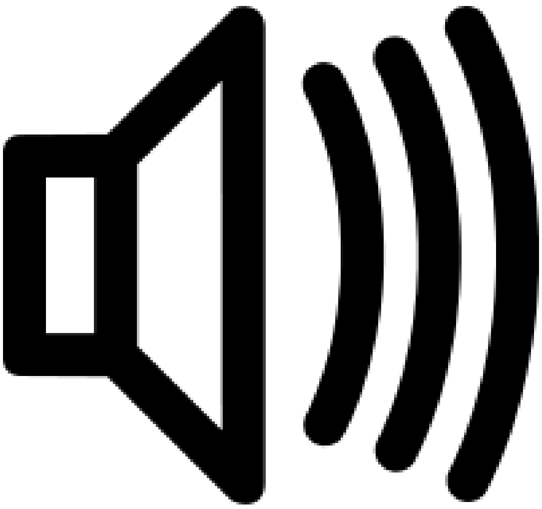
Music to the ears

Designing and creating a sound generator

Acoustic engineering

Sound

Unit for pupils from 9-11 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: 4 hours and 55 minutes (295 minutes)

Target group: 9, 10 and 11 year old pupils
Description: In this unit the pupils design and make their own simple string generator they can make a soundtrack for a movie clip that has no sound. This enables them to learn and experience properties of sound such as sound being a vibration and the differences in vibration between a low versus high pitch. They also work like engineers with the engineering design process.
Science curriculum: this unit relates to the science curriculum for sound.
Engineering field: this unit introduces the field of acoustic engineering.

Objectives, in this unit the pupils will:

- deploy the engineering design cycle to create a sound generator;
- examine the scientific characteristics of sound;
- use the scientific language associated with sound;
- be provided with opportunities to conduct design experiments in a collaborative way.

In terms of **Science** pupils will learn that

- sound is produced by a vibration force and needs a medium to travel in;
- a large vibration produces a loud sound and a small vibration produces a soft sound;
- a rapid vibration produces a high pitch and a slow vibration produces a low pitch;
- frequency and amplitude are basic concepts in vibration;
- the material and size of a resonance box influences the pitch of a sound.

In terms of **Engineering and Design** pupils will learn that

- engineered design is a significant aspect of everyday life;
- they can apply the engineering design cycle to their own engineering activity;
- successful engineering requires scientific knowledge;
- design creativity is best achieved through collaborative working in which the contribution of all are equally valued.

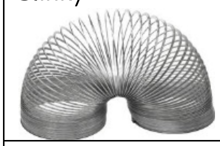
Evidence of learning will be obtained by

- teacher led lesson plenaries in which the pupil's understanding is evaluated
- the completion of worksheets.

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 problem is that there is a short movie clip with no sound. The pupils are challenged to make a soundtrack using their own design and made string sound generators. **In Lesson 2,** the 'ask' element of the engineering process leads to an investigation of sound. The pupils undertake experiments in which they discover the properties of sound. They also discover how the size of a resonance box influences sound.
Lesson 3 involves the pupils in applying the engineering design process to meet the challenge. The challenge is to make a soundtrack for a movie clip using a sound generator of their own design. **In Lesson 4,** it's time to evaluate the process of creating the sound generator and to present the soundtrack. This is also the moment for pupils to show whether they were able to meet all the criteria and to talk about how they made improvements.

Resources

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

Material	Total amount	Lesson 0	Lesson 1	Lesson 2	Lesson 3	Lesson 4
Smart board or computer with beamer	1		1	1	1	1
Internet connection (to show movie clip)	1		1	1	1	1
Movie clip (see lesson 1, page 10)	1		1		1	1
The design cycle printed on a big (A-2) paper	1	1	1	1	1	1
A4 paper	12		12			
Worksheet 1 Lesson 1 *Soundtrack*	30		30	30		30
The list of questions from lesson 1	1		1	1		1
Worksheet 2 Lesson 2 *Experiments with a ruler*	15			15		
Worksheet 3 Lesson 2 *Rubber band and paper cup*	15			15		
Worksheet 4 Lesson 3 *Let's build*	30				30	
Assessment sheet Lesson 4 Engineering *design cycle*	30				30	
Resonance boxes (e.g. cleaned food trays; cottage cheese, Pringles container, cans, bottles, etc. For examples see the appendices)	30 (1 each pupil)				30 (1 each pupil)	
Box for the materials (storage)	5				5	
String instrument (if possible)	1			1		
Slinky 	1			1		
Ruler (not wooden) 	15		15	15		
Paper cup 	75			45	30	
Plastic cup 	30			15	15	

