Frisky feet
Winter-proof a pair of shoes

Materials Engineering
Materials, heat transfer, insulation and methods in science

Unit for pupils from 9-12 years

This document is produced under the EC contract № 288989

Introduction

This is one of ten ENGINEER primary school units developed to support science learning within the context of a wide range of engineering design challenges. Based on the successful Boston Museum of Science *Engineering is Elementary* model of inquiry-based learning, each unit features a different science area and engineering field and requires only inexpensive materials in order to support pupil-led science exploration and problem-solving design. The units have been developed to appeal to a wide range of pupils and to challenge stereotypes of engineering and engineers and so enhance both boys' *and* girls' participation in science, technology and engineering.

Our pedagogic approach

Central to each unit is the engineering design cycle: ask, imagine, plan, create, improve. Emphasizing the cycle helps teachers to foster pupils' questioning and creativity, and gives space for pupils to develop their problem-solving skills including testing alternative options, interpreting results and evaluating their solutions. Tasks and challenges have been designed to be as open-ended as possible, and to avoid 'right answers'; in particular, the unit developers have aimed to avoid competition which may alienate some pupils, while retaining the motivation of wanting to solve a problem. An important goal of all of the units is to maximise opportunities for group work and to support pupils in learning to work together and communicate their ideas effectively. Students need to discuss their ideas as they explore a new problem, work out what they need to know and share their findings, design solutions, and then improvements.

How the units are organised

Each unit begins with Lesson 0, a general preparatory lesson which is common to all ten units. Teachers choosing to use more than one unit will want to start with this lesson the first time they use the units and begin at Lesson 1 in subsequent units. Lesson 1 introduces a story context or problem which drives what happens next: Lesson 2 focuses on what exploring the science that the pupils need to solve the problem, while in Lesson 3 they design and build their design solution. Finally, Lesson 4 is an opportunity to evaluate, present, and discuss what they have done.
Each unit is, however, unique, and some units are more demanding in terms of science understanding and the length of time required for the unit varies. Likely timings and age targets are indicated in each unit overview. Units have been designed to be flexible, however – teachers can choose which activities they want to include, and there are options for differentiating activities to cater for a range of abilities.

Teacher support

Each unit guide has been written to provide appropriate science, technical and pedagogic support for teachers with a wide range of experience and expertise. Each lesson includes suggestions and tips for supporting inquiry-based learning, classroom organisation and preparation. Science and making activities are illustrated with photographs. Science pedagogy notes in the Appendix explain and discuss the science involved in the unit and how to support understanding of the central concepts for pupils in the age range. Worksheets which can be copied and answer keys are also provided.

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Overview of the unit

Duration: 370 minutes (6 hours 10 minutes)

Target group: 9- 12-year old pupils

Description: In this unit the pupils work as materials engineers to find a solution to the challenge of constructing an insulating shoe sole. The challenge is introduced to the pupils in the context of a school trip to Greenland. When they arrive at the airport in Greenland they discover that the suitcase with all their winter boots has disappeared. They have planned a dog-sled tour for the next day and so they will need to construct shoe soles that will keep their feet warm.

Science curriculum: this unit relates to the science curriculum on properties of materials, heat transfer, insulation and working methods in science.

Engineering field: this unit introduces the field of Materials Engineering

Objectives: in this unit the pupils will learn:

- the principles of insulation;
- the ability of various materials to insulate and their different properties;
- to transfer knowledge gained from investigating insulators and heat conductors to the design and construction of a shoe sole;
- to work with and develop their own ideas to solve a problem using the Engineering Design Process.

The lessons in this unit:

A **Preparatory lesson** aims to raise awareness of how engineering contributes to our daily lives in ways that are not always obvious.

Lesson 1 introduces the engineering problem, its context and the engineering process. The class is going to Greenland, but their luggage is lost and they need to work as engineers do, designing and constructing an insulating shoe sole. In this lesson the pupils activate their prior knowledge about insulation and shoe sole design. A 5-phase model, The Engineering Design Process, is introduced as the working method.

In **Lesson 2,** the 'ask' element of the engineering process leads to an investigation of the science of heat transfer and the insulating properties of materials.

Lesson 3 involves the pupils in applying the engineering design process (EDP) to meet the challenge - designing and building an insulating shoe sole. The pupils apply their knowledge about insulation to their shoe sole design and test whether they are able to meet all the requirements. Based on their test results they make improvements to their designs.

In **Lesson 4,** it is time to evaluate their work and the working method.

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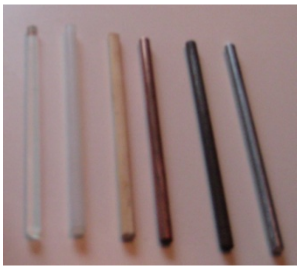
Resources

List of all the materials and quantities needed for 30 pupils.

Material List	Total amount	Lesson 0	Lesson 1	Lesson 2	Lesson 3	Lesson 4
Old shoes to be de-constructed 	15		15			
Ice cubes 	50			50		
Thermo cups, polystyrene 	10			10		
Rods made of various materials (10 cm x 0,5 cm):						
Iron	10			10		
Copper	10			10		
Aluminium	10					
Wood	10			10		
Plastics	10			10		
Glass 	10			10		
Electric kettle	1			1		

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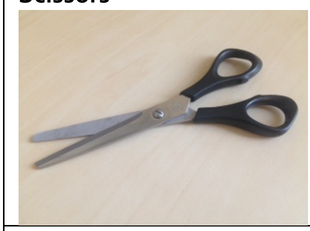
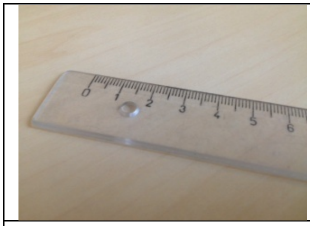
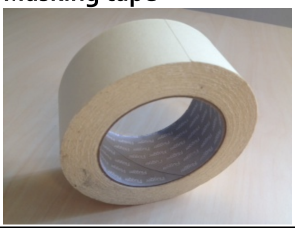
Hole maker (e.g nails) 	10			10		
Digital thermometer (measuring with 0,1 degrees accuracy) 	10			10	10	
A timer/stopwatch 	10			10	10	
Ice packs 	10			10	10	
Scissors 	10			10	10	
Rulers	10			10	10	

						
Disposable cloths/dishcloths (for the upper and lower part of sole) 	20			10	10	
Medium size matchboxes (with matches) 	12			12	12	
Plastic bags, 2 l 	20			20	20	
Washcloth, foam 	1 pk.			1 pk.	1 pk.	
Wool (e.g socks) 	4 pairs			4 pairs	4 pairs	
Rubber bands, wide	200			200	200	

						
Newspaper 	4			4	4	
Straws 	100			100	100	
Glue – preferably a glue gun or **stapler**  	10				10	
Masking tape 	15 m.				15 m.	

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Lesson 0 – Engineering an envelope
What is engineering?

Duration: teachers can choose how long to spend on this lesson depending on how much experience pupils already have. The introduction, main activities and conclusion will take up to 40 minutes; additional extension work can add a further 10-30 minutes.

Objectives, in this lesson pupils will learn that:

- engineers design solutions to problems using a range of technologies;
- technologies that are appropriate for a particular problem depend on the context and materials available;
- made objects have been engineered to solve problems;
- engineers can be men or women.

Resources (for 30 pupils)

- 8 'post-it' notes packs
- 8 sets of at least 5 different envelope types
- 8 sets of at least 5 different objects
- 8 sets of packaging examples for optional extension work
- Card, paper, glue, scissors for optional extension work

Preparation

- Collect together a range of different envelopes and packages.
- Print copies of worksheet 1 if using.
- Collect pictures for introductory activity.

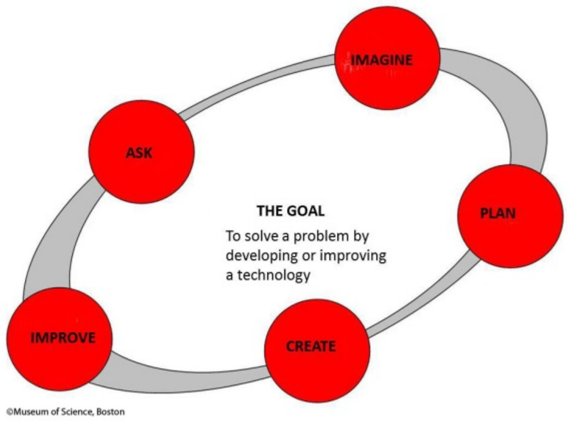
Working method

- Small groups
- Whole class discussion

Context and background

This lesson is the same in all units and is intended to encourage thinking about what technology is and to challenge stereotypes about engineers (particularly those associated with gender) and engineering.

It aims to develop the understanding that objects in the made world are designed for a purpose and that technology in its broadest sense refers to any object, system or process that has been designed and modified to address a particular problem or need.



Pupils can think about this by discussing what problem the technology of a particular artefact (in this case an envelope) is intended to solve. In this lesson, they discuss the range of technologies that are used to engineer an envelope for a particular intended purpose.

The lesson is also intended to avoid value judgments of ' high tech' versus 'low tech' and to encourage pupils to appreciate that it is appropriate technology in a particular context that is important: the range of available materials will determine the tech nology that the engineer applies to solving the problem.

0.1 Introduction - 10 minutes - small group and whole class discussion

Divide the class into groups of 4 and provide a packet of 'post-its' for each group. Ask the groups to discuss all the things they associate with the terms 'engineering' and 'technology'. Ensure that, as part of the discussion, each individual within the group puts at least one idea on a 'post it'.

