Life support
Direct water flow to plants
Agricultural engineering
Plants
Unit for pupils from 9-12 years

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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: 5 hours 55 minutes (355minutes)

Target group: 9 - 12 year old pupils

Description

This is an inquiry based learning unit which engages pupils with engineering by inviting them to participate in a design challenge concerning the transport of water. This unit introduces a new view on how we can learn from nature, focusing on agricultural engineering and the science of plants.

- Pupils will follow a story about travelling to another planet and building a settlement there. They will solve the same problems as the main character in the story while learning about how important plants are for life, how water can travel upwards and designing and building a system for transporting water.
- The unit supports group work and shared decision making.

Science curriculum: this unit relates to the science curriculum for plants.

Engineering field: this unit introduces the field of agricultural engineering.

Objectives: in this unit the pupils will learn:

- what the Engineering Design Process is and how to use it;
- that plants take up and transport water;
- that different materials absorb water in different ways;
- to work in groups and to evaluate their work.

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 design process. The unit begins with a story is about an attempt to colonize a new planet. The problem is to design a way of transporting water for plants on the new planet.

In Lesson 2 the 'ask' element of the engineering process leads to an investigation of the needs of plants, transport of water in plants, and the types of material that can transport water upward as plants do.

Lesson 3 involves the pupils in applying the engineering design process to meet the challenge. The main challenge is to construct a system to water plants gradually without using machines or human power.

In Lesson 4 it's time to evaluate the process of creating a system for transporting water. This is also the moment for pupils to show if they were able to meet all the criteria for success and to talk about how they made improvements.

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Resources

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

Material	Total amount	Lesson 0	Lesson 1	Lesson 2	Lesson 3	Lesson 4
Plastic bowl 				2		
Blue ink or food colouring, liquid or powder	5			2	3	
Wooden stick (skewer) 	10			2	8	
Chinese lettuce- leaf  Also fennel, celery can be used	1			1		
Scissors 	1					
Paper box (minimum 300 x 200 x 200 mm) from office paper or shoes	1			1		
Office tape 	2			1	1	
Bandage cotton, not plastic 	3			1	2	
Piece of material (minimum 50 x 200 mm) 	4			1	3	

Cotton yarn 	1			1	2	
Paper tissue- pack 	3			1	2	
Ball of wool 	2			1	1	
Straw 	6				6	
Plastic bucket 	6				6	
Plastic tube (3 cm in diameter) 	2 metres				2 metres	
Paper- Size A4 (210 x 297)	10			4	6	
Sponge – kitchen 	5				5	
Aluminium foil 	1				1	
Plastic sack (trash)	3				3	

						
Plasticine 	3			3		

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

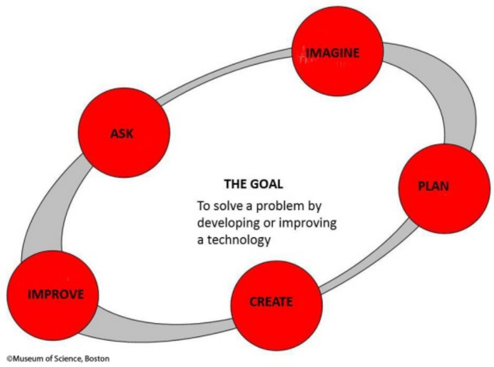
- Small groups
- Whole class discussion

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 technology that the engineer applies to solving the problem.

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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.

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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:

- that agricultural engineers are an important profession with a major role in food production;
- that the food we eat is derived from plants;
- that the scientific and engineering challenge for successful food production is to create the conditions in which plants can grow.

Resources (for 30 pupils)

- 30 x Worksheet .1: "What does an agricultural engineer do"
- 30 x Worksheet .2:"From plant to food"

Preparation

Print worksheets

Working method

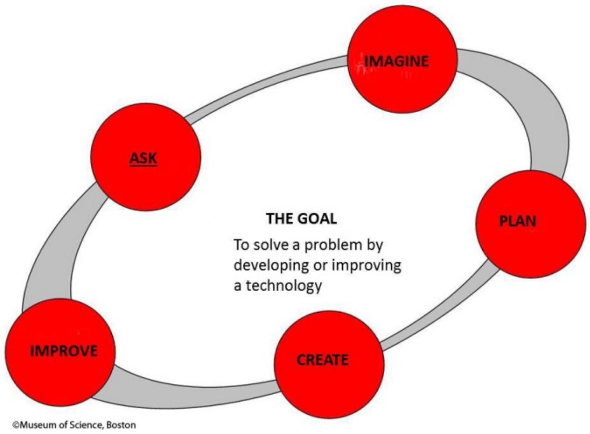
- Group and whole class discussion
- Individual work

Key ideas in this lesson

- That plants are the basis of our food.
- That plants require certain conditions to survive.
- Engineers are important to our survival in the modern world.

Context and background

The challenge and the design cycle are introduced. Pupils learn what an agricultural engineer does, and the importance of plants in human survival. The challenge of transporting water for plants is introduced.



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1.1 Introductory activity – 15 minutes

Welcome the pupils to this unit on agricultural engineering and explain that all of them could become agricultural engineers. Read the first 2 parts of the story "Water for plants" – see **appendix 2**

Ask the pupils: What do you think an agricultural engineer does?
Where do they work?
What kinds of problems do they solve?
Why do you think an agricultural engineer is needed in the story?

Write answers on the board.

Ask the pupils to complete **Lesson 1 worksheet 1:** "What does an agricultural engineer do." Emphasise that engineers work with the engineering design cycle in order to solve problems.

1.2 A new home - whole class discussion - 15 minutes

Read part 3 of the story.

Ask: "What do people need to build on a new planet so that they can survive there?"

Draw a circle on the board labelled "Landing dock". Ask pupils to add their ideas for other parts of the outpost.
Prompt the discussion: "What are people going to breathe?", "Where are people going to eat?" or "There are children on the outpost too. Where are they going to learn?"
Elicit a variety of ideas including power plant, workshop, greenhouse, accommodation unit, school, water processing plant.

1.3 The importance of plants – whole class discussion, game in pairs - 20 minutes

Finish reading the story (part 4). Remind the pupils that the unit is about transporting water so they need to focus on the greenhouse. Ask the following questions:

- What do we use a greenhouse for? (people grow plants in it)
- What is an advantage of a greenhouse compared to fields outside? (people can design conditions for growing plants)
- What are the disadvantages of using a greenhouse? (large area, fragile, etc.)
- Why do we need plants? (all the food that we eat is derived from plants)
- What about meat? (animals feed on plants, or on other animals which in turn feed on plants)
- Is there anything else which people need plants for? (oxygen)
- What plants are used to make the food that you usually eat?

Ask pupils to complete **Lesson 1 Worksheet 2** "From plant to food"

Additional activity if there is time:

Ask pupils to cut pictures of the food and plants from the worksheet to play the game 'Pelmanisms'. Players put the pictures on the table with the pictures face down. The first player picks up one card and looks at the picture and places it face up on the table so that both players can see. The second player needs to find a picture which is connected to the first (food – plant). They pick up one card. If the cards form a pair, that player keeps the pair. If not, both cards are replaced face down and the second player picks another card. Players who remember which cards and which are more likely to find pairs. The, winner is the player who has more pairs of pictures at the end.

1.4 Conclusion – plenary - 10 minutes

Recap on the main points of the lesson:

- What does an agricultural engineer do?
- What are greenhouses for?
- Why are plants important for people?
- What is the problem that the people on the new planet need to solve?

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Lesson 2 – What do we need to know?
Finding out about agricultural engineering and plants

Duration: 105 minutes including 15 minutes extension

Objectives: in this lesson the pupils will learn:

- the conditions necessary for plants to live;
- that water is transported upwards from the roots to all parts of the plant and that this can be replicated in manufactured material;
- that experimentation is central to scientific discovery.

Resources (for 30 pupils/ 10 groups)

- ☐ 30 x Worksheet 3: "Building the greenhouse."
- ☐ 30 x Worksheet 4: "Testing the materials"
- ☐ 20 x Plastic bowl
- ☐ 20 x Blue ink
- ☐ 20 x Wooden stick (skewer)
- ☐ 10 x Chinese lettuce (fennel, celery)
- ☐ 10 x Scissors
- ☐ 10 x Paper box
- ☐ 10 x Tape
- ☐ 10 x Bandage
- ☐ 10 x Piece of material
- ☐ 10 x Cotton yarn
- ☐ 20 x Paper tissue
- ☐ 10 x Cotton wool
- ☐ 10 x Paper (A4)

Preparation

- Copy the worksheets.
- Gather materials together.

