

BIOMECHANICAL ENGINEERING SECONDARY

Combining design technology,
science, and engineering

THE POWER OF PROSTHETICS

POWERED BY



IMAGINE

The background features a large, stylized 'X' shape. The top-left and bottom-right quadrants are red, while the top-right and bottom-left quadrants are purple. In the center, the word 'IMAGINE' is written in large, white, sans-serif capital letters, oriented diagonally from the top-left to the bottom-right. The background also includes a faint image of a person's face and a prosthetic arm.

AGES
11-14
Lesson plan x2

SKILLS COVERED:

- Technical drawing
- The skeletal/muscular system
- Different types of prosthetics
- The design process
- 3D printing
- Prototyping
- Troubleshooting
- Measuring
- Biomechanics



Taking inspiration directly from the amazing story of the man who built his baby son an intuitive prosthetic arm, this lesson combines biology, design, technology and engineering into an engaging insight into the exciting world of biomechanical engineering. With an important life lesson about the difference prosthetics can make to the lives of those who need them, this cross-curricular two-part lesson will awaken pupil's passion for using technical skills to help those in need.

Overview

The power of prosthetics

Meet Ben and his son Sol. They both feature in the intro video for this lesson, which is included in the presentation – slide 3.



Ben took matters into his own hands when the birth of Sol resulted in complications – and the loss of an arm. He wanted Sol to have as normal a life as possible, but found that prosthetics for babies, toddlers, and small children weren't very good, or very accessible. So he decided to use his skills as an engineer to build working prosthetics which his son could use as a normal baby would, to develop his muscles and play.

Ben is the RS Hero for these consecutive lessons, as your class takes a journey into the life-changing world of prosthetics, picking up some exciting new technical skills and knowledge as they broaden their world view, and explore the unlimited possibilities of an engineering career.



REMEMBER...

While this lesson plan has been timed to run over a two-lesson timeframe, it can also be spread out over a longer period. Younger or less advantaged classes may benefit from three or more sessions using the same material.

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LESSON 1 (informative)

- What a prosthetic is and the impact of needing but not having one
- What a prosthetic limb would need to do
- The structure of an arm/hand
- The different types of prosthetics
- Designing a prosthetic arm – the design process
- The greater impact of prosthetics

LESSON 2 (practical)

- Measuring for a prosthetic arm
- Technical drawing
- Designing a customised prosthetic arm
- Enhancing a customised prosthetic arm
- Planning the build of a prosthetic arm
- An introduction to 3D printing

DESIRED PUPIL OUTCOMES (LESSONS 1 & 2)

- Please see teacher notes for Desired pupil outcomes and curriculum links

Lesson 1



REMEMBER...

There are slides accompanying this lesson plan, including activities. Before you run this lesson, make sure you have the THE POWER OF PROSTHETICS presentation downloaded and set up on a projector at the front of the class. Please see teaching notes for further instructions.



Introduction - 20 mins

1. Play the video on slide 3. It explores the idea of prosthetics, as demonstrated by Ben and Sol, as well as an explanation of the tasks ahead from a teacher
2. Ask the class what they thought of the video, and if they have any questions
3. Use the slides to reaffirm what a prosthetic is, what it's for, and the different types available:
 - Non-functional
 - Body-powered
 - Brain-powered
4. Explain how a prosthetic is made up of mechanical components which mimic the look and/or functions of a real body part
5. Ask the class if they understand what is meant by the phrase 'quality of life'
6. Touch upon the reasons why not having a prosthetic (despite needing one) will impact on an individual's 'quality of life'. Use the slides to determine the definition

Stretch & challenge

1. Suggest an activity and have the class rate it from 1-10 in terms of difficulty (1 – effortless / 10 – impossible) with:
 - a) Both limbs in working order
 - b) One missing limb (no prosthetic)
 - c) Then with a 'functional' prosthetic limb

Repeat with a number of different activities until a solid understanding of the quality of life afforded by functional limbs is obtained