Invite each group to place their 'post its' on to a master display sheet and briefly explain their choices to the rest of the class. Keep the whole class list for review at the end of the lesson.

Additional support for discussion

This part of the lesson can be extended by providing pictures of stereotypical and unusual examples of engineering and asking pupils to group the pictures into those that they associate with engineering and those that they do not. You could use Worksheet 1 for this activity, or use the pictures there as a whole class display. Ask pupils to work in pairs to decide which of the pictures they think are related to engineering and to give their reasons why they think that some are and some are not. Each pair of pupils could share their ideas with another pair and discuss similarities and differences in ideas. You could use these ideas as a basis for a whole class discussion; encourage pupils to open up their thinking about what counts as engineering and who could be involved in it.

0.2 Activity 1 What is an envelope? - 5 minutes, small groups

Organise pupils into small groups to discuss what an envelope is and what counts as an envelope. To help discussion, provide a range of examples which cover and/or protect objects or materials for particular purposes (as in the pictures).

An important part of this activity is to encourage pupils to notice that there are many interpretations of the idea of an envelope. In the pictures there are some examples that might challenge their idea of an envelope: they include a broader interpretation of what an envelope is as something that 'houses', 'protects', 'holds in place', 'covers', 'hides' or even 'reveals' a range of different objects.

0.3 Activity 2 Matching envelopes to objects - 15 minutes - small groups and whole class discussion

Divide the class into groups of 4 and provide a range of 'envelopes' and objects that could go in them. Ask the pupils to select which envelopes would be most suitable for the objects and to explain why.

The objects could include: a pair of spectacles; a certificate or photograph that must not be bent; a delicate piece of jewellery; a returnable DVD; a set of confidential papers; a pair of scissors. The range of objects and envelopes can be varied according to context and what you have available.

The following questions can help guide the discussion:

– What material is the envelope made from?
– What fixings and fastenings are used in the envelope?
– What range or types of objects could the envelope be used for?
– What other materials it could be made from?

Each group should report their ideas back to the class.

There is an opportunity here for the teacher to lead the discussion and talk about the various technologies used in each engineered envelope including the types of structures, fixings and fastenings used (e.g. reusable or permanent fixings; reinforcement areas; internal and external materials selected; how edges are sealed.)
This is an evaluative activity and could be related back to the engineering design process: discussion could include thinking about the process that engineers need to be involved in when making something to solve a particular problem.

0.4 Extension work - optional - 10-30 minutes - small groups

1. Present pupils with a range of envelopes and ask them to evaluate their design in terms of their fitness for purpose (see picture).

Envelopes could be compared in terms of the types of fastenings and reinforcements used, and the mix of different materials used (e.g. bubble wrap, absorbency, strength- i.e. resistance to tearing).
This activity could be extended to looking at different types of packaging in relation to net folds and how these are used to reduce (or eliminate) the need for adhesives in the manufacturing process. The following 3 pictures demonstrate packaging that does not use any form of adhesive; the making involves only one type of material using cuts and folds for fastenings.

2. Organise pupils into small groups to design and/or make an envelope in order to deliver a particular chosen object. Groups will need to draw on their understanding of materials and the design making process to produce a range of alternative designs. These could then be evaluated in whole class discussion.

0.5 Conclusion – 10 minutes - whole class discussion

Lead a plenary discussion drawing on the original class 'post its' (and where appropriate their groupings of the 'engineering' photographs), reminding the pupils of how their original thinking might now have changed. Ask pupils to reflect on what an engineer does and what technology is.

- Emphasise that most things we use are made for a purpose and that engineers use a range of skills in finding solutions to problems.
- This involves thinking about solutions to solve problems; some of these work and some are less successful – the engineering design process includes evaluation and improvement.
- It is not 'high' tech or 'low' tech but *appropriate* technology that matters - engineers need to consider their context and resources.
- There are many types of engineering, and many different types of people from across the world, and both men and women, are engineers.

There might be a range of equally acceptable definitions for the terms 'engineer' and 'technology'; these terms are often used interchangeably, e.g. engineering could be considered as the use of technology for problem solving. In talking about the relationship between engineering, science and technology, pupils can be encouraged to think about how engineers, in the process of making objects to solve problems, use a range of technologies (including fixings and fastenings, various types of materials and different components in a range of systems) and a range of science understandings. This is an opportunity to open up discussion about how things are made and by who, and what is involved in the process of thinking about solutions to problems.

0.6 Learning outcomes - for optional assessment

At the end of this lesson pupils should be able to**:**

- Recognise how a range of systems, mechanisms, structures, fixings and fastenings are used in artefacts in different ways to provide a range of solutions to solve problems
- Understand that appropriate technology is often dependent on the context and materials available
- Recognise that engineers use a wide range of skills in developing solutions to problems
- Recognise that many different types of people with different interests and skills can be engineers

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Lesson 1 – What is the engineering problem?
Finding out about the challenge

Duration: 60 minutes

Objectives: in this lesson the pupils will learn:

- to begin to deploy the Engineering Design Process to address an engineering problem;
- to investigate product design (shoes) to establish their insulation qualities.

Resources (for 30 pupils)

- 15 old shoes to be deconstructed
- a saw or a utility knife
- an interactive screen or a computer and a projector

Preparation

- Ask the pupils to bring an old shoe which can be broken apart.
- Read the background information (see appendix).
- Make copies of worksheets 1.1 and 1.2

Working method

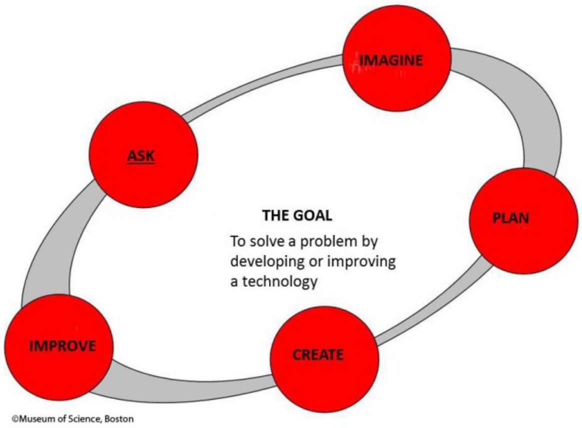
- Whole class discussion
- Group work

Key ideas in this lesson

- engineering is a problem-solving approach to design
- engineering design includes gathering relevant knowledge
- engineering design includes looking at what others have done

Context and background

The challenge, the context and the engineering design cycle is introduced. In this part of the 'Ask' phase the pupils look at arctic conditions and activate their prior knowledge about shoe sole construction and insulation.



1.1 Introductory activity – The trip to Greenland – whole class discussion - 15 minutes

Decide on how you will present the information about Greenland - either pupils can read the text: "Facts about Greenland," or you can tell them about these.

Setting the scene for the engineering challenge can be done in many ways. One way is to arrange all the chairs in the classroom as if they were seats on an aeroplane. Start the lesson by telling the pupils, that they are going to Greenland on a school trip. They are going to visit Ilulissat, which is the third largest city (5000 inhabitants). They are going on a dog sled tour where they can probably see icebergs in many different colours, eat meat from a seal and have a great time.

On the 'plane trip' you could discuss the following questions:

- Where is Greenland?
- What does the landscape look like?
- How many people live there?
- How big is the country?
- What kinds of animals live there?
- How cold is it? Night and day?
- What is the Arctic Circle?
- Where is the sun at this time of year?

Continue the story…

Unfortunately the luggage has not arrived with them when the plane lands in Greenland… It is on the wrong plane and has been sent to Russia. At the earliest, it will be here the day after tomorrow. The dog sled tour is already planned for tomorrow. The winter clothes they are wearing are okay for the trip, but their shoes are all much too thin. What are they going to do?

1.2 The Engineering Design Process and the challenge - whole class discussion - 10 minutes

The pupils need to think and work like engineers solving a problem. Having cold feet in Greenland is not exactly fun. They want to go on the dog sled tour. So there is only one solution; *design and make a shoe sole that can keep feet warm.* How will they do this? Remind the pupils about the Engineering Design Process. Ask pupils to look at **Lesson 1 Worksheet 1.1** and discuss how they might apply the Engineering Design Cycle to the problem. Focus strongly on the 'ask' stage at this point in the unit in order to encourage them to think of the questions they will be seeking to address. It is probably best if this is a whole class discussion aimed at generating thinking and commitment.

1.3 The "ASK" phase – Looking at shoe soles – group/pair work – 25 minutes

In this part of the lesson, pupils will look at different shoe sole designs and talk about the use of materials, the purpose of the shoes and how they are constructed. The pupils start out in the “ASK” phase, looking at other shoe sole designs. Ask each group or pair to de-construct a shoe sole and answer these questions:

– What is the purpose of the shoe (Different purposes could be: for walking a long distance, for running, for very hot weather, for airing the feet, for swimming, for dancing…)
– What kind of materials is the shoe sole made of?
– What purpose does each material have? (To make the sole soft, waterproof, moveable…)
– How is the sole constructed? (How many layers, how do the parts fit together e.g. by glue, sewn, welded…?)

Pupils can record their observations on **lesson 1 worksheet 1.2**.

Tip: Pupils might need help in cutting the soles open.

Record pupils’ findings on the board. Ask them to:

– Fill in information about the type of shoe and materials used.
– Try to explain the purpose of the material.
– Look at construction and fastenings.

The table gives examples of what could be found in the soles of different shoes.