Working method

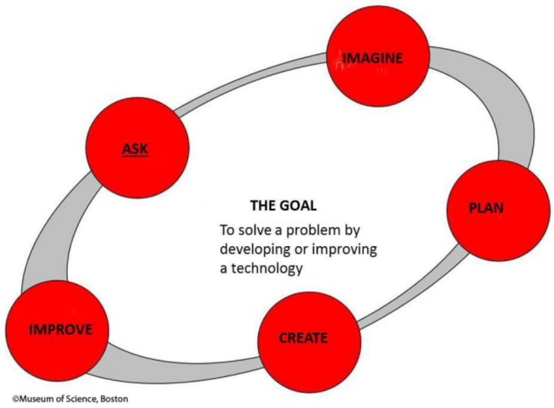
- Small groups
- Individual work
- Whole class discussion

Key ideas in this lesson

Water can be transported upwards and this is called capillary action
People use materials made from plants to soak up water.

Context and background

The pupils already know that people need plants to survive. They will gather the information about plants that they need for the challenge in this lesson. They will learn about what plants need and how people must provide them in certain circumstances if plants are to survive.



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2.1 Introductory activity – whole class discussion - 10 minutes

Recap on what was covered in lesson 1:

- What was the story about?
- Who was the main character?
- Why did people need to build the outpost on the other planet, New Earth, in the story?
- Why did they need the greenhouse?
- What plants are used to make the food that you usually eat?
- What was the problem that the new settlers had to deal with?

2.2 The greenhouse – whole class and group/ individual work - 20 minutes

What does a greenhouse need to include?
What do plants need in order to grow? (Soil, air, water, light, heat…)
Collate answers on the board.

Ask pupils to work on **lesson 2 worksheet 3** 'Building the greenhouse'. The upper half rehearses facts about plants and what they need. The lower half of the worksheet shows a base for the greenhouse. The task is to design the greenhouse, so it can provide plants with everything that they need.
Greenhouses need to include: Ventilation system, soil, heating, irrigation system, glass walls

2.3 Transport of water in plants – experiment in groups - 20 minutes

In this experiment pupils will find out how plants transport water.
Divide the class into groups of 3 (4 pupils maximum).

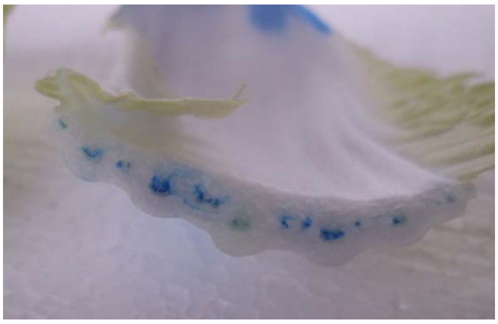
You will need these materials:

- Plastic bowl
- Blue ink or food colouring
- Wooden stick (skewer)
- Chinese lettuce /other appropriate vegetable (e.g. fennel, celery)
- Scissors

The pupils will need to place the Chinese lettuce leaves so that they are standing upright in the plastic bowl. This can be a small engineering problem in itself, and pupils will need to work out how to do it. Next they pour the ink/food colouring into the bowl so that the leaves are standing in the ink, and take note of the time. Each group should use two leaves as a minimum. The leaves will need to stand in the ink for ten minutes.

Next, pupils should take the leaves out and start to cut them from the top in strips of 1-2 centimetres wide across each leaf. *Watch out with the ink! The pupils need to be careful or their clothes may get stained.*

The pupils should observe every cross section very carefully to see if there are ink spots. They should continue to cut off strips until they can see blue spots (see illustration). They should then measure how high the ink has risen up the leaf and record this in worksheet 4.



Ask pupils to explain what they think has happened. The experiment shows that plants can transport water upwards.

2.4 Extension parallel activities – 10 and 5 minutes

The pupils should be given the following additional tasks while they wait for the ink to be soaked up into leaves;

Tearing up a paper tissue - 5 minutes

Every pupil takes one paper tissue and unfolds it. They should hold it between two fingers with one hand. The task is to tear a strip of paper from the paper tissue. Then turn the paper tissue through 90 degrees and try to tear other strip. Pupils will find that it is easy to tear the strip in one direction, but it is impossible to tear it in the other.

Why? *The paper tissue is made from cellulose, the most common organic substance on Earth. Cellulose is made up of long chains of molecules called glucose. That's why the cellulose has a direction and the paper tissue can only be torn in one direction.*

2.5 Testing materials – experiment in groups - 30 minutes

Working in the same groups as they did in Activity 2.3, pupils can now test how materials can transport water in the same way as plants.

Materials needed for this experiment:

- Scissors
- Cardboard box
- Tape
- Bandage
- Piece of material
- Cotton yarn
- Paper tissue
- Wool
- Paper (A4)
- Ink or food colouring

– Plastic bowl

Ask pupils to look closely at the materials (bandage, textile, cotton yarn, paper tissue, wool, paper) and predict which will soak up the ink the fastest. They should write their predictions on **lesson 2 worksheet 4** "Testing materials". Make sure that the pupils to realise that all the materials are made from plants.

The pupils should cut a slit in the top side of the box and a large viewing hole in the front side (see illustration). Next, they need to cut each of the materials to the same length so that they fit inside box (see illustration). They then need to arrange the materials side by side, hanging vertically from the slit at the top of the box. They will need to stick the pieces in place with tape, so that they stay in place. The pupils should then pour the ink into the plastic bowl and place it into the box, so that each material touches the ink and the ink can soak in.

After five minutes, pupils should measure how high the ink has reached in each of the different materials. They should record the height of each on worksheet 4.

Note: *this lesson can be a little hazardous. The pupils need to be careful; they must not eat anything and they need to wash their hands after each activity. Although the ink should be washable, you can use diluted food dye instead, which is more easily washable.*

2.6 Conclusion – plenary - 10 minutes

Ask the following questions:

– What are the parts of plants?
– What do plants need for life?
– When is it possible for water to travel upwards? The pupils have observed two situations when this happened; one with the plant and the second with the different materials. What causes water to be transported up?
– What materials can soak up water in a similar way to plants? And how fast?

Ask pupils to look at the picture in worksheet 4. Explain the phenomenon of capillary elevation. A capillary is a very thin tube. If water covers the surface of the capillary well enough, it will rise. This also occurs in plants.

How might all this be helpful for solving the problems of the settlers on the new planet?

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Lesson 3 – Let's build!
Design your construction for transporting water

Duration: 115 minutes

Objectives: in this lesson the pupils will learn:
- to deploy the engineering design process to meet an agricultural engineering challenge;
- that different materials have different capillary properties;
- that practical problems can be solved through the careful and collaborative application of skills and thought.

Resources (for 30 pupils)
- ☐ *30 x Paper tissues*
- ☐ *30 x Straws*
- ☐ *10 x Construction kits:*
- ☐ Scissors
- ☐ Paper box
- ☐ Tape
- ☐ Bandage
- ☐ Piece of textile
- ☐ Cotton yarn
- ☐ Paper tissue
- ☐ Wool
- ☐ Paper (A4)
- ☐ Ink or food colouring
- ☐ Plastic tube
- ☐ Plastic bucket
- ☐ Two sponges
- ☐ Aluminium foil
- ☐ Plastic sack
- ☐ Wooden sticks (skewers)
- ☐ Plasticine

Preparation
- Make copies of worksheet 5
- Collect materials
- Make a large copy of the EDP

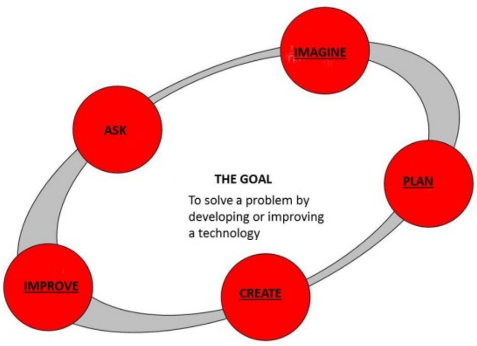
Working method
- Discussion
- Group work

Note: All the constructions that the pupils build in this lesson will, take at least one night to soak up the water. Make sure that there is a suitable place for them to be stored before the pupils start to build.

Key ideas in this lesson
- The pupils can now work as engineers. They will work in groups and will learn that teamwork is important. An important feature of the lesson is realising that they can build something with their hands.

Context and background

The pupils will solve the main engineering challenge in this lesson. They will create a system to transport water from a reservoir to a plant. They will follow the engineering design process, planning their construction before building it.



3.1 Introductory discussion - setting out the engineering challenge – 15 minutes

Re-read part 4 of the story. Tell the pupils that they will now work on the main engineering challenge. The main challenge of the unit is to build a construction which can transport water from the reservoir to the model of a plant.