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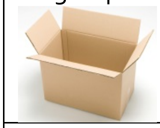
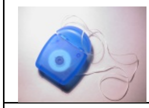
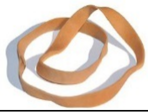
Material	Total amount	Lesson 0	Lesson 1	Lesson 2	Lesson 3	Lesson 4
Large square carton box 	1			1		
Small square carton box 	1			1		
A small amount of sugar grains (for extension activity)	1 portion		1 portion			
Balloon (for extension activity)	1		1			
Dental floss 	6 boxes			1 box	5 boxes (1 each group)	
Fishing thread (0,3-0,8 mm) 	6 spools			1 spool	5 (1 each group)	
Paperclips 	90			15	75 (15 each group)	
Buttons 	90			15	75 (15 per group)	
Skewers 	105			15	90 (18 each group)	
Thick rubber band 	90				90 (18 each group)	
Thin rubber band 	105			15	90 (18 each group)	
Sewing thread 	5 spools				5 spools (1 each group)	
Cotter pins 	75				75 (15 each group)	

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Material	Total amount	Lesson 0	Lesson 1	Lesson 2	Lesson 3	Lesson 4
Eye lag 	90				90 (18 each group)	
Material	**Total amount**	**Lesson 0**	**Lesson 1**	**Lesson 2**	**Lesson 3**	**Lesson 4**
Ice cream sticks 	90				90 (18 each group)	
Scissors	15			15	10 (2 per group)	
Blunt embroidery needle or perforating tool  	15			15	15 (3 per group)	
Tape  	5				5 rolls (1 per group)	

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

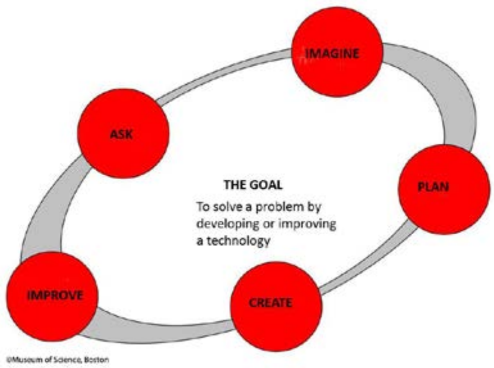
Working method

- 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.

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.

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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 pupils will

- be introduced to the concept of design and the design cycle as a means of effectively engineering products;
- examine the work of sound engineers;
- establish the principal qualities of a soundtrack;
- organise themselves for the unit activity.

Outcomes, in this lesson the pupils will learn

- to follow the different steps and terms of the design cycle and to use it as an engineer;
- that the design cycle can be used for solving a problem.

Resources (for 30 pupils)

- the design cycle printed on large (A-2) paper
- sheets A4 paper
- a movie clip of about 50 seconds
- worksheet 1 Lesson 1 *Soundtrack*
- smart board or computer with beamer

Preparation

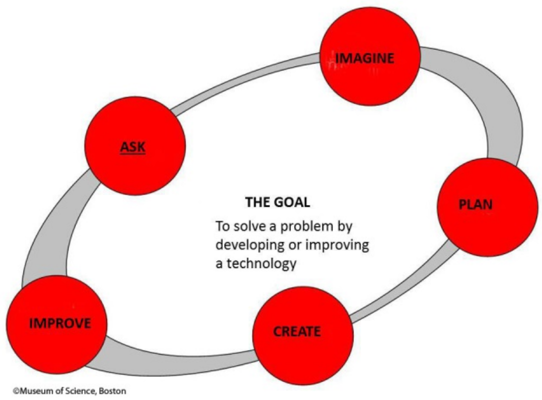
- Select a movie clip of about 50 seconds (see page 10).
- Prepare how you will show the movie clip.
- Make copies of the Worksheet 1 Lesson 1 – *Soundtrack*.
- Put up the poster of the design cycle.