Materials	**Type of shoe**					**Material purpose**
	Running shoe	Hiking boot	Sandal	Winter boot	Tennis shoe	
Leather		II	I			
Rubber			I			
Foam						
Plastic	III				IIII	
Wood						
Canvas					I	
…						
Construction						
1 layer					I	
2 layers	II		I		III	
3 layers	I			II		
Holes inside						
Channels with air in heel	III	II				
Fastenings						
Glued					IIII	
Sewn			I		IIII	
Welded		II				
…						

If old shoes are hard to obtain, let the pupils take a look at the shoes they are wearing. However, without deconstructing the shoes, it will often be hard to answer questions about construction.

1.4 Conclusion – plenary - 10 minutes

What's important about shoes that keep our feet warm?

Having looked at existing shoe sole designs, the pupils might be able to point out some of the things that work well when designing shoes that keep feet warm. Collect all these observations and write them for the whole class to see.

Ask 'What else do we need to know?' *Explain that they will need to investigate a lot of things before building a shoe sole that will withstand the cold on the dog sled tour.*

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Lesson 2 – What do we need to know?
Finding out about heat transfer and insulating materials

Duration: 170 minutes

Objectives: in this lesson the pupils will learn:
- to deploy the Engineering Design Process as a template for successful design;
- to work to a set of product criteria;
- how scientific concepts to do with thermal properties and insulation underpin successful product creation.

Resources (for 30 pupils)
- 10 Digital thermometers (measuring with 0,1 degrees accuracy)
- 50 Ice cubes
- 10 Thermo cups
- Electric kettle
- 10 x rods made of different materials with the same length and diameter (e.g. 10 cm x 0.5 cm): e.g. iron, aluminium, copper, glass, plastic and wood.
- 10 pointed things for making holes in thermo cups, for example awls
- 12 large matchboxes (with matches)
- 1 pk. Washcloths, foam
- 4 Newspapers
- 200 Rubber bands, wide
- 4 Pairs of wool socks
- 100 Straws
- 20 Plastic bags, 2 litre
- 10 Ice packs
- 10 Rulers
- 10 Stopwatches/timers
- Masking tape, 15 m.
- 10 Pairs of scissors

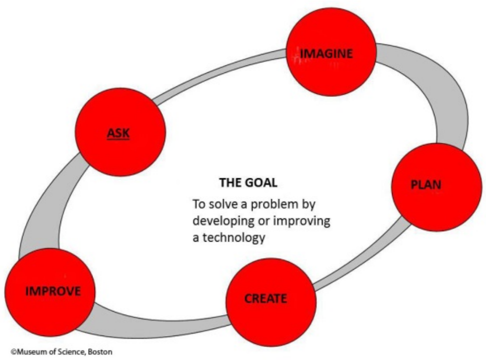
Preparation
- Ask pupils to bring things from home that are used to keep things hot or cold.
- Make ice cubes.
- Freeze ice packs.
- Prepare testing materials for each group.
- Make copies of worksheets 2.1, 2.2, 2.3, 2.4, 2.5 and 2.5 – page 2.

Working method
- Group work
- Whole class discussion

Key ideas in this lesson
- Heat transfer always occurs from hot to cold. However, the activities in this lesson do not demonstrate this. It is something that the pupils need to be told.
- It's important to be accurate and consistent when measuring temperature using a thermometer.

Context and background

The 'Ask' phase now leads to an investigation of insulation. The pupils investigate hot and cold, heat transfer and the insulating properties of different materials.



2.1 Introductory activity – What happens to the snowman? – group work/ whole class discussion - 20 minutes

Pupils should work in groups of 2-4. Give each group a copy of **Lesson 2 worksheet 2.1,** or draw the snowman on the board. Remember the sun, the coat and the three options.

Ask the pupils to discuss the picture: What happens to the snowman when you put a jacket on him?

There are 3 options:

1. Nothing happens
2. He melts more quickly
3. He melts more slowly

Concepts Cartoons

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Allow the pupils 4-5 minutes to discuss this. Then pick a corner of the classroom for each of the 3 possible answers and ask the pupils to stand in the corner which they think represents the correct answer. Ask the pupils to explain their choices. Guide the discussion to discuss the possibility that:

- the jacket/insulator keeps the cold in
- the jacket/insulator keeps the heat out
- the jacket/insulator warms up the snowman and melts him

Several of the pupils probably believe that a snowman wearing a coat melts faster. Their experience tells them that when we are cold, we put on a coat to get warm. However, the reality is that the heat we produce is kept inside by insulating the body with a material that does not let body heat escape.

The snowman is colder than its surroundings. Therefore, we need to prevent the heat surrounding the snowman from melting it. The greater the difference between the internal and external temperatures, the more rapidly the snowman melts. A good coat is made from an insulator, containing lots of still air and will preserve the snowman the best! If the surrounding temperature is the same as the snowman (zero degrees or less) the jacket has no effect.

Heat transfers always from hot to cold.

Tip: Wait until the next activity before deciding on the answer.

It is time to introduce the concept of insulation to the class. Why do we want to keep things hot and cold? And how do we do that? In this activity the pupils talk about things that we use for keeping things hot/warm and cold, including our own bodies. Comparing these things they find that we use the same materials for keeping things hot and cold – and these are what we call insulators.

2.2 How can we stop an ice cube melting? - group work – 15 minutes

How do we keep things cold? In this activity the pupils will try to prevent an ice cube from melting. This is similar to protecting the snowman, but now they will test different materials and find out which ones work best as insulators.

Give each group (approximately 3 pupils per group) an ice cube. They have 3 minutes to decide which way is the best way to preserve it, using the materials available. They must stay inside the classroom, but can use whatever is present, except a freezer. They are allowed to do whatever they want with the ice cube, but it is important, that the pupils choose only one kind of material for this task.

After 3 minutes, they must leave the ice cube alone, and wait for 15 minutes to see what happens.

So that they can compare, place an ice cube on a plate to find out how far it melts with no insulating materials around it.

An ice cube is usually cold compared to its surroundings. The pupils' results will vary depending on the materials they decide to use to protect their cubes. Their main goal is to prevent heat from the outside from melting the lump of ice. A good "coat," made by an insulator, containing lots of still air (e.g. styrofoam, flamingo, an old wool sock) will preserve the ice cube best!

A poor insulator can be, for example, water. Water releases energy (warmer) to the ice cube, thus melting it more quickly. Pupils who choose to put just their ice cubes on the table will discover that their ice cubes melt more slowly than ice cubes put in water, but faster than those which are wrapped up. This is because water is a good heat conductor (and a poor insulator), and air is a poor heat conductor (but a good insulator).

NOTE: *While the ice cube is left for 15 minutes the pupils can begin the next activity.*

2.3 More about insulation - group work/ whole class discussion - 20 minutes

Ask pupils to look at their ice cubes in their groups and to complete **Lesson 2 worksheet 2.2**

- How well is the ice cube preserved? (scoring it 1 – 5)
- How did they decide to preserve the ice cube?
- Why did they choose this solution?
- Looking at the class results, what is the best way to preserve an ice cube?

Help the pupils discuss the solutions they have reached and think about good and bad ways to keep an ice cube frozen.

It might be interesting to let the pupils compare what they were thinking of doing in the snowman exercise, with what they chose to do with the ice cubes.

Finally, tie all their knowledge about insulation together: The snowman solution, the ice cubes, the examples of keeping things hot and cold that they have brought from home:

- What is similar between the materials that work well in preserving an ice cube and the materials that keep things hot/cold?
- Return to the snowman and ask them if they have changed their mind about the solution.
- Talk about the solution and the jacket working as an insulator - keeping the cold in.

An additional question:

- What happens to the snowman if the snowman has the same temperature as the air?

2.4 Heat transfer - Feeling and measuring the world – group work/whole class discussion- 25 minutes

Tip: If the pupils have no previous experience of working with digital thermometers, it is important that you give them a thorough introduction now in order to get accurate results.

In groups of 2-3 pupils should walk around the classroom. Let them feel various things: a chair leg (metal?), a chair back (plastic or wood?), the window, a chair seat, a school bag and various other things. The items listed in the table below are suggestions.

Each pupil records their observations of whether things feel hot/cold on a scale of 1-5 on worksheet 2.3. Collate their answers on the board. .

Discuss what the data means. Do they all agree on what is hot and what is cold?

Next, ask the pupils to measure the temperature of the same things with a digital thermometer.

An example of test results:

Name of material	**Feel the materials** How cold/hot are they? Circle one of the numbers 1 = coldest 5 = warmest	**Measure the temperature** Write down the temperature of the material
Wood	1 2 3 4 5	21 degrees
Plastic	1 2 3 4 5	21 degrees
Water	1 2 3 4 5	21 degrees
Iron	1 2 3 4 5	21 degrees
Aluminium	1 2 3 4 5	21 degrees
Glass	1 2 3 4 5	21 degrees
Air	1 2 3 4 5	21 degrees
	1 2 3 4 5	
	1 2 3 4 5	
	1 2 3 4 5	

Discuss the pupils' observations:

- What did their measurements show in the first and the second part of the activity?

– Were some of the results surprising?
– Which kind of materials feel the same?
– What are the properties of these materials? (insulator or conductor?)
– What happens when you feel the material for a long time?

Why does this happen?

The pupils are not expected to be able to explain why there is a difference between the perceived temperature and the measured temperature. Perhaps it may be necessary to tell them that:

– What they are witnessing is heat transfer.
– A material's ability to transfer heat varies.
– Your hand is probably warmer than its surroundings, so the materials that are good at transferring heat from your hand will be perceived as colder. The heat from your hand is transferred more quickly to the material.
– Some materials speed up heat transfer, but some slow the heat transfer down – these are the ones we call insulators.

Compare the good insulators with the ones found in the previous activities for wrapping the ice cube, keeping things cold and warm and materials found in shoe soles.