First, talk through the engineering design process using the diagram (see Appendix 1). Ask the pupils to think about what parts of the process they will go through to build their construction. What have they already done in the previous lesson? *The have followed the Ask phase.* What comes next? *The imagine and plan phases*.

But first they need to make their own model of a plant.

3.2 Making a plant – 20 minutes

Ask pupils to follow the instructions on **lesson 3 worksheet 5**. Each pupil should take one layer of paper tissue and fold it lengthwise with two folds (see illustration on the worksheet). Then roll it loosely. This creates the flower. They then need to roll the rest of the paper tissue very firmly to create the stem. This needs to be rolled tightly enough to get it into the end of a straw. Finally, place a piece of the paper tissue into the other end of the straw to serve as a root.

They now have their plant that will need water.

3.3 Planning phase – whole class discussion and work in groups - 25 minutes

The pupils will now plan their constructions in groups so the class needs to be divided into groups of 4/5 pupils. Provide each group with a materials kit and give them a few minutes to familiarise themselves with the kit. Emphasise here the need for careful planning as being central to the success of an engineering project. The pupils need to discuss and agree a set of criteria on which the success of their project will be based. These are:

- The water must reach a plant which is 30 cm from the bucket.
- Water must not be spilt.
- The construction must be stable and able to stand alone.
- The model plant must soak up the coloured water and so that the flower changes colour

They then need to list the material needed for building the construction and draw their plan on **lesson 3 worksheet 5**. They need to think carefully about the function of each item in their resources kit and how best to use it. The bucket is clearly the reservoir and the sponge has to be in contact with the roots of their plant but how to convey water to the sponge without catastrophic water loss is a challenge (clue: the plastic tube and aluminium foil might be especially important here). Emphasise that working in a team and listening to everyone's point of view is important.

Once each group has a workable plan they can build their water supply.

3.4 Constructing the water supply – work in groups - 45 minutes

Working in the same groups and following their plans from the previous activity, they can use any of the available materials. The bucket needs to be empty for the building phase, and should be filled when the construction is complete. Fill the bucket with water and colour it with ink or food colouring. Pupils need to fix their model plant into the sponge, which works as a model of the soil. Water needs to be delivered to the sponge.

When the groups are satisfied that they have created the best agricultural engineering structure they can, given the constraints of time and resources, they need to leave their model and gather together for a concluding discussion

Note: the models will now need to be left overnight to allow time for the water to travel so it is really important that the teacher has a space where the models can be left and that they are robust enough to be moved if necessary.

3.5 Conclusion – plenary - 10 minutes

Summarise what the pupils have done and discuss their experiences:

- Did your construction go well from the beginning?
- Did you need to change the construction? If so, how many times?
- What kind of materials did you use?
- Do you think your experiment will be successful? Why?

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Lesson 4 – How did we do?
Is the challenge met?

Duration: 75 minutes

Objectives: in this lesson the pupils will learn:

- that evaluation and thinking about improvement is an important part of the Engineering Design Process;
- that presentation involves important skills which can help contribute to product improvement.

Resources (for 30 pupils)

- 30 x worksheet. 6

Preparation

- Check the constructions that have been left overnight for any problems and decide how to resolve these.

Working method

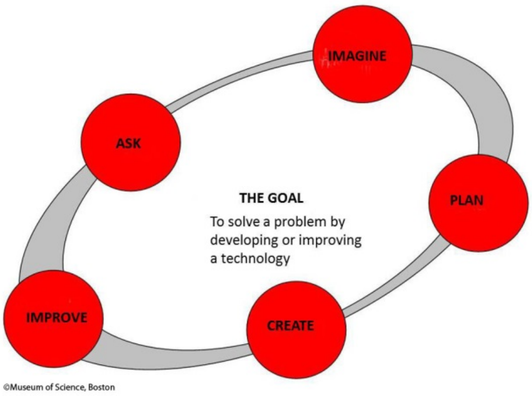
- Whole class discussion
- Individual work

Key ideas in this lesson

- A major skill to develop is that of explaining what you have built to others.
- It is important to think about how to make improvements and to look at our work from another perspective.

Context and background

This lesson is about evaluating our constructions. The pupils will assess their constructions against the agreed criteria to see if they have been successful. The class will discuss how to make improvements.



4.1 Evaluating our constructions – whole class discussion and work in groups - 25 minutes

Begin by revisiting the Engineering Design Process and asking them at which point do they think they are at now (answer = improve). Explain that improvement means careful evaluation which they will be doing in groups and presentations to others. These provide an opportunity to collect the responses of others to the way they have solved the engineering challenge. Remind the pupils of the challenge in the story. How have they helped to solve the problem? What were the criteria for success?

Write the criteria needed for a successful construction on the board:

- The water must reach a plant which is 30 cm from the bucket.
- Water must not be spilt.
- The construction must be stable and able to stand alone.
- The model plant must soak up the coloured water and so that the flower changes colour.

In their groups, pupils should evaluate their work on the engineer challenge 'Transporting water', using Lesson **4 worksheet 6.**

They should then plan how they will present their construction and their evaluation to the rest of the class. They will have just 5 minutes to present their construction to include any questions the other pupils may have. They need to report on:

- How far they transported the water.
- What materials they used and why.
- What difficulties they met.
- Ways for possible improvements.
- How they used the Engineering Design Process.

They need to plan the presentation and decide whether they will all talk or have different roles.

4.2 Presentation of constructions- whole class activity – 40 minutes

Each group has 5 minutes to present their construction and their evaluation of it. Allow time for other pupils to suggest improvements. Ensure that the discussion is constructive.

4.3 Concluding the Unit – 10 minutes

End the lesson by returning to the story. The class built a construction to transport water, but agricultural engineers work on more problems. They work also with agricultural machinery and animals. Agricultural engineers care about water, soil, environment and waste.

- What else could an agricultural engineer do on New Earth?
- What do agricultural engineers need to understand? (technology, nature, environment etc.)
- Do you the work of engineers is interesting?
- Do you feel you can be engineers now?

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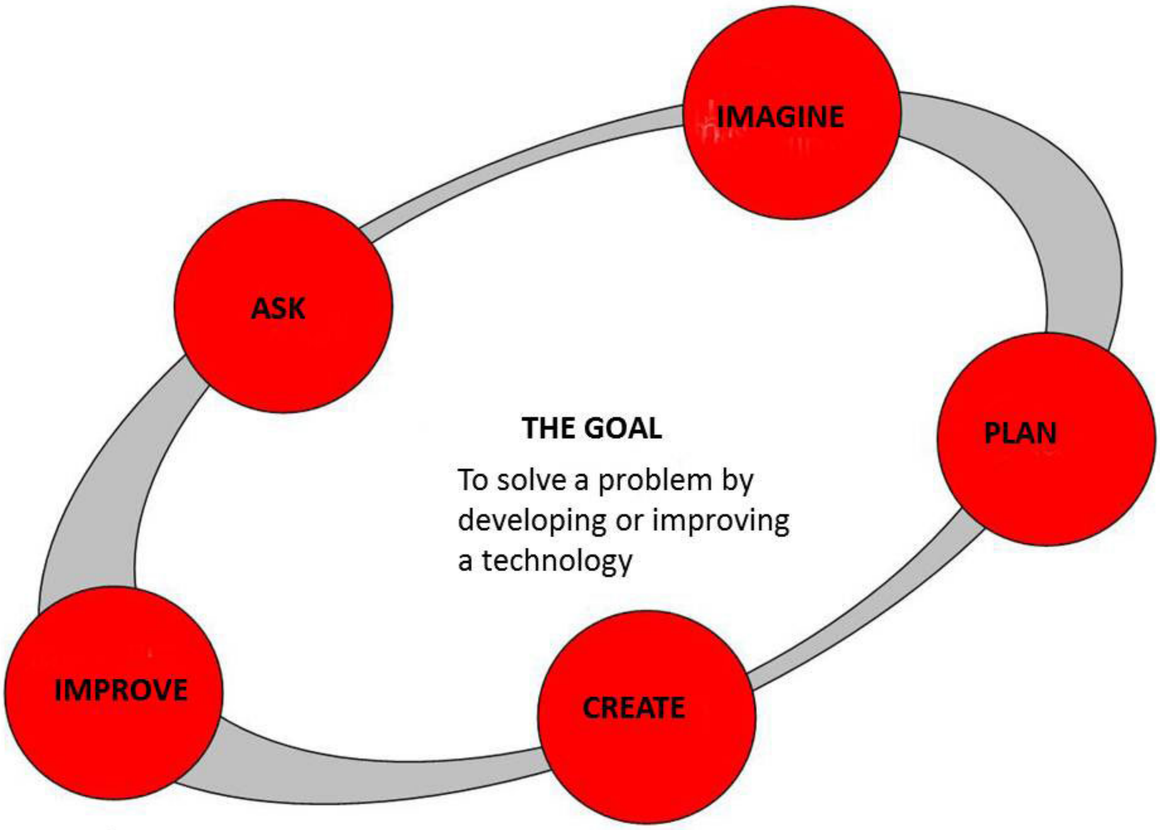
Appendices

Appendix 1: The Engineering Design Cycle



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Appendix 2: Story to set the context - Water for plants

Part One: A long journey

The last bag landed with a loud thud in the corner of the room. Jack straightened up and looked around. The room which had been his for the whole of his twelve years of life suddenly seemed strange. He saw bare furniture and no toys on the shelves or on the floor, where there used to be a significant number, and the marks of adhesive the walls where his pictures and posters had once been. He had been looking forward to what awaited him tomorrow for almost a year. But now, he was surprised by his uncertainty, whether he really wanted it to happen. But Jack, by nature, was not a boy who would be afraid to try something new. Every time he had had the opportunity to do something that he had not tried before, he had done it. Occasionally, this characteristic led him into trouble, but he nevertheless could never resist the next time.