Working method

- class discussion
- working in groups

Context and background

The challenge and the design cycle are introduced. The challenge is to design and make a simple string sound generator. With this sound generator the pupils compose a sound track for a movie clip. Before actually designing and making the sound generator in lesson 3, the pupils first consider what knowledge they need to meet the challenge.



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1.1 Introductory activity – introducing the design cycle – class discussion/ in groups – 10 minutes

The teacher introduces the lesson by using an object that the pupils use every day as an example to explain the process of the design cycle. For example a tea bag, a paper cup or a pen. Why is it designed the way it is? And who does that?

The design cycle is introduced by asking the pupils to solve a short problem. The problem is that a piece of A4 paper has to travel from one side of the classroom to the other.

- What is the problem? *This A4 sheet has to travel from this side of the classroom to the other end of the classroom.*
- What do you need to know? Probably in this case pupils will only think of the restrictions (materials, time, cost) they need to take into account. However, when a challenge/problem is more complex, encourage them to think also about what knowledge they need to have.
  Each group has one sheet of paper, 2 minutes to think of a solution together and to make it. Testing is not allowed until everyone is finished.

When all the pupils have a solution, let them test/show it.
Take the large illustration of the design cycle (see appendix). Go through this cycle step by step, referring to the process the pupils went through in the simple challenge of the travelling paper.

- What did you do? Probably most groups will have made a paper plane. Why did you make a paper plane?
- Okay you decided to make a paper plane, what did you do? *You made it.*
- And then? *We all tested it.*

Now that you have tested yours and seen what other pupils made. Do you want to change something?

1.2 The challenge – class discussion – 10 minutes

The challenge is to design and make a simple string sound generator, which will be used to compose a soundtrack for a short movie clip. The movie clip has no sound; it has accidently been deleted. Can the pupils help the teacher by making a soundtrack of their own design, using a string sound generator which they make themselves?

There are some possibilities for the movie clip; choose one of the following options:

1. Select a movie clip of about 50 seconds. This can be a cartoon or a movie in your own language or a clip that suits a particular topic being taught in school, for example, space or wildlife. Watch with the sound off.
2. Use a pre-recorded video created by your pupils to suit a topic being taught at school;
3. Let the pupils select their own movie clip/cartoon. Make sure that the movie clips are age appropriate.

Tip - On http://movieclips.com there are a lot of clips. For example use a part (0.40 - 1.35 seconds) of the clip of the movie 'Modern times' with Charlie Chaplin http://cli.ps/xruv.
Or the ice scene from Bambi (0.0 – 0.50 seconds) http://cli.ps/hGMo.
Or a Rube Goldberg machine, like this http://youtu.be/qybUFnY7Y8w (*OK Go - This Too Shall Pass)*

Discuss the function of sound in movies or radio plays. Let the pupils think about the sound and why there are made. Why is sound important in a movie? *Sound can give you a strong feeling which makes you experiences what you see more intensely.*
Show the movie clip. What happens in the movie clip?

1.3 Worksheet 1 Lesson 1 – Soundtrack - class discussion/in groups – 15 minutes

The pupils make their own simple string sound generator, but for composing the soundtrack they work in groups. Divide the class in groups of approximately 5 pupils each. Give each group one copy of the Worksheet 1 Lesson 1 – *Soundtrack*.
Show the movie clip again and let the pupils work on Worksheet 1 Lesson 1 *Soundtrack* (except the last question).
After 10 minutes, hold a discussion with the class and talk about what kind of sounds they want to make.

Also take the opportunity to talk about what sound engineers do. Engineers who solve problems associated with sound are called acoustical engineers. The main thing acoustical engineers do is to try to control sound. This can mean reducing it, or using it for a useful purpose. This can include:

- Solutions for unwanted sounds, like sound barriers or sound proof rooms for making music.
- Developing a concert hall with good acoustics.
- Developing a solution to minimize the sound produced by cars.
- Solutions for navigation, like sonar or echo location.
- Ultrasound for medical diagnostics.
- Optimising sound effects for musicians.

Tip –It may be necessary to offer the pupils a clearer image of 'pitch'. This can happen in a discussion.

1.4 The 'ask' step – class discussion – 20 minutes

Look at the 'ask' step from the design cycle. What do we need to know to do this challenge?