2. Go into further detail about the types of prosthetics, and their technical terms (see teaching notes)

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Main activity - 20 mins

1. Discuss how important prosthetics are for those who need them, and make a list of tasks that missing a dominant arm would make difficult/impossible
2. Using the slides, discuss:
 - a) The skeletal/muscular system overall, broken down into the functions of
 - Skin
 - Bones
 - Tendons and ligaments
 - Muscles
 - b) The structure of the hand and arm
3. Play the video explaining how muscles make limbs move
4. Ask the class to think about 'prosthetics', and how they would go about designing prosthetic limbs
5. Discuss customisation, and how/why each prosthetic needs to be different for each person depending on their specifications
6. Explain why this can cause big challenges such as cost, time etc. and why efficiency and cost effectiveness are important when considering design
7. Reveal the 'design process' and talk them through the different phases (see teaching notes)
 - Empathise
 - Define
 - Ideate
 - Prototype
 - Test
8. Explain basic technical drawing on isometric graph paper (see teaching notes)
9. Distribute isometric grid paper for the class to experiment with, either by themselves or in pairs
10. Ask them to experiment with drawing:
 - Cubes
 - Stairs
 - Spheres
 - Misc. objects (curves and 'round' objects encouraged)

LESSON 2 TIP:

During the main activity for lesson two, encourage pupils to use isometric grid paper to draw their prosthetic designs to scale. Depending on time and class ability, you may have to limit this to a demonstration, and use plain paper for the actual design of the prosthetic. If they haven't encountered isometric drawing before, it is advisable that they use plain A3 paper.



Plenary - 10 mins

1. Explain that, in the next lesson, the class will be designing prosthetic limbs to match specifications of other people in the class
2. Introduce the concept of the 'third world impact' of being without a limb for a number of years, talking about: (limiting education, career, social lives, happiness, etc.)
3. Ask: what can you do, when designing a prosthetic limb, to reduce the waiting list? Focus on:
 - Reducing the cost
 - Improving the process
 - Developing new methods

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Lesson 2

➤ Introduction - 20 mins

1. Split the class into small groups of three and ask them to spread themselves around the classroom
2. Instruct the groups to examine each other's arms and hands as they different perform tasks:
 - Pick things up
 - Put things down
 - Wave to each other
 - Shake hands with each other
 - Write with a pen
3. Explain the concept of a 'joint', and tell them to perform the above tasks again, with joints in mind. Tell them to focus on:
 - Where they are in the arms and hand
 - How they 'work' (single direction like the finger joints, multiple direction like the elbows, 'ball' joint which rolls like the wrists)
 - Count how many joints there are, what type they are and where they are on the arm/hand

➤ Main activity - 20 mins

1. In the same groups, explain that they are now going to work together to design a prosthetic arm, which works just like a normal arm (see teaching notes for the main activity explanation)
2. Run the main 'technical drawing' activity (see teaching notes)
3. Leave the 'Cheat Sheet' on the screen
4. Remind them that, once the item has been designed, it would then be made out of manmade, resistant materials such as metals, plastics and foam
5. Play the video introducing 3D printing and ask:
 - Would this reduce the waiting time for prosthetics?
 - If so, why?

Stretch & challenge

1. Discuss building the arm – sourcing materials, troubleshooting, etc.
2. If time allows, ask the class to research the ‘best’ materials for cost-effective prosthetics, paying attention to:
 - How much the materials cost
 - How easy they are to get hold of
 - How easy they are to work with
 - How ‘fit for purpose’ they are (i.e. are they strong, but lightweight?)

Plenary - 10 mins

1. When the teams have finished designing their basic prosthetic arm, ask how they could ‘enhance’ it. Ask:
 - What would the enhancement be? (e.g. extra fingers, magnets in finger tips, NFC chips etc.)
 - What would the enhancement be used for? (playing instruments, picking up tools, communicating with devices etc.)
 - How would you design them into the prosthetic?
 - If time allows, ask the class to draw the enhancements on their existing designs, as accurately as possible, and label them
2. To wrap up, ask the class the following questions:
 - Why are prosthetics important?
 - What would happen if you didn’t have access to them?
 - How can the waiting list for prosthetics be reduced?
 - How can your new biomechanical skills be used to help people?
3. Define ‘biomechanics’ as the study of biological movement

Stretch & challenge

1. Ask the class to think about Ben and Sol again. Ask: why are babies and children harder to make prosthetics for?
 - Prosthetics need to be custom-made for each person
 - Babies and children grow quickly
 - Prosthetics are very expensive to make
2. Discuss ways of making it easier for babies and children to get access to prosthetics (cheaper materials, adjustable depending on growth, simpler designs)
3. Ask if the same solutions can be applied to make it easier for people in the third world to gain access to prosthetics

TEACHING NOTES

Types of prosthetics

ARM

Either replace the arm missing below the shoulder (transhumeral – includes an elbow joint), or the elbow (transradial – no elbow joint)

LEG

Either replace the parts missing below the hip (transfemoral – include a knee joint) or below the knee (transtibial)

JOINT

Replace damaged joints, such as knees and hips

COSMETIC

Purely aesthetic and non-functional i.e. for 'the look', includes artificial eyes, breasts, fingers and toes