Jack ran downstairs and walked into the living room. It was lively there. Open bags were strewn across the floor. Although they seemed to be full already, his mum was still putting more things into them. His dad was walking around with a long list and checking that they had packed it all. His little sister Eve was trying to add to what mum had packed but was taking things out of the baggage at the same time. That was how his dad saw the charger lying on the floor, even though he had already checked it off the list, and why he began to demand that everything had to be unpacked and the whole packing must start all over again. Jack decided that it was none of his business and sat down in front of the television.

He waited for two seconds, until the sensor on the television flashed to show that it had noticed him. Then he raised his hand and began to scroll the on-screen menu to choose the program. His dad noticed this.

"Put the news on from channel six; there should be something about us on."

Jack switched over to the news.

A rocket appeared on the screen and the reporter was talking in an excited tone: "A unique international project called Second Earth will begin tomorrow at 9 am. Last preparations are on schedule ..."

Jack called to his dad: "It's about us now!"

His dad dropped what he was doing and went to sit with Jack: "Are you looking forward to our venture? It will be great. So many years of work and it's starting tomorrow. I probably won't sleep today."

Meanwhile, the television report continued. A smiling reporter appeared, with huge engines behind him. A lot of other reporters working for other TV stations were hovering around too. The reporter nodded and began talking: "Good evening from the space centre, where a historic event will happen tomorrow. From this place, a rocket will take off carrying entire families as the first colonists of planet Gemini PX-572. These first pioneers will build a base that will be fully self-sufficient and independent of our Earth. If all goes well, this mission will be followed by others. We already know of dozens of planets, where additional bases can operate. Now, the entire staff here is checking all the systems. It seems everything is in order and ready for take-off."

A woman back in the studio continued: "We're making an important step for our future. This graph shows the number of people on our planet. It's a well-known curve, and you can see the rapid growth from the industrial revolution which has continued to today. We must admit that we've

learned to cope with this and the growth rate is decreasing. But despite this, the situation on Earth is unsustainable. This mission is the beginning of our efforts to survive.”
Jack´s dad turned the TV off: "She´s right, isn’t she? Go to sleep. Tomorrow will be a long day, but you will certainly remember it for the rest of your life. So get some rest. Good night."
"Good night."
Although his dad advised him to get a good night’s sleep, Jack’s excitement about tomorrow’s kept him awake for a long time. He was imagining again and again what the take-off would be like but he finally fell asleep: Jack's last sleep on Earth.

Part Two: Take-off
The doctor smiled reassuringly at Jack and patted him on the shoulder: "You're as healthy as a horse. There's nothing to worry about."
"I'm not afraid of anything"
The doctor laughed: "That’s good. You can go."
Jack left the room and sat down on the bench. He had to wait until the rest of the family had been through a final medical check-up before the take-off.
"Hi", said a voice next to Jack. He was so deep in thought about what it would look like inside the rocket and what the flight would be like, that he hadn’t noticed a girl sitting next to him. She was about a year or two older than Jack and was looking curiously at him.
"Hi," said Jack, because he was well-behaved.
"Are you flying with us? My name is Eve."
"Yes. I´m flying too with my parents. My dad is a commander," Jack said rather unwillingly, as he didn’t want to show off, but now he couldn’t do anything about it.
"Oh, my Dad is a great agronomist."
"Oh, really," Jack shrugged.
"Do you know what agronomists do?"
Jack hesitated. He had definitely heard something about it, but he was afraid to say something silly. Eve was watching him with amusement.
"Something to do with working in the fields?"
"That’s part of it - at least you know it has something to do with fields. He manages plant production, or rather he *did* manage it. He gave up his job so that we can fly. It was all incredibly fast. He didn’t expect to be chosen. When he told me, I didn´t even have enough time to say goodbye."
"Jack! Come on, we're going!" His Dad was standing at the end of the hallway and waving at him: "It’s time!"
Jack turned to Eve: "Got to go; see you then."
"Who knows, there will be a lot of families."
The rocket was huge. Jack had seen it from a distance. But now, when he was directly below it, it seemed so large that the nose was lost in the clouds. Jack knew from his dad that everything he could see from underneath was engines and fuel tanks. Jack tilted his head back so much that he nearly fell over backwards.
His dad looked up too: "We have to take a lift, it will be a long ride."
A group of engineers guided the whole family to the elevator and closed it behind them.
"I just thought - this is probably the last time my feet touch the ground on Earth," said Jack’s mum. The elevator started to move noisily, and the whole family was taken to the top of the rocket.

Part Three: New Earth

The first thing Jack felt was the cold. He began to shiver. At the same time, a bright light pierced his closed eyes. He tried to cover his eyes with his hands, but his body wasn´t responding. Then he heard his father's voice: "Jack, wake up. Open your eyes. You need to drink this." His dad threw a blanket around Jack´s shoulders and lifted him up. Jack got to his feet, stumbling, but fortunately, his father held him. He opened his eyes and looked around. They were in a cabin, where the whole family had been kept in an artificial sleep throughout the flight, in boxes. All the others had gone. His dad had woken Jack up last of all.

"Drink this up. It will do you good; you will wake up faster. You've slept for eleven months. It's hard to wake up."

Jack drank the dense yellow liquid.

"Well, now come into the main rocket and we can go down to the base. For the first time you can see your new home. We can walk around the base, so that you can find out what is where."

Part four: Working in the greenhouse

The corridor at the base was quiet and empty. Suddenly a door to a classroom flew open and more than twenty children piled out. The corridor was filled with yelling the way only pupils know how to do when they need to tell to their friends everything they couldn't say during lessons.

Jack left the classroom with Eve. There were three boys waiting for them in the corridor. They were around Eve's age. The tallest one asked Eve: "Are you coming to the store room this afternoon?"

Eve shook her head: "No, I promised my dad I would help him in the greenhouse."

Jack added: "We were almost caught there the last time. They've been suspecting that we were crawling in there somehow"

The boy persisted: "We've found a new way, through a ventilation system!"

Eve just waved and started to leave. But she turned back and said." I can't go. Go without me if you want. I have to go to see my father; he has some problems."

The boy looked at Jack: "What about you, are you in?"

"No, I'm going with Eve. Bye."

Jack ran after Eve to catch up with her.

"Wait for me. Can I go with you? I'll help your father too."

"Fine, I'm not sure what is going on. He only said it's something about the greenhouse."

Eve knocked at her father's office door. It took a moment before they heard his voice: "Come in!"

Jack and Eve went in. The office was small, but well arranged, like everything at the base. It was necessary to save every small space and everybody had to be careful about being tidy and keeping everything in order. It was a problem for Jack at the beginning of his life at the base, because being tidy was not Jack's strong point.

Eve's father was sitting at a table and typing on his laptop. He barely looked up at them: "Hi. You brought a backup person. Hi Jack. I was just talking with your father."

"What are you doing?" Eve looked at her father's table. It was covered with papers - blueprints, graphs and similar things.

"We're working on a pretty big problem, but I'm not sure if I am supposed to tell you about that."

"Why?"

"I don't want to worry you."

"Wait. If it's serious, we should know about it. We're involved in all things at this base."