- Ask the pupils what they need to know to meet the challenge. Each group discusses this and writes down two questions on Worksheet 1 Lesson 1 – *Soundtrack.*

Tip – If the pupils only ask questions about the materials or criteria, try to trigger them to think about science questions by asking questions like: Do you know how to make a sound? What is the difference between a high pitch sound and a low pitch sound?

- After 10 minutes, make an inventory of the questions. Write them on the board. Which can already be answered and which require more investigation before answering?
- Make sure that the restrictions and criteria are clear. Some questions will be about the science of the challenge. Tell the pupils that in lesson 2 they will do experiments to learn about sound and acoustics.

It is important that the vocabulary used is clear for the pupils. For example, the concept of a loud and a high pitch can easily be confused. Write high/low pitch, a loud/soft sound and any

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other words that need explanation somewhere visible. Also write an inventory of other words that maybe not clear. Discuss these words. Keep a list in a visible place during the time you work on the unit.

Tip – Complement the vocabulary list during teaching this unit.

1.5 Plenary – review learning outcomes via class discussion – 5 minutes

Conclude this lesson by going through the things they have found out during this lesson. Possible questions:

– What can we use the design cycle for?
– Who can explain the different steps of the design cycle?
– What do we already know about sound?
– Which questions do we still need to answer?

Lesson 2 – What do we need to know?
Finding out about sound and acoustics

Duration: 85 minutes

Objectives, in **this lesson the pupils will**

- examine how sound travels;
- through experimentation examine some of the qualities of sound;
- examine the means to amplify sound;
- review the engineering design cycle.

Outcomes, in this lesson the pupils will learn

- that sound is a vibration;
- that sounds need a medium to travel in;
- that the size and material of a resonance box influences the sound;
- basic concepts of frequency and amplitude of a vibration and the effect these have on the sound produced

Resources (for 30 pupils)

- ☐ Slinky
- ☐ List of questions from lesson 1
- ☐ List of vocabulary
- ☐ A small amount of sugar
- ☐ 1 balloon
- ☐ Smart board or computer to show the You Tube video
- ☐ 15 Worksheets 2 Lesson 2 - *Experiments with a ruler*
- ☐ 15 rulers, not wooden
- ☐ 15 Worksheets 3 Lesson 2 - *Experiment with rubber band and paper cup*
- ☐ 45 paper cups
- ☐ 15 thin rubber bands
- ☐ 15 scissors
- ☐ 15 rulers
- ☐ 1 large box and 1 small box made from the same materials and with same shape
- ☐ 15 plastic cups
- ☐ 1 box floss (20 cm for each pair)
- ☐ 1 spool fishing thread (20 cm for each pair)
- ☐ 15 paperclips
- ☐ 15 buttons
- ☐ 15 skewers

Preparation

- Arrange the materials needed, including a guitar or another stringed instrument.
- Make copies of the worksheets.
- Put up the list of questions from lesson 1.
- Put up the vocabulary list.
- Prepare the smart board or computer to show the You Tube video of the wave in the stadium.

Working method

- Class activity
- Class discussion
- In pairs

Context and background

The 'ask' element of the engineering process leads to an investigation of sound. The pupils experiment and so discover the properties of sound. They also discover how the size of a resonance box influences the sound. Overall they experience that undertaking an investigation can result in finding answers;

2.1 Introductory activity – Sound is a vibration – class activity – 5 minutes

Today we are investigating sound. What step in the cycle are we on? Which questions do we want to answer today?

Start by asking the pupils some questions, and write the answers on the board, grouped round the word 'sound'. Possible questions:

- What do you think sound is?
- What types of sound are there? Let the pupils make sounds like humming or clapping.

Introduce pitch by letting the pupils make a high pitch sound and a low pitch sound. Do the same for loud and soft.

- Ask the pupils to put a hand on their throat and feel.
- Now let them do the same but while humming. What do you feel now? *They feel their throat vibrate.* Conclude that sound is a vibration.

Take the list of questions from lesson 1. Was this one of our questions?

2.2 Sound travels through a medium – class activity – 10 minutes

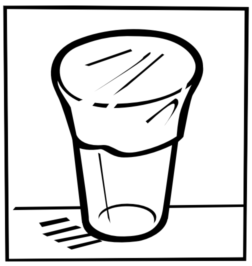
We discovered that sound is a vibration. Moving sound is called a sound wave.