The 5 phases of the design thinking process

1. Empathise

Gain an 'empathic understanding' of the problem you are trying to solve. This involves consulting experts, observing, engaging and empathizing with those who will use your design. To understand their experiences and motivations. It helps to immerse yourself in their physical environment so you can gain a deeper personal understanding of the issues involved

2. Define

Analyse your observations and define the core problems you have identified up to this point. This helps designers gather ideas to establish features, functions, and any other elements that will allow them to solve these problems

3. Ideate

Generate ideas - identify new solutions to the problem statement you've created, and look for alternative ways of viewing the problem

4. Prototype

The production of several inexpensive, scaled down versions of the product, or specific features found within the product, so they can investigate the solutions generated in the previous stage

5. Test

The complete product is built, tested and evaluated. Once this is complete. The previous stages can be revisited to troubleshoot any flaws

Isometric drawing

Isometric drawings are 3D drawings. They show three sides, all in dimensional proportion. All vertical lines are drawn vertically but all horizontal lines are drawn at 30 degrees to the base line. Isometric is an easy method of drawing 3D images.

It is recommended you have a foundation of teaching technical drawing before beginning this lesson



INSTRUCTIONS FOR TEACHERS

LESSON 1

BEFORE YOU START

1. Make the classroom ready to show a presentation and download the slides from the resource pack (set to the beginning SLIDE 2 – Lesson 1)
2. Ensure you have a basic understanding of how to teach isometric drawing for beginners. Be prepared to demonstrate this for the main activity

RESOURCES

- The Power of Prosthetics presentation slides
- Screen and projector
- Plain A3 paper
- Isometric grid paper
- Rulers
- Pencils
- Rubbers
- Colouring in pencils or pens

LESSON 2

BEFORE YOU START

Make the classroom ready to show a presentation and download the slides from the resource pack (set to the SLIDE 22 – Lesson 2).

Main activity (preparation)

Ensure you have a basic understanding of the concept of isometric drawing, and technical drawing using isometric graph paper. While using it in your lesson is an optional extra, it would be a valuable insight into working in design engineering.

Main activity (instructions)

OPTION A (for older/advanced classes)

1. Remind the class of their use of isometric grid paper in Lesson 1. If required, run a brief refresher session on the basics
2. Instruct the class to stay in the groups they began the lesson in, with one of the members 'losing a limb' in order to be measured for a prosthetic
3. Distribute the isometric grid paper
4. Instruct the class to work in their groups use their isometric drawing skills to design an accurate and to scale 3D prototype prosthetic, based on these measurements

HINT: Isometric drawing is an advanced skill, so use this session as a taster for the further study of technical drawing. Keep plenty of grid paper on hand so mistakes can be easily made, and corrected.

OPTION B

1. Instruct the class to stay in the groups they began the lesson in, with one of the members 'losing a limb' in order to be measured for a prosthetic
2. Distribute the plain A3 paper
3. Instruct the class to design an accurate and to scale 2D prototype prosthetic, based on these measurements

RESOURCES

- Presentation slides
- Screen and projector
- Plain A3 paper
- Isometric grid paper (optional)
- Rulers
- Pencils
- Rubbers
- Colouring in pencils or pens

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Desired pupil outcomes and curriculum links

TEACHING NOTES

DESIRED PUPIL OUTCOMES

- I can now identify and explain what prosthetics are and the different types available
- I can now understand the concept of 'quality of life'
- I can now explain and elaborate on the importance of, and function of, prosthetics
- I can now understand the challenges surrounding providing prosthetics to those who need them, on a global scale
- I can now identify and explain the basic components of the human body, including the skeletal/muscular system
- I can now identify and explain the structure of the hand and arm, including joints
- I can now explain how the human body moves
- I can now describe and reflect on the 'design process' and its different stages
- I can now use isometric graph paper to draw simple 3D shapes
- I can now use my knowledge to measure for design and evaluate a prosthetic arm

CURRICULUM LINKS

SCIENCE

- The structure and functions of the human skeleton, to include support, protection, movement and making blood cells
- The function of muscles
- Biomechanics – the interaction between the skeleton and muscles

DESIGN

- Use research and exploration, such as the study of different cultures, to identify and understand user needs
- Develop specifications to inform the design of innovative, functional, appealing products that respond to needs in a variety of situations
- Develop and communicate design ideas using annotated sketches, detailed plans, 3-D and mathematical modelling
- Test, evaluate and refine their ideas and products against a specification, taking into account the views of intended users and other interested groups



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