“Maybe you’re right.”
Eve’s father finally turned and looked at Eve and Jack. It was obvious it was difficult for him to talk about problems with the children.
“You know I care about the operation of our greenhouses, so that we can grow plants for food.”
“Yes, we know. I told Jack.”
“The problem is the water supply is much deeper under the ground than our earlier research showed. And other sources of water are too far.”
Jack was surprised: “So, we’re running out of water? That means running out of food too!”
Eve’s father smiled: “We’re not running out of food. You don’t have to worry. But we need to solve the problem somehow or we will have problems in future. We have enough supplies for now.”
Eve repeated it again: “So the water supply is too deep.”
“Yes, that’s right. We use pumps to extract the water now, but we need so much water that the pumps are using too much fuel. We have enough fuel for only a couple of weeks. We can’t use it all on the pumps.”
Jack wanted to get it clear: “We need to find a way to transport water from deep down under the surface without using pumps?”
Eve’s father nodded: “Yes, without using the pumps. We need to do it without using energy, because we don’t have enough electricity. I was just talking with your father about whether we can turn off something to free up more electricity for pumping water. But that means slowing down other constructions. It’s complicated.”
Jack was surprised. He had never realised how complicated it all was. He had thought that everything was operating according to plan. But that’s how things go. There is always some plan, but in practice, problems come up. People often need to find solutions for problems and every solution can be improved. That‘s how engineers work.
Jack noticed how sad Eve was, because of the things they had heard. He wanted to make her happy, but he couldn’t promise her anything.
Can Jack work out a solution where Eve’s father can’t?

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Worksheets and answer sheets

Where necessary, the pupil worksheet is followed by a completed worksheet with answers, for use by the teacher.

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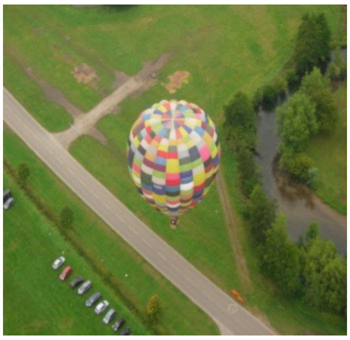
Worksheet 0 Lesson 0 - Engineering?











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Worksheet 0 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.

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Worksheet 1 Lesson 1 - What does an agricultural engineer do?

Name:
Date:

Draw lines to connect each activity with the right profession:

Designing a planting project

Managing the farming process

Engineer

Putting new plants in the ground

Take care of plants as they grow

Scientist

Bringing in the harvest

Studying plants

Solving farming problems

Farmer

Finding out new information about plants

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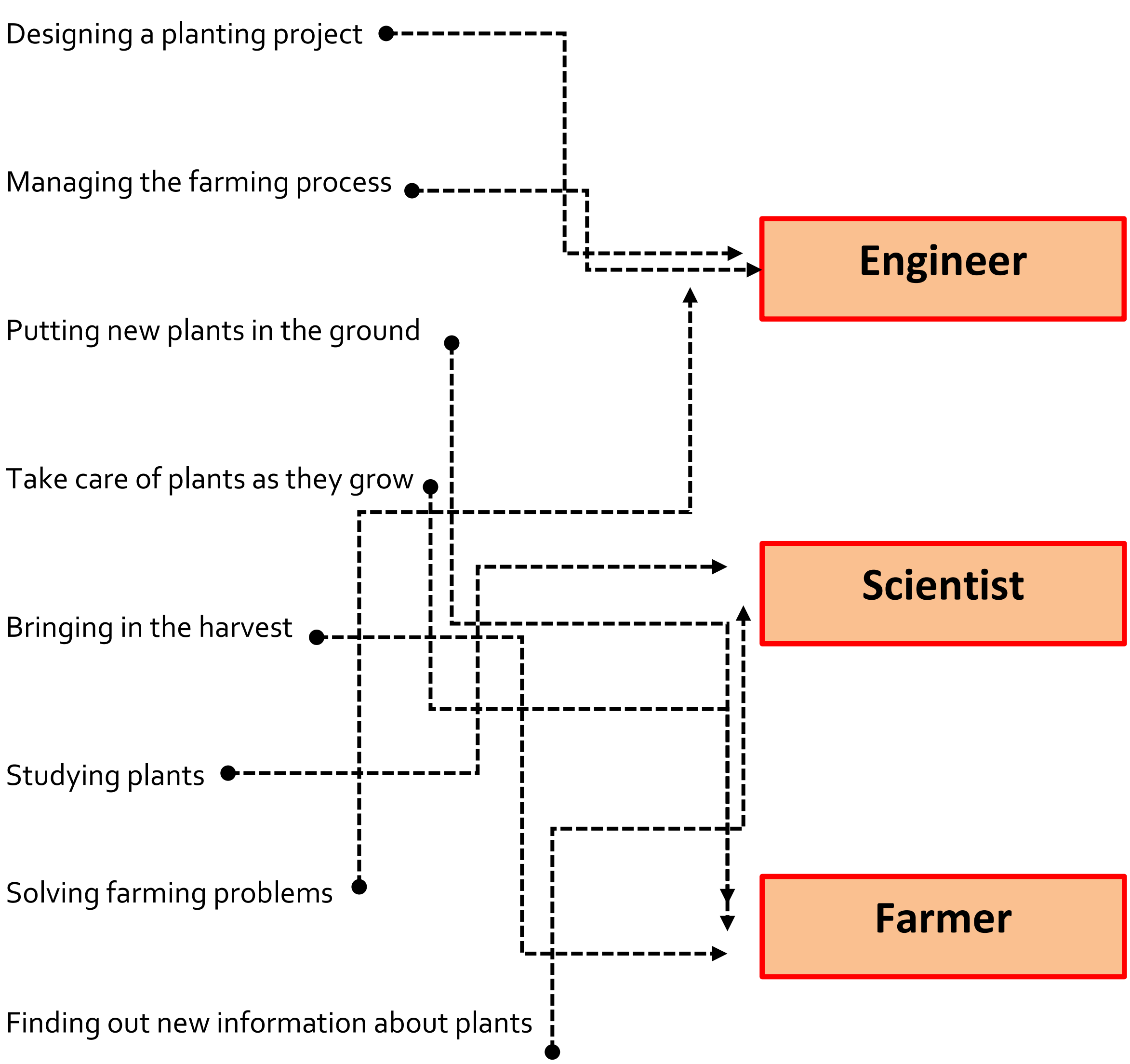
Worksheet 1 Lesson 1 - What does an agricultural engineer do?

Name:

Date:

Draw lines to connect each activity with the right profession



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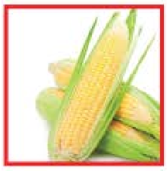
Worksheet 2, Lesson 1 - From plant to food
















Draw a line to connect each food with the plant which it is made from.

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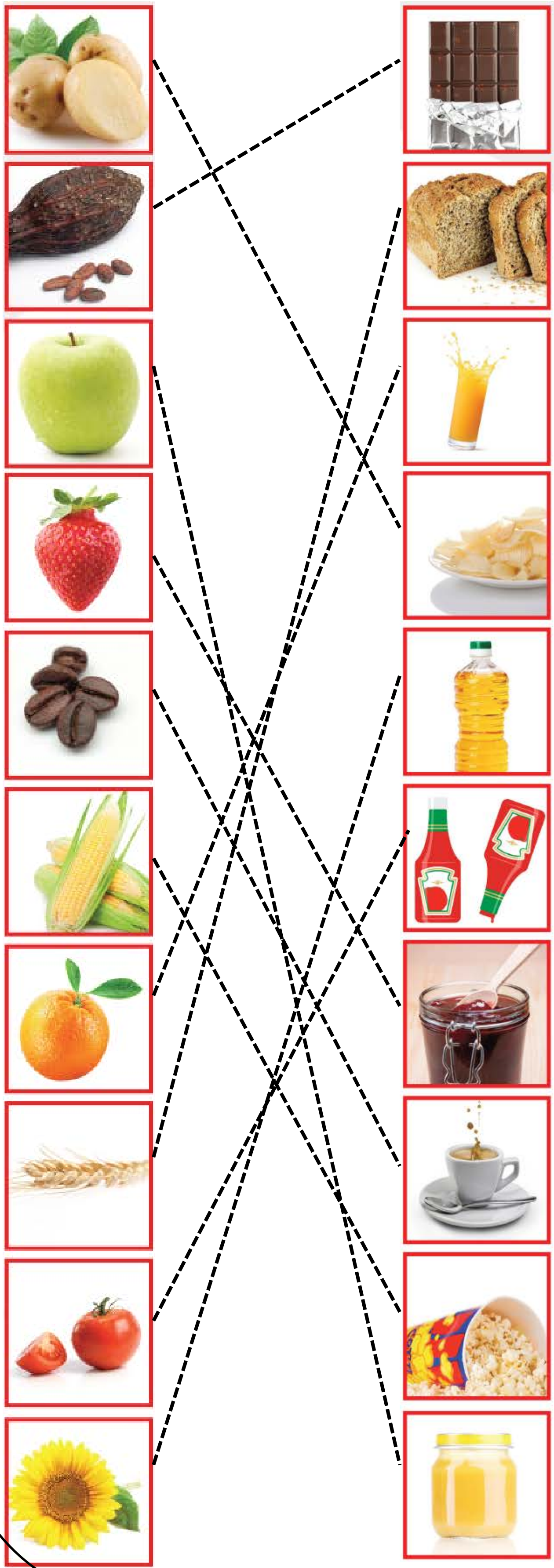
Worksheet 2 Lesson 1 - From plant to food



Draw a line to connect food with the plant which it is made from.

