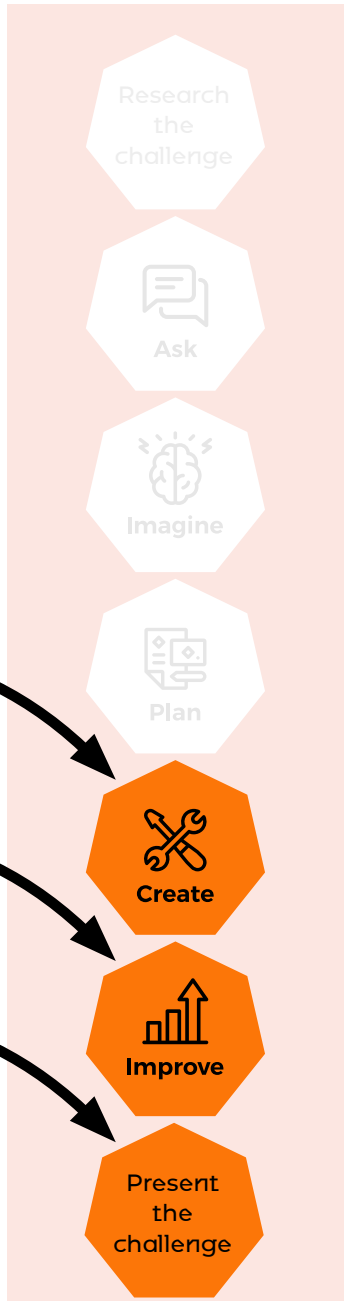
To begin the process, present two initial categories of materials from which teams can choose. Afterward, they can propose alternative or additional recycled materials that they believe will further enhance their build. Or combine the two.

Option One

- Lolly stick
- Pipe cleaners
- Ping pong ball
- Plasticine

Option Two

- Meccano
- Lego
- K'NEX
- Construction kits



Time to create

The aim of this activity is to work together to construct and build a implant for a Barbie doll using the materials selected.

Teams start constructing their implant using the materials and designs they planned for. Provide guidance and support as needed, encouraging experimentation and creativity.

At various points, ask teams to share their progress and any difficulties they faced during the build process. Discuss potential solutions and collaborative ideas for overcoming these problems.

After the construction is complete, give teams some time to test and make adjustments to their implants, if necessary.

Materials

- Various dolls with different leg lengths (e.g. Barbie dolls, action figures and stuffed animals)
- Various craft supplies (lolly sticks, pipe cleaners, balls, elastic bands and construction kits)
- Recycled materials
- Reference images of implants (optional)

Time to reflect

Success can be based on the skills pupils 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.

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.

- A summary of the final product and its features
- What went well during the design and construction process
- What challenges they faced and how they overcame them
- How could the outcome be improved or enhanced?

Presentations can also be framed using the following stages of the engineering design cycle

1. Research and material investigation
2. The design process
3. The construction and engineering process
4. Reflection on the outcome

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.

Policy & engagement

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

We're engaging the public by opening their eyes to the wonders of engineering and inspiring young people to become the next generation of engineers.

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