When we talk about the 'hotness' of a material being a relative experience, this underlines that there is a discrepancy in your experience, such as the difference felt between wood or metal. Both of the materials were at room temperature (21 degrees in the example), but metal feels a lot colder to the touch than wood. The reason for this is that metal is a better heat conductor and is, therefore, better at transferring heat from the hand. Wood, on the other hand, is a poor heat conductor and stops the transfer of heat from your hand.

2.5 Optional additional activity - Good and bad heat conductors – group work/ whole class discussion – 15 minutes

In groups of 2/3, pupils need to test the ability of the rods made of different materials to transfer heat and cold. First they need to punch holes in the thermo cups - make 6 small holes made with an awl, about 1.5 cm from the cup's edge. Distribute the holes evenly around the entire cup. Gently press the rods of different materials through the holes (see illustration).

They then fill the cups with water and ice cubes. The rods inside the cup must be completely covered.

After a few minutes, pupils need to feel the different rods and range them from the 'coldest' to the 'hottest,' recording their findings on worksheet 2.4.

You can, perhaps also, let the pupils measure the temperature of each of the rods with a digital thermometer.

If you are permitted to work with hot water:
Pour out the cold water and fill the cup with hot water (at 60 degrees). The rods inside the cup must be completely covered. The pupils need to wait 2-3 minutes and then touch the rods again and range them from the hottest to the coldest, recording 1-6 on the worksheets.

Tip: It is important that the pupils gain a comprehensive understanding of the term, heat transfer. Do this by discussing their experiences in the previous activity and combining it with their results in this activity. The most important point to understand is that the materials we call insulators are the materials that slow down heat transfer.

2.6 Investigating insulating materials – group work/whole class discussion - 30 minutes

In this activity the pupils carry out a fair test on the materials available for designing the shoe soles. They also try to improve the materials' insulating capacity by finding out about the 5 criteria that really matter when talking about insulation.

The 5 crucial things are:

1. The insulating properties of the material.
2. The amount of air standing still (measured by the distance between the materials).
3. The amount of material (thickness and size of material)
4. Dryness
5. Time

Decide how you will group the class in order to test the 7 different materials. It is possible to remove any of the materials or add new ones (as long as they are part of this fair test). We suggest groups of 3 pupils, testing one of the following materials each:

1. Newspaper
2. Matches
3. Wash clothes
4. Wool socks
5. Plastic bags
6. Rubber bands
7. Straws

Each group will also need a digital thermometer, a washcloth, an ice pack, ruler, a plastic bag and a stopwatch to carry out the test.

Start by setting the scene for the challenge again. They are in Greenland, they are sitting in a hotel room looking at the materials available to them for building the shoe sole.
Pupils need to investigate the insulating properties of the materials. In order to compare the results, they need to carry out a fair test.
Emphasise that a 'fair' test means testing one variable at a time, keeping constant all the other things that can influence the outcome.
These are some of the important variables that they need to keep constant. Ask the pupils why they need to:

- Start the measuring at room temperature

- Time the measurement (5 minutes in this case)
- Cover the materials with a cloth (*keeping the air still just above the point where they measure. Otherwise the room temperature has too great an influence on the measurement*).
- Hold the thermometer steady (not pressing too hard/not lifting it)
- Measure the same spot on the material (preferably in the middle of the material).

Ask pupils to work with worksheet 2.5, which has the instructions they need and space for recording the results.

All pupils will test one kind of material using the same amount e.g. 1 cm (in depth). It is important that they put the materials in a plastic bag, preventing it from getting wet from the ice pack, and more important, making sure that the air stays still.

First, they need to feel the effect of 1 cm of insulation with bare feet:

1. Pack 1 cm depth of the material in a plastic bag
2. Put it on the ice pack
3. Stand with bare feet on the 1 cm of material for one minute.
4. Question: Is this a good enough insulation solution?

Next, they need to take measurements:

1. Cover the materials with a washcloth for 5 minutes
2. Measure the room temperature
3. Make a hole in the washcloth, put the thermometer through and measure the material in the same spot for 5 minutes. Hold the thermometer steady (not pressing too hard/not lifting it).
4. Record the result.

An example of measurements made with 1 cm of material:

Name of material	The amount	Start temperature	Temperature after 5 minutes	Difference in temperature
Newspaper	1 cm thick	23,5	14	9,5
Matches	1 cm thick	22,6	15,5	7,1
Wash clothes	1 cm thick	22,5	16	6,5
Wool Socks	1 cm thick	23	17,3	5,7
Plastic bags	1 cm thick	23,4	12,6	10,8
Rubber bands	1 cm thick	22,3	15,3	7
Straws	1 cm thick	23	18,8	4,2

Display the data in the classroom for all to see. Ask the class to rate the results and discuss their ideas about the reasons for differences in temperature

2.7 Improving insulating capacity – whole class discussion – 15 minutes

Ask the pupils:

- How can they improve the insulating capacity using the same kind of material they used the previous activity.
- They are allowed to use more material, but the insulation has to be better.

Let the pupils discuss the possibilities, carry out a new test and complete page 2 of worksheet 2.6.

2.8 Concluding - review – whole class discussion - 10 minutes

Discuss with the class what the data shows:

- What did they do?
- What were their hypotheses?
- What do they now think made the difference? (More material, thicker material, more air…)

Help the pupils formulate their conclusion using this sentence:

The ____________________, the better insulating capacity!

The thicker the material, the better insulating capacity!

Write all the concluding statements on the blackboard.

Guide discussion towards the engineer's 5 criteria for insulation

1. The insulating properties of the material.
2. The amount of air standing still (measured by the distance between the materials).
3. The amount of material (thickness and size of material)
4. Dryness
5. Time

Compare the 5 criteria with the pupils' conclusions.

Lesson 3 – Let's build!
Design and build your own insulating shoe sole

Duration: 110 minutes

Objectives: in this lesson the pupils will learn:
- To ask about the product requirements before developing it
- To design for a specific purpose
- To test and improve their products

Resources (for 30 pupils)
For designing a shoe sole:
- ☐ 10 Disposable cloths/dishcloths
- ☐ 12 Big matchboxes (with matches)
- ☐ 1 pk. Washcloths, foam
- ☐ 4 Newspapers
- ☐ 200 Rubber bands, wide
- ☐ 4 Pairs of wool socks
- ☐ 100 Straws
- ☐ 20 Plastic bags, 2 l
- ☐ Masking tape, 15 m.
- ☐ 10 Pairs of scissors

Fastening and binding tools:
- ☐ 10 glue – preferably a glue gun or staplers

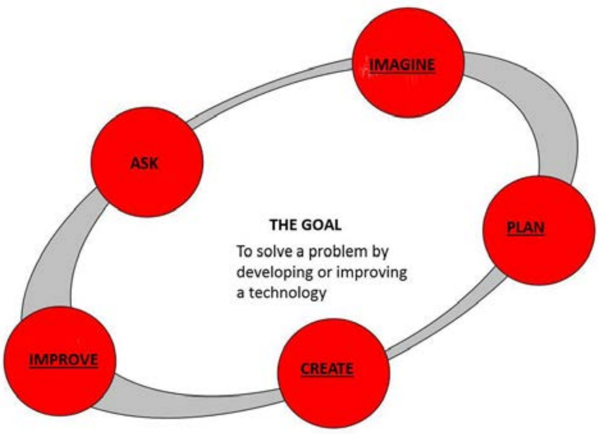
Materials needed for testing:
- ☐ 10 Digital thermometers
- ☐ 10 Ice packs
- ☐ 10 Rulers
- ☐ 10 Disposable cloths/dishcloths
- ☐ 10 Stopwatches/timers

Preparation
- Freeze ice packs
- Prepare building materials
- Prepare equipment and tools for each group
- Print worksheets and a copy of the engineering design cycle

Working method
- Group work
- Whole class discussion

Context and background

In this lesson the pupils work through the 'Imagine', 'Plan', 'Create' and 'Improve' steps of the Engineering Design 'Ask', Process. They apply their science knowledge to the design of an insulating shoe sole.



3.1 Introductory activity – The engineering challenge and design process – whole class discussion - 5 minutes

Start by outlining the engineering challenge: Design a shoe sole that can insulate against the cold.

Tip: You need to emphasise to the pupils that they only have to design and construct the sole – not the whole shoe.

Worksheet 1.1) which describes the working method that the pupils should use. Introduce the "Ask", "Imagine", "Plan", "Create" and "Improve" phases again. Make clear to the pupils that keeping track of time is essential in this working process. Give them deadlines in each phase and make administrating time and work a learning process too.

3.2 'Ask' – group work and whole class discussion – 15 minutes

The pupils have already worked a lot with the "ASK" phase in lessons 1 and 2, researching different aspects of the challenge (Greenland, shoe sole designs and the insulating properties of materials). Before developing their own shoe sole, the pupils now "ask" the same question that an engineer does: What are the requirements?

Working in groups of 3, with Worksheet 3.1, the pupils discuss and list the requirements for the shoe sole.

An example of what they might say is - the shoe sole must be: insulating, waterproof, comfortable to wear, pretty, wear resistant…

In whole class discussion, agree on the requirements. Limit the number. If pupils define their own requirements, they need to indicate how to measure them. It might not be possible to test all requirements using a scientific method. Then they must agree on:

- When do we know it is 'nice to wear'?
- How do we test it?