Worksheet 3 Lesson 2 - Building the greenhouse

Name:

Date:

Fill in the spaces to complete these facts about plants:

Parts of a plant:

R _ _ _
S _ _ _
L _ _ _
F _ _ _ _ _
F _ _ _ _

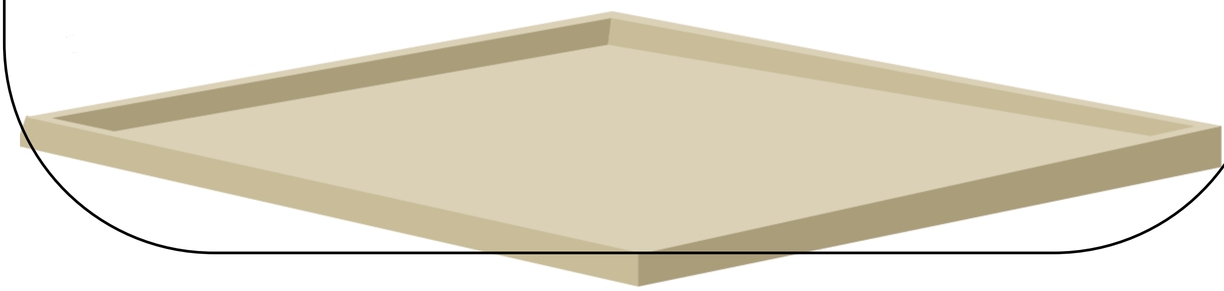
What does a plant need:

W _ _ _ _
H _ _ _
A _ _
M _ _ _ _ _ _ _

What does a plant make:

O _ _ _ _ _

Design your greenhouse on this base:



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Worksheet 3 Lesson 2 - Building the greenhouse

Name:

Date:

Fill in the spaces to complete these facts about plants:

Parts of a plant:

R OOT

S TEM

L EAF

F LOWER

F RUIT

What does a plant need:

W ATER

H EAT

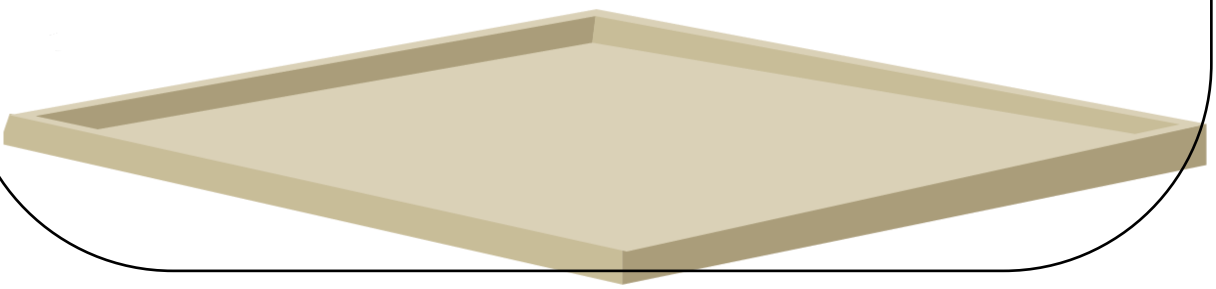
A IR

M INERALS

What does a plant make:

O XYGEN

Design your greenhouse on this base:



engineer

Worksheet 4 Lesson 2 - Testing materials

Name:
Date:

How high did the ink reach in your Chinese leaves?

_ _

Predict which material will soak up most:

_ _

Predict which will soak the least:

_ _

Now do the experiment.

How high did the ink go?

Cotton yarn _ _ _ _ _ _ _ _ _ cm
Bandage _ _ _ _ _ _ _ _ _ _ _ cm
Textile _ _ _ _ _ _ _ _ _ _ _ _ cm
Paper tissue _ _ _ _ _ _ _ _ _cm
Paper_ _ _ _ _ _ _ _ _ _ _ _ _ cm
Wool _ _ _ _ _ _ _ _ cm

The material which is best at soaking up water is _ _ _ _ _ _ _ _ _ _ _ _ _ _ _.

The material which is least good at soaking up water is _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _.

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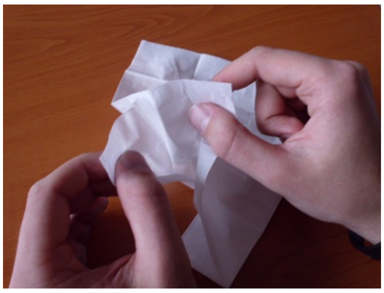
Worksheet 5 Lesson 3 - A model plant

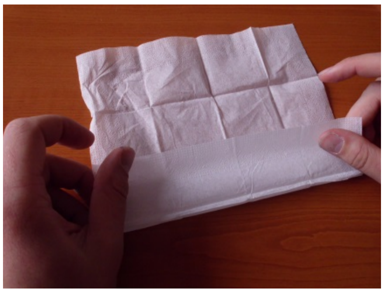
Name:

Date:

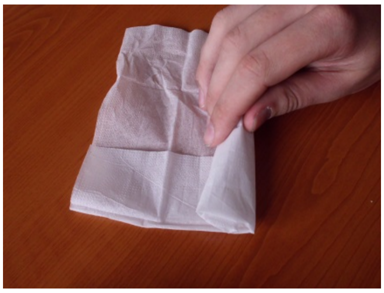
- **Make your own model plant, following the pictures.**



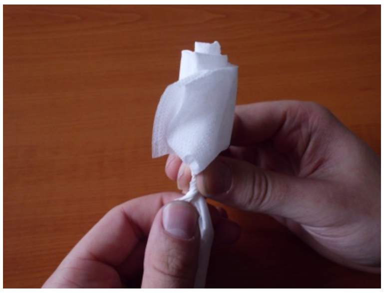
Separate out one layer of the paper tissue.



Fold the tissue layer into thirds. Don't press the edge.



Roll the paper from the side very gently



Hold the model under the folded part. This is the flower. Roll the rest of the tissue up very tightly to make a stem.

Put the "stem" into a straw. The tissue should stick out of the other end, to make a root.

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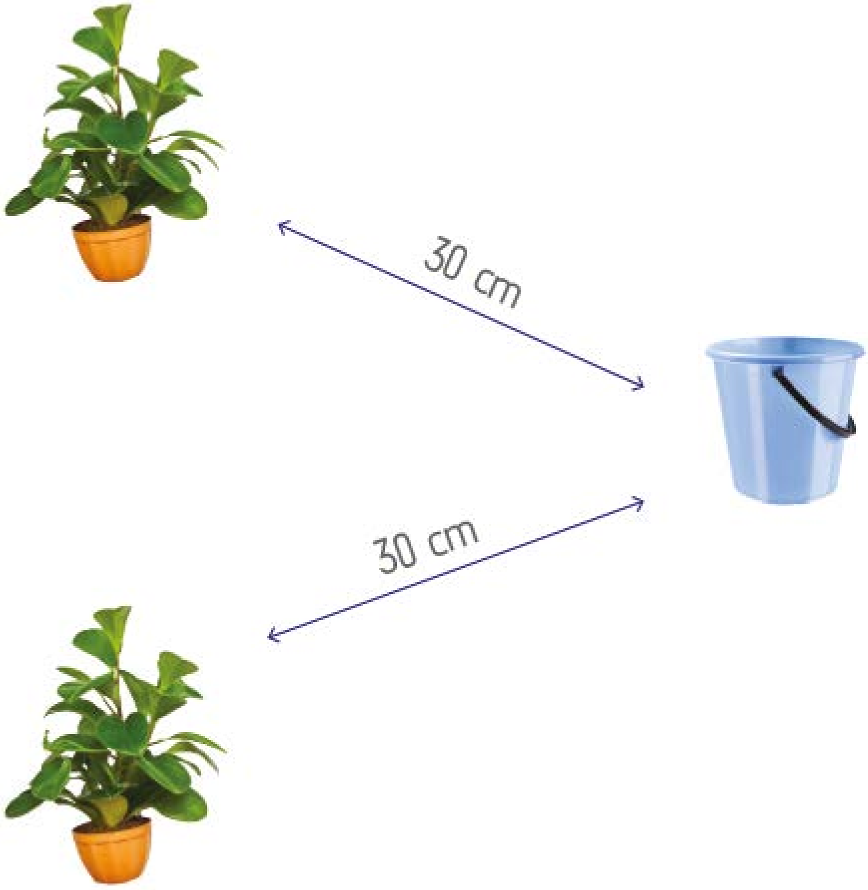
- **Plan your construction**



- **What materials will you use?**

____

____

____

____

____

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Worksheet 6 Lesson 4 - Evaluation

Name:
Date:

Which of the criteria for a successful construction did we meet?

- ☐ The water must reach a plant which is 30 cm from the bucket.
- ☐ Water must not be spilt.
- ☐ The construction must be stable and able to stand alone.
- ☐ The model plant must soak up the coloured water and so that the flower changes colour.

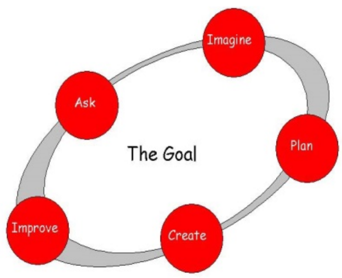
Improvements we could make:

____

____

____

The Engineering Design Process



Phases of the Engineer Design Process:

Imagine
Plan
Create
Improve
Ask

What did we do in each phase?

Imagine____

Plan____

Create____

Improve____

Ask____

Science notes for teachers relating to water movement in plants and materials

Some key science concepts involved in Lesson 2
• **conditions necessary for plant growth: water, air, light, nutrients and appropriate temperatures** • **water is transported upwards from the roots to all parts of a plant** • **natural materials can also transport water upwards (e.g. paper is made from cellulose)**

Conditions necessary for plant growth

Plants are defined by their ability to carry out the process of ***photosynthesis***. Photosynthesis is a complex process that combines *carbon dioxide* (from the atmosphere) with *water* (taken in by the plant roots) in order to produce *glucose* (a sugar). The by-product of the reaction is *oxygen* that diffuses into the atmosphere. The whole process is driven by *energy* in the form of sunlight that is trapped by a green pigment in plants (chlorophyll). While most plants have green pigments, others may have additional pigments. Brown seaweeds, for instance, contain a larger amount of additional brown pigment (fucoxanthin) that absorbs more of the blue light that penetrates further in seawater. It allows the seaweed to photosynthesise at lower light intensities when covered with water.

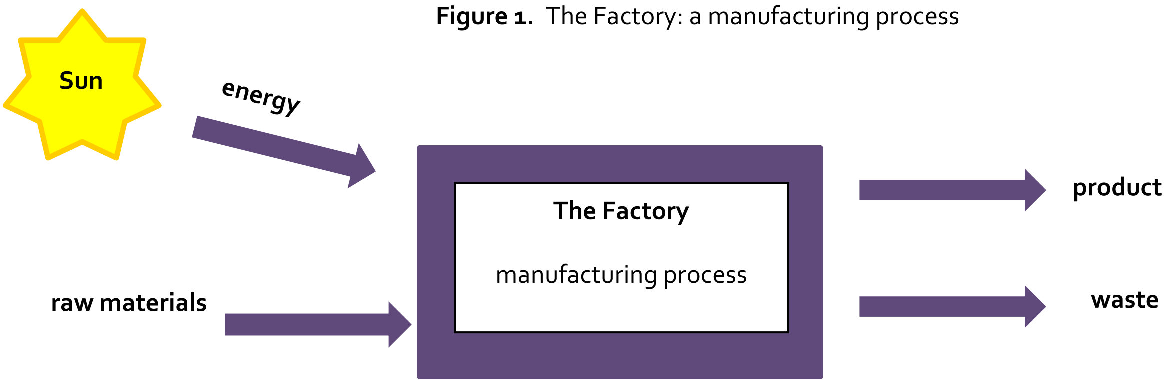
In order to carry out photosynthesis, plants have certain requirements for healthy growth:

- a supply of water (from the roots)
- a supply of carbon dioxide (from the air)
- energy (from sunlight)
- an appropriate temperature range in which the reaction may proceed

The leaves of a plant are the main site for the manufacture of glucose by photosynthesis. Consequently, plants need to expose their leaves in such a way as to optimise the sunlight that might be absorbed. Plants vary according to the size and arrangement of leaves, and they are able to adjust leaf angle in order to maximise exposure to light. Plants living in shade, for example, often have large leaf surfaces that are densely packed with chlorophyll contained within structures called chloroplasts.

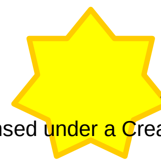
It may be useful to think of photosynthesis as a manufacturing process. Any manufacturing process involves fashioning raw materials using a source of energy to make a product. Manufacturing produces waste material (see Figure 1)

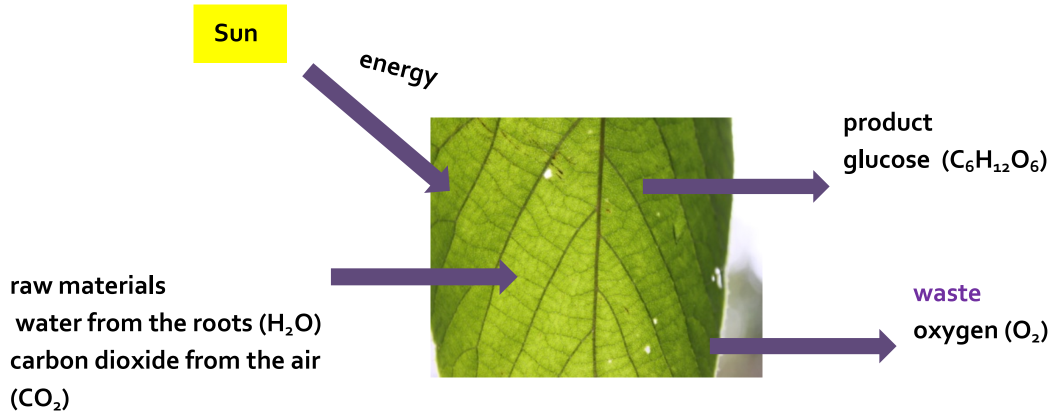
Figure 1. The Factory: a manufacturing process



We can think of the manufacture of glucose by photosynthesis using this factory analogy:

Figure 2. The Leaf Factory photosynthesis





Glucose is an extremely important molecule for plants: it provides a source of energy as well as being a building block for other substances needed by the plant for maintenance and growth. Glucose molecules joined together in long chains become coiled to make starch granules in plant cells. Staple foods such as potatoes, rice and cassava are high in starch. Cellulose (a major constituent of plant cell walls) is made of several hundred to over ten thousand glucose molecules linked in a different way to make a long chain.

Glucose also plays a critical role in the process of ***respiration*** that provides a source of energy for the myriad of biochemical reactions that take place inside plant cells. You can learn more about photosynthesis and respiration at:
http://www.bbc.co.uk/learningzone/clips/respiration-and-photosynthesis-in-plants/10608.html

Of course, as any gardener knows, plants also need a supply of other nutrients to support healthy growth. In particular, they need a source of nitrogen, phosphorus and potassium (key elements of fertilisers used to boost plant growth). They also need a whole range of trace elements in small quantities and these are absorbed from the soils they grow in. The carnivorous plants that grow in soils where nutrients are likely to be deficient, supplement their diets by ingesting insects. Learn more about these fascinating plants at:
http://botany.org/Carnivorous_Plants/

The nutrients taken in with water by the roots of a plant are used in the manufacture of an array of plant molecules including proteins that require a source of nitrogen for their production. Nuts and seeds are high in plant proteins.

How water moves through a plant

This unit concerns making water available to plant roots and understanding that water travels up from the roots to all parts of a plant carrying with it nutrients required for plant growth. This can be quite a feat in the case of plants such as giant redwood trees that can grow up to almost 100m tall! The unit does not require explicit understanding of *how* water and nutrients are taken in by plants and conducted through their tissues; it simply requires that pupils understand that this occurs. However, the teacher may desire a more in-depth understanding and the following is aimed at supporting that.

Understanding *how* plants acquire and conduct water and nutrients requires us to think about what is happening in various parts of the plant. Key elements involved are:

The leaves – on the under surface of the leaves of most plants are small pores called the **stomata** that can be opened or closed. Carbon dioxide for photosynthesis enters the leaf via the stomata and water evaporates from the pores while they are open. The leaves have a waxy cuticle that prevents water loss across the whole of the surface, so water leaves the plant through the open stomata. This process is called ***transpiration***.

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Xylem cells- are the cells that transport water from the roots to the rest of the plant. They are elongated cells connected together in bundles called **vessels.** If you soak the stem of a plant such as celery in water containing dye, the vessels can be seen easily in cross section when the stem is cut. In Lesson 2.3 Chinese lettuce leaves are used to illustrate this and to explore how the water travels through the plant. Xyolem cells form an extensive system to deliver water to the whole plant.