A final requirements list might look like this:

The requirements for the shoe sole:

1. **The shoe sole is built from a maximum of 2 kinds of insulating materials (masking tape and the actual sole material do not count)**
2. **The shoe sole stays on when the pupils walk for 10 meters.**
3. **The shoes sole is a maximum of 2 cm thick**
4. **The insulating capacity is considered "Good" on a scale from "Very good" – "Good" – "Not so good". This is defined by the test done on the shoe soles in the class.**

Note: these requirements are listed on worksheets 3.4 and 3.5. You might want to adapt these worksheets if your class decides on different criteria.

3.3 'Imagine' – group work - 10 minutes

The second phase is "Imagine". Help the pupils brainstorm possible solutions in groups of 3. Remind them what materials are available. They could, for example, brainstorm the following issues:

- What is a good shoe sole?
- What materials would be good for insulating?
- What materials could be good for construction?

The pupils write, draw or create a mind map with their ideas in worksheet 3.2.

Each group decides on the best idea. They work on planning the design in the next activity.

3.4 'Plan' – group work - 15 minutes

Display the materials for designing the shoe sole.
In their groups of 3, the pupils need to work with their ideas from the Imagine phase to make the idea more concrete. You can choose to let the pupils work knowing what kinds of materials are available for the design. This is a good exercise, applying the science knowledge to the task. For some pupils this might be very abstract and they may require help to keep focusing on making the plan before building.

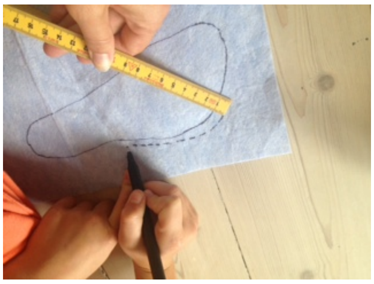
In the pupils' worksheet 3.3: "Plan" they work planning the shoe sole design answering:

1. What does the sole need to contain to meet the requirements?
2. What 2 kinds of materials will you use to make the sole?
3. Make a drawing of the shoe sole.

3.5 'Create & test' - group work – 35 minutes

Working in their groups of 3, pupils now need to build and test their shoe sole, following their plan.
Divide the materials into: Insulation materials: Newspaper, wash cloth, matches, plastic bags, wool, rubber bands and straws; and Fastening and binding materials: Glue, stapler, 50 cm of masking tape, a plastic bag.

The top and bottom sole:
Start by cutting out two identical soles from a wash cloth. Make a 1 cm seam for closing the sole.
These work as the top and bottom layer for the shoe sole. *They do not count as an insulating material. Make this distinction clear. It is also important that the pupils know that materials*



are limited.

Pupils then construct their insulated sole, with instructions on worksheet 3.4. *Allow 15 minutes for building*

Testing the sole:

The group next need to test their shoe soles. Hand out worksheet 3.5: "Test" which has instructions for how pupils can test their products against the requirements.

When the testing is finished, let the pupils rate their products as: very good, good, not so good.

3.6 'Improve' – group work – 25 minutes

Pupils continue to work in their groups to consider how to improve their shoe sole designs. Instructions and support are given in worksheet 3.6, which asks them to discuss their choice of materials, designs, test results and what to improve:

- What kinds of materials did they use - and why?
- Why did they choose this kind of shoe sole design?
- Did the shoe sole meet the requirements? What did the tests show?
- How can they improve the sole?

Improving and testing the shoe sole:

Based on their evaluation, the pupils can try to improve their shoe sole. They are now given 10 minutes to improve their shoe sole and a further ten minutes to test it, recording their results and conclusions on worksheet 3.7

3.7 Conclusion – plenary - 5 minutes

The pupils will be presenting the outcome of their work to the class in the next lesson. Briefly prepare for this by discussing how the pupils have worked through the engineering design cycle. Did they manage to meet the requirements and to improve their designs? Ensure that the 'shoes' are safely stored for the final lesson.

Lesson 4 – How did we do?
Was the challenge met? Evaluating the method and the outcome

Duration: 40 minutes

Objectives: in this lesson the pupils will learn:

- the importance of thorough evaluation of their work as an important part of the Engineering Design Cycle;
- the skills involved in successful presentation of their work.

Preparation

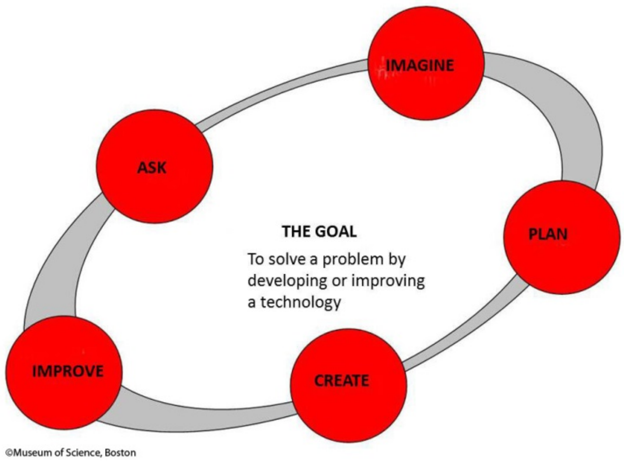
- Make copies of worksheet 4.1

Working method

- Group work
- Pupils' presentation
- Whole class discussion

Context and background

In this lesson the process is evaluated. How did the Engineering Design Process and their new science knowledge help pupils to meet the challenge?



4.1 Introductory activity – group work - 20 minutes

Ask pupils to evaluate their work using worksheet 4.1 "How did we do?" In their groups, ask them to discuss:

- Was it good fun?
- The process has 5 phases: What are their names?
- Which phase did you like the best?
- What worked well in the process?
- What did not work so well?
- What has been the best learning experience?
- Have you gained any new skills?
- What was the biggest challenge you faced?

Ask each group to prepare a short presentation (maximum of 5 minutes including questions) about their shoe sole and what they have learned. In their explanation they should draw on their knowledge from the previous lessons.

4.2 Presenting our work – 45 minutes

The teacher introduces the presentation. The importance of this final opportunity for collective review of the unit and their success in creating an insulating shoe sole needs to be underlined. Designers are accountable for the effectiveness of the products they create so those listening to the presenters have an important role to play. If they were parents meeting their children from the airport would they be convinced that their children's feet had been kept warm on the dog sled journey?

Each group then presents their shoe sole, demonstrating how the key scientific concepts around insulation have helped to determine their design

4.3 Teacher led - plenary - 5 minutes

The teacher reviews the unit overall reminding the pupils about the ways in which they have deployed the engineering design cycle, praising the children for their contribution and expressing confidence that their feet stayed warm.

Appendices

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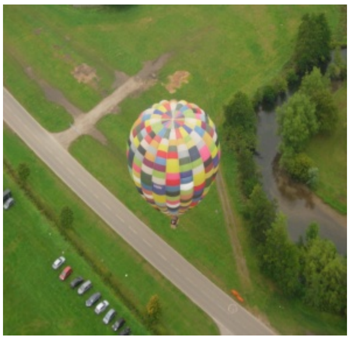
Worksheets

Worksheet 1 Lesson 0 – Engineering?











Worksheet 1 Lesson 0 - Engineering? – Teacher notes

The pictures on the worksheet are intended to promote pupils' discussion about what engineering is, what engineers do and who could be involved in different types of engineering.

The pictures of the spider and snail present some interesting challenges. The pupils could for example, decide that the spider is 'engineering' a web and this could be related to other animal 'engineering' examples (such as a beaver building a dam). An interesting point to make is that it is more common to think of engineering in terms of the made world. We can however, learn from studying nature and the environment. For example, the material that spiders use for making a web has been copied to make a very strong material (Kevlar) that has many useful properties. Similarly, the snail has developed a useful strategy for travelling over rough surfaces to protect its soft body from being damaged. An interesting question is whether this would be useful to solve a problem in the human world (a good example is Velcro which was developed from the burrs of burdock plant).

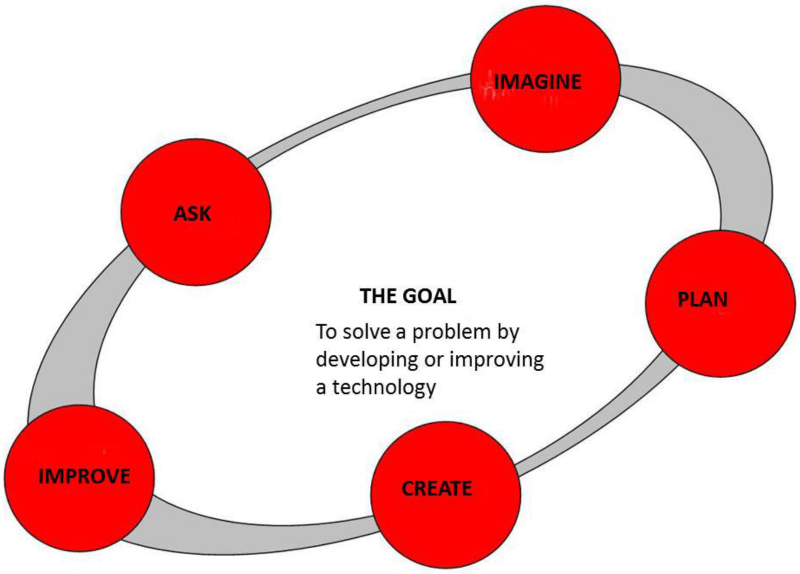
The toys could be considered engineering since they demonstrate the application of cams but it is interesting to ask what materials they could be made from and who actually makes them. This is likely to lead to some gender issues (many of the class may think that toys are made for children by toy designers who are male).

A similar issue might arise when pupils discuss the knitted garment and the prepared meal - pupils may think that these are only made by women, and that they are not the product of engineering.