The roots –is the part of the plant that generally grows below the ground (although some plants do have aerial roots that can extract moisture from the air). Roots are branching structures of various types that have the role of absorbing water and inorganic nutrients from the soil. They also anchor the plant and may act as a store of food (for example, the sweet potato). They may also play a role in asexual reproduction (for example the suckers produced by cherry trees).

Root hairs – the branching roots produce small tubular extentions of their outer (epidermal) cells, mainly in the younger parts of the roots. The root hairs greatly increase the surface area across which water and nutrients can enter the plant. They permeate the soil and lie in very close contact with soil particles and form the entry point for water and nutrients.

For a more detailed description of plant structure try:
http://www2.estrellamountain.edu/faculty/farabee/biobk/biobookplantanat.html

In order to understand *how* water moves into the roots of a plant, you will need to understand the process of **osmosis**. Osmosis occurs where there are two solutions of different concentrations that are separated by a semi-permeable membrane. A semi-permeable membrane is one that lets some substances pass through but not others. The outcome is that water moves from the more dilute concentration across the membrane to the more concentrated solution until the concentrations equalise. You can see an animation of this process at:
http://www.bbc.co.uk/schools/gcsebitesize/science/add_aqa_pre_2011/cells/cells4.shtml
Osmosis is the process that brings water from the soil into the roots and carries it towards the xylem cells. It is dependent on the maintenace of a *water potential gradient*.This is created as water moves up the xylem cells thereby setting up a tension as the xylem sap becomes more concentrated than that of surrounding cells. The outcome is that water moves into the xylem cells by osmosis from surrounding cells. This is ultimately transmitted through the cells of the roots. The root hairs have a higher osmotic concentration than the soil solution and so water is taken into the plant and conducted towards the xylem cells.
But why does water travel upwards through the xylem cells?
In Biology, the explanation of how water moves through plants has been a subject of debate, especially when it comes to explaining how this works in very tall trees. The *Cohesion-Tension Theory* is currently used to explain the process. This theory is based on the idea that within a plant water travels in a continuous network from roots to leaves, including all parts of the plant. The driving force (the 'pull') is created by water evaporating from leaf stomata (transpiration). The water loss creates a 'transpiration pull' through the long xylem cells, ultimately causing water to be taken into the plant via the roots as we have seen. Within the network, from roots to leaf surfaces, there is hydraulic continuity. It means that any changes in tensions in cells are transmitted instantaneously throughout the plant. This is possible because of the cohesive properties of water (water molecules are attracted to each other) so the water network does not fracture when subject to the transpiration pull.

How water moves through natural materials
The natural materials used in this unit are made from plant material and contain a high proportion of cellulose. How does water travel up these materials?

As we discussed previously, cellulose (a major constituent of plant cell walls) is made of several hundred to over ten thousand glucose molecules linked to form a long chain. When natural materials high in cellulose are placed in water, water travels easily through the materials (we explore this in Lesson 2.5). The unit does not require that pupils know *why* this happens; simply that some materials are better at conducting water in this way than others. In trying to understand why this happens we need to consider a process called ***capillary action or capillarity.***

Capillary action refers to the flow of liquids in narrow spaces or tubes without the assistance of other forces (such as gravity) or even against the action of gravity (upwards movement). This is what we commonly call 'wicking' and it can be seen in the supply of wax through a candle wick, the movement of paint upwards between the fine hairs of a paintbrush, the way paper absorbs water quickly and the permeation of water through a soil. If we think about water in a thin tube, movement upwards is dependent on:

- the diameter of the tube (water moves higher up a thinner tube Figure 3)
- the need for water to 'wet' the tube – that is, the water is attracted to the substance that the tube is made from (**adhesion**)-this can be seen as water forms a meniscus when poured into a glass container
- surface tension of the water (caused by the molecules being chemically attracted to each other – cohesion)

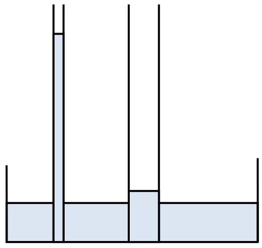

Figure 3. Capillary action

The attraction to the container (adhesion) and the cohesion of the water molecules creating surface tension have the overall effect of pulling the water upwards through the tube.
Read more about this at:
http://ga.water.usgs.gov/edu/capillaryaction.html

Some pupils' ideas relating to water movement in plants and materials

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.

Pupils' ideas about plant nutrition

There is a substantial amount of research to show that pupils are unlikely to possess the prerequisite concepts required to build a complete understanding of photosynthesis at this stage (1). This would entail, for example, understanding plant structure and function at depth, understanding gases and chemical reactions including energy transfer. It is easy to see why photosynthesis is a counterintuitive idea when the accumulation of carbon comes from a gas (CO_2) that is transformed into a solid state by the process. Many pupils will think that plants get their food via the roots from the soil, despite being aware of the idea that 'plants make their own food'. Few pupils in later education will appreciate the role of glucose in plant metabolism (1).

A key focus of this challenge is for children to understand the importance of water as one of the necessary conditions for plant growth and maintenance. Research into primary pupils' ideas indicates that children generally acquire an understanding that plants need water relatively early on (2). As they proceed through the primary years they increasingly become aware of the importance of other factors such as soil, sunlight, and warmth. While some children begin to formulate ideas that these conditions might relate to food production processes and may begin to think of the leaves as sites of food production, others may not. Some may depict plants kept indoors and mention the need to supply plant food, while others think that plants obtain their food from the soil:

'The plant will need leaves to get air. It will need roots to collect food and water from the soil and a stem to carry the food to the flower'. (2)

In Lessons 2.1 and 2.2 there is opportunity for pupils to discuss their thinking further on this issue as they consider carefully the conditions they must create in order to sustain plant life in the greenhouse. This provides opportunity to combine everyday observations of plant growth with prior scientific learning. The teacher will need to tolerate partial understanding of plant nutrition, but should be able to focus on what happens to plants if they are deprived of water. There is scope here for extending thinking by talking about plant adaptations in hot climates such as deserts. Cacti, for example, are well adapted for desert life. Their stems can store water, they have an extensive root system to collect water quickly over a wide area when it rains and they have spines instead of leaves that protect from animals that might eat them and act to minimise the surface area over which water is lost.

Pupils' ideas about how water moves through plants

At this age, children's ideas about how water moves through a plant are likely to be limited unless they have detailed prior learning experience of plant structure. Lesson 2.3 provides an excellent opportunity for them to experience water moving through a plant in a visual way that can be explored. They can see the dyed water being channelled through narrow tubes in the stem and through the leaves. This can be extended to plants bearing flowers so that they gradually construct the idea that water is distributed around the whole plant. It is important that they begin to view water transport as a connected system. An interesting extension is to

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encase the upper parts of the plant in a plastic bag and to observe the condensation that occurs as a result of transpiration.

Pupils' ideas about how water moves through natural materials

Pupils ware likely to be aware that natural materials such as paper towel, cotton wool and sponges soak up liquids. They may have had prior learning experiences that involved them in exploring the absorbency of materials in science. They may not, however, have had the opportunity to draw parallels between this and what happens in plants. In lesson 2.5 some key ideas to focus on are:

- natural materials are made of plant material
- both natural materials and plant material contain small, narrow channels through which the water moves

Extension work might usefully focus on capillarity and explore how the distance water moves up a tube depends on the diameter of the tube.

(1) Driver, R., Squires, A., Rushworth, P. & Wood-Robinson, V. (1994) *Making Sense of Secondary Science.* Routledge: London.
(2) Nuffield Primary Science: Teachers' Guides (Ages 7-12): Living Processes (1995) HarperCollins Publishers: London
91) Driver
(2) Living Processes

Partners

Bloomfield science Museum Jerusalem
The National Museum of Science and Technology "Leonardo da Vinci"
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Teknikens hus
Techmania Science Center
Experimentarium
The Eugenides foundation
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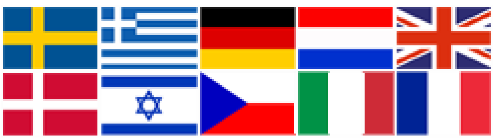
Science Oxford
The Deutsches Museum Bonn
Boston's Museum of Science

Netiv Zvulun – School
Istituto Comprensivo Copernico
Daltonschool Neptunus
Gränsskolan School
The 21st Elementary School
Maglegårdsskolen
The Moraitis school
EE. PU. CHAPTAL
Pegasus Primary School
KGS Donatusschule

ECSITE – European Network of Science Centres and Museums
ICASE – International Council of Associations for Science Education
ARTTIC
Manchester Metropolitan University
University of the West of England

Er zijn 10 lessenseries beschikbaar in deze talen:



The units are available on www.engineer-project.eu till 2015 and on www.scientix.eu

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