Some of the other pictures of sculptures and works of art might be perceived as not engineering and without any real practical purpose. This will raise a question about the links between engineering and art and whether or not a made object needs to have a practical purpose for it to count as being engineering.

The pictures are meant to stimulate engagement and dialogue about engineering. This could lead to a discussion about what is involved in engineering, in which you might choose to introduce the Engineering Design Cycle.

Pupils’ Worksheet 1.1 – The Engineering Design Process



ASK

What is the problem?

What have others done?

What can science tell us?

What are the requirements?

Imagine

Brainstorm ideas

Choose the best one

Plan

Draw your idea

Choose materials

Create

Follow your plan

Test it out

Improve

Make your design even better

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Pupils' Worksheet 1.2 – Looking at shoe soles

Names:
Date:

Cut the shoe open and look at the shoe sole design.

Fill in your observations in the table:

- **What kinds of materials are used for making the shoe sole?**
- **Describe the construction of the shoe sole: number of layers, patterns or other characteristics?**
- **Describe how the materials are held together: Glued, sewn, welded…other?**

Type of shoe ……………………………………………

What kinds of materials are used for the shoe sole?	**Material purpose**
Describe the ways of construction	**Construction purpose**
Describe how the materials are held together	

Pupils' Worksheet 2.1 - What happens to the snowman?

Name:
Date:

What do you think happens to the snowman?

Concepts Cartoons © Millgate House Education Ltd.

Pupils' worksheet 2.2: How to keep an ice cube frozen

Names:
Date:

What makes an ice cube melt?
Find the best way to keep it from melting.

What do you need?

- 1 ice cube
- One material that you think will keep the ice cube from melting

To work!
Decide how to preserve an ice cube so that it melts as slowly as possible.

Rules:
You can use whatever is in the room.
You can only use one kind of material.
After 3 minutes you must leave it.

You have 3 minutes to decide what to do

Questions:

1. What did you do with the ice cube?

2. Why did you choose this material?

3. Which materials were good insulation materials?

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Pupils' worksheet 2.3: Feel and measure the world

Names:
Date:

Temperature is not always what it feels like. Investigate the things around you and find out more about why some things feel warmer than others.

What do you need?

- One digital thermometer

To work!
1. Find different materials in the room – feel them and decide if they are warm or cold. Circle one of the numbers 1 for coldest and 6 for warmest.

2. Measure the same things with a digital thermometer and write the temperature in the table.

Name of material	**Feel the materials**  **How cold/warm are they? Circle one of the numbers . 1 = coldest 6 = warmest**	**Measure the temperature**  **Write down the temperature of the materials**
	1 2 3 4 5 6	
	1 2 3 4 5 6	
	1 2 3 4 5 6	
	1 2 3 4 5 6	
	1 2 3 4 5 6	
	1 2 3 4 5 6	

Conclusion:
4. Why do some materials feel warmer than others?

____

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Pupils' worksheet 2.4 - Good and bad heat conductors

Names:
Date:

Some materials are good for insulation – some are not. You can investigate this by putting different materials in hot and cold water and finding out what happens.

What do you need?

- 1 digital thermometer
- 1 thermo cup
- 6 material rods: iron, copper, aluminium, plastic, wood and glass
- 1 nail
- Cold and hot water

To work!

1. Make 6 small holes in the cup with the nail as shown in the picture. Put the different rods in the holes.

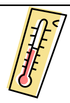
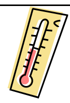
2. Pour iced water into the cup until the rods inside the cup are covered.

3. Wait one minute and feel the rods. Rank them from 1 to 6 (1 is coldest). Write it in the table.

4. Try to measure the rods with the thermometer. Hold the thermometer for 1-2 min. on the end of the rod before reading the temperature.

5. Empty the cup and pour in hot water. Be very careful not to scold yourself. Feel the rods. Rank them again and measure with a thermometer.

Which materials reacted to cold/heat?

Materials	 coldest - warmest	 Measured temperature	 coldest - warmest	 Measured temperature
	Cold water	**Cold water**	**Hot water**	**Hot water**
Wood	1 2 3 4 5 6		1 2 3 4 5 6	
Glass	1 2 3 4 5 6		1 2 3 4 5 6	
Iron	1 2 3 4 5 6		1 2 3 4 5 6	
Cobber	1 2 3 4 5 6		1 2 3 4 5 6	
Plastic	1 2 3 4 5 6		1 2 3 4 5 6	
Aluminum	1 2 3 4 5 6		1 2 3 4 5 6	

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Pupils' worksheet 2.5: Testing insulating materials

Names:
Date:

In this activity you undertake a fair test of the materials available when designing the shoe sole. Secondly you try to improve the insulating capacity of the materials.

What do you need?

- ☐ A digital thermometer
- ☐ An ice pack
- ☐ A ruler
- ☐ A stopwatch/timer
- ☐ One washcloth
- ☐ A plastic bag
- ☐ One kind of the building material

To work!

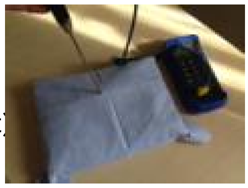
1. Choose one kind of insulating material for testing

2. Testing 1 cm with bare feet

- Pack the material 1 cm deep in a plastic bag.
- Put it on the ice pack.
- Stand with bare feet on the 1 cm of material for one minute.
  Is this a good enough insulation solution? _______________

3. Testing 1 cm depth

- Cover the materials with a washcloth for 5 minutes
- Start measuring the room temperature
- Make a hole in the washcloth, put the thermometer through it and measure the material in the same spot for 5 minutes. (Hold the thermometer steady, not pressing too hard/not lifting it)
- Write down the result.



Name of material:	**1 cm**
Start temperature (room temperature)	
Temperature after 5 minutes	
Difference:	

Pupils' worksheet 2.5: Testing insulating materials – page 2

1. Improving the insulation

Talk about how you can improve the insulating capacity using the same material.
You are allowed to use more material, but the insulation has to be better.

– This means the difference in temperature has to be smaller or bigger - which? _______________

2. Testing again

- Put the improved insulation in the plastic bag
- Cover the materials with a cloth for 5 minutes
- Measure the room temperature
- Measure the material for 5 minutes. (Hold the thermometer steady, not pressing too hard/not lifting it)
- Write down the result.

Name of material:	**Describe what you did**
Start temperature (room temperature)	
Temperature after 5 minutes	
Difference:	

3. Conclusion

What did you think made the difference in the second test? Write your hypothesis using this sentence:

The _____________________________, the better insulation!

4. The 5 criteria for insulation

Write down the criteria

1. ………………………………………………………………… 4. …………………………………………………………………

2. ………………………………………………………………… 5. …………………………………………………………………

3. …………………………………………………………………

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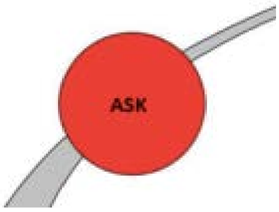
Worksheet 3.1 - ASK



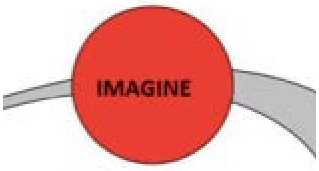
Names:
Date:

Before designing, an engineer always makes sure to ask a lot of questions about the thing they are going to develop. Now is a good time to ask yourself - When can I tell if the sole is a success? What are the requirements?

1. Make a list of all the important requirements for the shoe sole design

2. What are the final requirements?

Worksheet 3.2 – IMAGINE



Names:
Date:

It is now time to get all the great ideas for your shoe sole design.

What do you need?

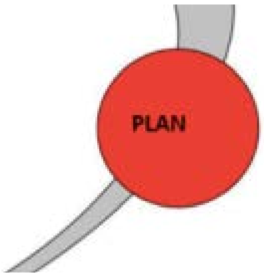
- A pencil

To work!
Discuss, and draw or write down all the things that could be fun to try out. Have in mind that they need to meet the requirements.

These questions might help you on your way:

- What is a good shoe sole?
- What materials would be good for insulating?
- What materials would be good for construction?

Worksheet 3.3 - PLAN



Names:
Date:

Decide on your shoe sole design.

1. What does the sole need to contain to meet the requirements?

……………………………………………………… ………………………………………………………………

……………………………………………………… ………………………………………………………………

……………………………………………………… ………………………………………………………………

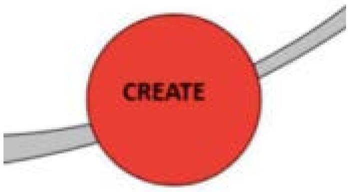
2. What 2 kinds of materials will you use to make the sole?

………………………………………………………

……………………………………………………

3. Make a drawing of the shoe sole

Worksheet 3.4 – CREATE



Names:
Date:

It is now time to create your shoe sole following your plan.

What do you need?

- A wash cloth (to make the outside of the sole)
- A pencil
- Scissors
- Glue or staplers
- Masking tape, 50 cm
- A plastic bag
- Building materials

To work!

Start by cutting the outside of the shoe sole:

1. Put your foot on the wash cloth
2. Draw a line around your foot
3. Add 1 cm all the way round (for closing it)
4. Cut out the sole by the outer line

Create your shoe sole

1. Choose your insulating materials
2. Build the shoe sole

The requirements for the shoe sole:

- **The shoe sole must be built from a maximum of 2 kinds of insulating materials.**
- **The shoe sole needs to stay on for a 10 metre walk.**
- **The shoe sole is a maximum of 2 cm thick.**
- **The insulating capacity is considered "Good".**

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Worksheet 3.5 – TEST

Date:
Names:

It is now time to test your shoe sole.
Follow the test guidelines 1 – 4 and fill in the test results in the tables.

What do you need?

- Your shoe sole
- An ice pack
- A digital thermometer
- A ruler
- A stop watch
- 2 rubber bands

To work!

1. Write down what kinds of insulation materials your shoe sole contains:

1. ....

2. ....

2. Measure how thick the sole is. .... cm

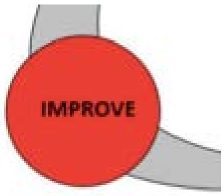
3. Walk a distance of 10 metres wearing the shoe sole.
Did it keep the air inside the sole? Yes ___ No ___

4. Feel and measure the temperature drop

1. Place the shoe sole on the ice pack.
2. Use the rubber bands to keep it firmly in place.
3. Place a bare foot on the shoe sole for 1 minute.
   Does it feel cold? __________
4. Cover the shoe sole with a wash cloth for 5 minutes.
5. Measure the room temperature (start temperature) ________________
6. Put a hole through the wash cloth and stick the thermometer through it, placing it on top of the shoe sole. Measure the temperature for 5 minutes: ______________
   Calculate the difference in temperature, from start to finish. _______________

4. Compare the results with the rest of the class.
How well does your shoe sole insulate: **Very good** **Good** **Not so well**

Worksheet 3.6 - IMPROVE



Names:
Date:

Improving is a very important part of the design process. It gives you time to reflect on your task and it gives you an opportunity to make it even better.

Discuss these questions in the group and write the answers down.

1. What kind of materials did you choose for the sole?

………

2. Why did you choose these materials?

………

………

3. We talked about the 5 criteria for good insulation. Does your shoe sole make use of one or more of these criteria?

………

4. Did your sole meet the demands? What did your test show?

………

………

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Worksheet 3.7 – A SECOND TEST

Date:
Names:

After improving your shoe sole, it is going to be exciting to see if the insulation has changed. Do the test again.

What do you need?

- Your shoe sole
- An ice pack
- A digital thermometer
- A stop watch
- 2 rubber bands

To work!

1. Measure the temperature drop

1. Place the shoe sole on the ice pack.
2. Use the rubber bands to keep it firmly in place.
3. Cover the shoe sole with a wash cloth for 5 minutes.

4. Measure the room temperature (start temperature) ________________

5. Put the thermometer through the hole in the wash cloth, placing it on top of the shoe sole.
   Measure the temperature for 5 minutes: ______________

6. Calculate the difference in temperature, from start to finish. _______________

2. How well does the shoe sole insulate now: Very good Good Not so well

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Worksheet 4.1 – How did we do?

Names:
Date:

It is now time to think about how you worked and what was the outcome.

Discuss the questions and write down the answers:

1. **What it a good experience? Why?**

2. **The engineering design process has 5 phases: What are their names?**

3. **Which phase did you like the best?**

4. **What worked well in the process?**

5. **What did not work so well?**

6. **What has been the best learning experience?**

7. **Have you gained any new skills?**

8. **What was the biggest challenge you faced?**

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Science notes for teachers about insulation

Some key science concepts involved in Lesson 2
• heat is transferred from hot to cold • different materials have different thermal properties and transfer heat at different rates • an insulator slows down heat transfer • a conductor speeds up heat transfer • the rate of heat transfer depends on the temperature difference between two objects/materials • the thicker the insulating material, the better its insulating capacity • temperature is a measure of how hot or cold something is

What is heat?

In order to understand what heat (or thermal energy) is, we must think about what matter is made of. Matter is composed of atoms and molecules (groups of atoms). Energy causes the atoms and molecules to be in constant motion (they vibrate and, given sufficient energy, they can move and bump into each other). The energy is present in the motion of the molecules (kinetic energy). Even in deepest space where temperatures are lower than minus 240 degrees Celsius, matter still has small amounts of heat energy. At the theoretical temperature of absolute zero (273 ^{o}C), all motion ceases. Heat refers to the energy of the motion of the atoms and molecules.

Thermodynamics

Energy can take on many different forms (for example: mechanical energy, light energy, chemical energy, sound energy) and many different types of energy can be converted into heat energy. An example might be when we rub our hands together to keep them warm. When energy is added to a system, it heats up and when energy is taken away, the system cools down. ***Thermodynamics*** is a branch of Physics that concerns the relations between heat and other forms of energy.

Thermodynamics creates the preconditions for the technical sciences and, thus, for a number of technical developments of great historical importance. During the Industrial Revolution in the 1800s it was discovered that machines do not consume energy, they convert energy from one form to another (e.g. the steam engine converted chemical energy from coal into kinetic (motion) energy that is able to work). It was also discovered that no matter how well the machine was designed, heat was always formed from the friction (rubbing) of the machine parts, thus spreading to its surroundings. The dream of a "perpetual motion machine" was demolished. The same is true of all natural systems where energy eventually ends up as heat. Living things operate only within certain temperature limitations and so nature provides us with a wealth of examples of heat conservation in cold climates and heat dissipation in hot climates. Some examples of insulation are provided at the end of this section.

The main principle of thermodynamics is, highly simplified:

- Energy can be converted from one form to another, but it cannot be created or destroyed. The amount of energy, in a closed system, is constant. Or simplified further:

  "You cannot take out more than you can put in."

- Heat is very special amongst energy forms. All of the other forms of energy can be converted into heat, but not necessarily vice versa. It is not possible to completely convert heat to the form of energy that it came from. In other words, heat is lower quality energy. Another word for this is the Greek word "entropy", which describes the energy's "unavailability" to be used.

Hot, cold and temperature

Hot and cold are expressions of temperature difference. When a temperature difference occurs, heat is transferred until an equilibrium in temperature is achieved. When you heat up something, the heat transfers towards the cool material, as well as the other way around if you cool something down. ***Temperature*** is a measure of the average kinetic energy (motion) of atoms and molecules expressed in terms of units or degrees designated on a standard scale (usually degrees Celsius or Farenheit).The common liquid thermometers are made of a glass tube filled with liquid alcohol (formerly they were filled with mercury but this is now less common due to health and safety concerns). Liquid thermometers work on the basis of thermal expansion. As the liquid gets hotter,molecules move more vigorously and the liquid expands, rising up the glass tube. As the liquid cools it, motion decreases and it contracts (the liquid moves down the tube). The glass tube is calibrated and so changes can be quantified.

Conduction

Conduction defines a material's ability to conduct heat energy. Some materials – mostly metals – are good heat conductors. When a temperature difference occurs between two objects (or materials), a heat transfer begins from the hot towards the cold. This process continues until the temperature difference is no longer present (is offset).

Insulators

An ***insulator*** slows down heat's migration between materials. This enables the same insulation material to keep something both cold and hot, as it both prevents heat from entering and escaping. Wood and plastic are poor heat conductors – we call those insulators. An insulating material has several parameters that determine how good an insulator it is:

> ***Thermal conductivity*****:** how easily the heat is moves and runs through the material and thus on to another material.
>
> ***Specific Heat Capacity*****:** how much energy is needed to get the temperature of the material to rise one degree centigrade

In addition, thickness and shape also determine how well a material insulates: the thicker the material, the slower the heating or cooling. Shape is also important as heat can be easily lost across a large surface area, while it is the other way around for a small surface

Good insulators

A good insulator is typically a material with high air content that prevents heat from migrating through the material. Stationary air inside the material is a good insulator because its molecules are far apart and heat energy cannot be transferred easily between them. The more air, the better the insulation. Good insulation materials consist of 94-99% air. In metals, where the atoms lie close together and are orderly in a grid, heat is more easily transferred. Metals are, therefore, relatively poor insulators but good conductors of heat.

Difference between temperature perception and measured temperature.

Sometimes our perceptions of temperature turn out to be inaccurate compared with measurements of the temperature of objects or materials. This forms the focus for Lesson 2.5. When objects are at the same temperature as the room, some will be perceived by us as colder (for example a metal spoon), and others will be perceived as relatively warmer (for example a woollen jumper).To understand why this happens we need to think about the temperature of the room *in relation to* our hands and about the insulating properties of the objects/ we are touching. If the room temperature is lower than our hands, materials that are good at transferring heat from your hand will feel cooler (metals are poor insulators but good conductors). In contrast materials that are slower at transferring heat will feel comparatively warmer (woollen jumpers are good insulators and poor conductors).

The shoe:

The warm shoe is a result of chemical energy being converted into heat. The body's cells burn glucose from the food we eat together with oxygen that we breathe in the process called ***respiration***. This process causes heat to be transferred and we use this to control our body's temperature at 37° C. Keeping the shoe warm requires energy, otherwise the foot in the shoe ends up having the same temperature as the ice underneath the sole. Our challenge is a question of slowing the heat flux through the sole as much as possible by using everything we've learned about insulation.

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Some pupils' ideas about the science of insulation

Children's thinking about the natural world comes from their everyday experiences. They may not represent the established current scientific view but they usually contain sensible reasoning based on observation and interaction. Offering opportunities for children to challenge their thinking through activity is more likely to shift their perceptions than telling them facts. However, this presents a significant pedagogical task. It is extremely demanding for learners at all levels and ages to accommodate new ideas about a particular phenomenon, especially when these seem to contradict common sense reasoning. Although through research we have some insight into the ideas pupils are likely to have in particular conceptual domains in science, often, pupils have difficulty in articulating their thinking so there is a need to exercise some caution in making assumptions about their reasoning. This highlights the importance of providing opportunity for children to discuss their thinking.

Research shows that heat, temperature and energy are difficult concepts for pupils (1). A few common misconceptions include the idea that some objects (such as blankets) produce their own heat. Children may believe this because they have experienced feeling warmer after covering themselves with a blanket or putting on a sweater. They may think that some substances (e.g. flour, air) cannot heat up or that temperature depends on the size of an object. Another area of misconception deals with the words "hot" and "cold." Pupils often believe that heat and cold are different, and that they are substances rather than a subjective reflection of temperature. Pupils may also believe that "cold" is transferred from one object to another – their experience with coolers and refrigerators seems to confirm this misconception. As in many areas of science, there is the potential for the everyday use of language to conflict with precise scientific use.

Read more about pupils' ideas in this area at:

Source: http://beyondpenguins.ehe.osu.edu/issue/keeping-warm/common-misconceptions-about-heat-and-insulation

Scientific understanding of heat (thermal energy) depends on understanding the motion of atoms and molecules. Such abstract concepts may be beyond the comprehension of many pupils engaging in this unit. Teachers will need to use their professional judgement in deciding whether to explain or how far to go in explaining that heat is a consequence of the motion of atoms and molecules. For the purposes of the unit, it is important that the pupils understand the *direction* of heat transfer (from hot to cold), and that the *consequence of the heat transfer* is that the hot object/material becomes cooler and the cooler object/material becomes warmer and that they eventually reach *the same temperature*. At this stage, the teacher will simply tell the pupils that heat transfers from hot to cold as there is no *simple* way to prove that this is the case. It is important, therefore, to ensure throughout that this idea is reinforced. Teachers should avoid talking of 'the cold' as an entity (this is easy to do in everyday conversation). They should encourage pupils to think in terms of heat transfer. In Lesson 2 pupils develop knowledge of the different thermal properties of some materials and know that an insulator slows down heat transfer and a conductor speeds up heat transfer. They will also gain knowledge through practical experience of the influence of temperature differences between objects/materials and thickness of insulating material on the rate of heat transfer.

Lesson 2 also helps pupils understand that temperature is a measure of how hot or cold something is. When pupils measure the changing temperatures of materials/objects, teachers can use this as an opportunity to address the common misconception that temperature is a property of an object. Lesson 2 also calls attention to the fact that our senses may deceive us in estimating how hot or cold something is (metals feel cold) and that there is a need for an accurate way of measuring temperature.

References

(1) Driver, R., Squires, A., Rushworth, P. & Wood-Robinson, V. (1994) *Making sense of secondary science. Reserach into children's ideas.* London: Routledge.

Background information for the teacher

Insulation in nature

This background section is meant for the teacher, but the stories can also be adapted for the pupils.

How the polar bear stays warm

The polar bear's fur protects the bear well against the cold. The secret is that the fur is good at trapping air and air is a good insulator. The polar bear's fur consists of two layers: an undercoat of short hairs that are good at trapping air between them, and the guard coat consisting of long tubular hairs. These long hairs assure that the air does not escape from the undercoat. Since the hairs are hollow, they are filled with air, which also helps the bear to stay warm. The polar bear's fur is so efficient that the bear can maintain its body temperature even when temperatures around it are below minus 30 degrees. A polar bear's fur does not insulate very well if it gets wet. That is why it shakes it as soon as it gets out of the water. The Eskimos copy the polar bear when they make clothes. They use bearskin for clothes that do not often get wet, while they use sealskin for a lot of their other clothes. Researchers have photographed polar bears with infrared cameras that can detect heat emitted from living organisms or objects. Polar bears are 'invisible' on these pictures, because their fur insulates them so well that they hardly lose any heat.

The musk ox stays warm at 40 degrees below

The musk ox is famous for being the animal with the warmest coat in the world. Its coat consists of two layers. The guard coat consists of thick long hair. The undercoat consists of insulating wool. Musk ox wool is eight times warmer than sheep's wool. The thickest and longest guard coat hairs are on the ox's rear, and when the cold polar wind blows, the musk ox stands with its rear facing the wind.

The snowy owl has feathers on its feet and in the face

The snowy owl is one of the few birds that can live in the coldest polar areas. Its plumage insulates it efficiently against the cold. Long feathers cover its face as well as its legs and feet.

Seals have a thick blubber layer

The seal spends most of its time in the water where fur doesn't insulate well. For this reason, sealskin is waterproof and lined with a thick layer of fat, which insulates against the cold. The seal's fat is also called blubber. There isn't any blubber in its flippers, but they stay warm anyway because of the principle of 'counter current heat exchange'. The principle is that cold blood in the flippers is warmed by warm blood from the body. In fact, the same principle is used in buildings where hot water from a district heating system is used to heat cold water in the building. This is achieved by placing cold-water pipes close to hot-water pipes to enable heat transfer to the cold water.

Down and feathers keep the eider duck warm and dry

You may have tried to sleep in an eiderdown duvet. If you have, you know that eiderdown is good at retaining heat. The eider duck's feather covering is very efficient at keeping the bird warm and dry. The covering consists of two layers – down and contour feathers. The down layer is very insulating because it traps air between the down feathers – and air insulates well. However, the down layer isn't waterproof or windproof, which is why it is covered with a layer of contour feathers. Contour feathers shed water, they are windproof, and they can trap the warm air in the down layer. The feathers are strong and air-filled. This is why the plumage is very light and voluminous at the same time. When it is cold, birds can inflate their plumage. This traps more air between the feathers and helps insulate against the cold. Birds have more feathers in the winter in order to stay warm. Some of the finest duvets are filled with eiderdown.

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Eskimo clothing

The Inuit – or Eskimos – live close to The Polar Circle in a very cold climate. Their traditional clothing consists of at least two fur layers with a layer of insulating air between the fur layers.

Insulation inventions

In this unit, the pupils test and improve their products. This is also how it works in the real world, where the inventor isn't always the one to put an idea into production. Others, with a better or quicker eye for its potential, can snatch the idea.

Mineral wool – wool made from rock

Mineral wool can be used to insulate walls. The idea comes all the way from Hawaii. Hawaii is an island group of volcanic origin. Several of the volcanoes are still active. When they spew lava, some of the lava is drawn into thin rock filaments that can be found on the beaches as a kind of rock wool. In the old days, the natives thought that it was their goddess Pele who had been so angry that she had pulled her hair out. This inspired the production of mineral wool which today is used all over the world to insulate buildings. The reason for this is that mineral wool is a strong and durable material that can trap air and thus insulate against the cold.

The thermos is an old invention

Some inventions start as a solution to a definite and defined problem. Later on, the same principle can turn out to be useful in another context. This was the case with the thermos.

The scientist James Dewar invented the thermal flask in 1892. Among other things, he was working with liquid gases, and he got the idea that they could be stored in a kind of double flask consisting of a big flask, surrounding a smaller flask, with a vacuum in-between. He discovered that this vacuum was very efficient at keeping the heat in place and at keeping a certain temperature in the inner flask. Although, today, we know that this is a very good idea, many years passed before James Dewar's idea left the lab – and he wasn't the one who made money from this invention. It was two German glass blowers who got the idea to transform the thermal flask into a product for the general public – the thermos. For a long time thermos flasks would easily break, because the flask was made of glass. In the 1980s, however, the thermos was improved further with the flask itself being made of steel, making it much tougher.

Synthetic fibres copy the polar bear's fur

In the olden days, winter clothing was often made from animal skin and fur. Today synthetic materials are widely used, and nature's solutions are copied in the design, the materials and in the technology. For instance, the polar bear's fur has inspired the development of hollow synthetic polyester fibres leading to a material that is lightweight and warm.

Facts about Greenland

Greenland is the biggest island in the world with a total acreage of 2.166.000 km² (approximately 50 times as big as the acreage of Denmark). It has a population of about 56.000 people. Greenland A Danish colony until 1953) today it has self-government.

Greenland is situated in the polar climate zone. The temperature during the winter is often less than -50° C. and during the summer it is rarely above 10-15°C. Nearly 80% of the island is covered by ice all the year round. During the summer months the land can be ice-free along the coasts and this is where the Greenlanders live. From ancient time, the dog sledge has been the Greenlanders obvious means of transport on land. The Greenlandic dogs, which pull the sledges, have totally adapted to the very cold climate and they live outside all the year round.

The Arctic Circle goes through Greenland**.** The Arctic Circle is the boundary between the area where you can and cannot experience the midnight sun. Precisely at the Arctic Circle there is a single 24 hours midnight sun at the time of midsummer, and the further you get to the north the longer becomes the period with daylight at all hours.

Ilulissat, which is situated a bit north of the Arctic Circle, has the midnight sun from the 19th of May to the 22nd of July. North of the Arctic Circle, you can experience that the sun during these periods doesn't set below the horizon and therefore it is light, day and night. It is the reverse during the winter; the sun doesn't rise above the horizon and therefore it is dark, day and night. Although the sun is in the sky all summer it does not get warm in the far north because the sun hangs low in the sky; there is hardly any difference between day and night temperatures. The closer you get to Equator, the higher the sun is in the sky and this generates more heat.

The world's largest island contains a huge amount of richness of exciting species which are adapted to the arctic climate both at land and in the sea.

The polar bear is the biggest predator and is the essence of the wildlife, which also include other distinctive animals like the musk ox, the narwhal and the walrus. Along with the reindeer, the musk ox is one of the terrestrial animals which travellers have the best opportunity of seeing. Wolves, polar foxes, mountain hares and other smaller terrestrial animals also exist; however, they are not seen close to civilization. Around 60 species of birds breed in Greenland, among these are the sea eagle. Whales appear all over in Greenland and are often seen during the summer. It is most common to see fin whales, humpbacks and minke whales. Yet, species like the Greenland whale, blue whale and the sperm whale often visit the waters around Greenland.

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Er zijn 10 lessenseries beschikbaar in deze talen:

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