- Who knows what a wave is? *The pupils may come with waves as in the sea.*
- What is a wave in the sea? *In the sea a wave is water that is travelling.*
- Is this the same for sound in the air? *No it is not. In air the sound is passed by air, the air is not 'blown' by the sound.*

Demonstrate this with a slinky. Put the ends of th slinky about 80 centimetres apart and push a wave in motion. Let the pupils observe.

- Do they see the wave (area of compression) go from one side to the other? *Yes.*
- The slinky moves from side to side and then it returns to its original position.
- Sound travels the same way. The air moves a little, but it doesn't blow the sound in your ear. The air particles are set in motion, the vibration travels through the air.

Tip - Demonstrate how the eardrum works with a simple model. Cut off the blowing nozzle of a balloon and stretch the other part of the balloon over a plastic cup. Put a little sugar on the balloon. Hold a paper cup close to your mouth, the opening towards you. Direct it towards the model of the eardrum. Shout 'hello'. Walk around the class and ask the pupils to tell you what they see. The vibrations of the voice make the skin of the balloon vibrate, and so the sugar grains jump.



Resume: so sound needs a medium to travel through, air for example. Do you think sound moves only through air? Could it also move through this table? Let everybody lay an ear against the table and tap with their hand on the table. What do you hear? *Sound is passed through the wood of the table.*

Tip –Often it is a misconception by children that a wave in water and a sound wave are the same. Give sufficient attention to this.

Tip – You can also make the comparison with a wave in a stadium. It is not that the people are moving from one end of the stadium to the other, it is the wave which does this. For example: http://youtu.be/6SGeUVOP3GE *(2012-05-26 Denmark - Brazil* **|** *Wave going through the stadium)*

2.3 Experiment with ruler – in pairs/class discussion – 20 minutes

Let the pupils work in pairs on the experiments in Worksheet 2 Lesson 2 - *Experiments with a ruler*. In this experiment the pupils investigate the difference between the vibration of a loud and a soft sound. And the difference in vibration between a high and a low pitched sound.

Tip – If the pupils are at an appropriate level, the terms frequency and amplitude can be introduced.

Note that describing what they hear can be difficult; remind them of the vocabulary list**.**
There can be a lot of noise in this activity.
After 10-15 minutes discuss their findings and fill in this schedule with the pupils.

- A loud sound comes from ....vibrations. *large*
- A soft sound comes from ....vibrations. *small*
- A high pitched sound comes from ....vibrations. *fast*
- A low pitched sound comes from ....vibrations. *slow*

If the pupils are at the appropriate level, introduce the terms amplitude and frequency. Put those on the vocabulary list.

- If the vibration is large, the amplitude of the vibration is large.
- If the vibration is small, the amplitude of the vibration is small.
- A high pitched sound has high frequency vibration (lots of vibrations in a time unit).
- A low pitched sound has a low frequency vibration (few vibrations in a time unit) .

Tip – If you do not want to use the worksheet for the pupils, put the instructions and questions on the board. Or only ask guiding questions like: What do you need to do to the ruler to make a soft sound? What do you need to do to the ruler to make a high pitched sound?

2.4 Experiment with rubber band and paper cup – in pairs/class discussion – 20 minutes

In this experiment the pupils investigate two things. First they explore the difference in pitch of a sound of a tight, and a less tight, rubber band. Secondly they discover the function of a resonance box and that the larger the resonance box, the louder the sound.
Introduce 'fair testing'. Explain that you only can make a fair conclusion from an experiment if only one variable is changed each time. Otherwise you will not be able to know why things happened.

Work in pairs, starting with Worksheet 3 Lesson 2 - *Rubber band and paper cup*.

When the pupils have finished, discuss their findings about the tightness of the string.

- A tight rubber band makes a high pitched tone.
- A looser rubber band makes a low pitched tone.
- So if you want to make a high pitch sound what does your string have to be? *Tight*
- If you want to make a low pitched sound what does your string have to be? *Slightly tight, otherwise the string can't vibrate, but not too tight.*

Plenary, discuss their findings about the resonance box.

- The sound from the large paper cup is louder than from the small paper cup. The paper cup acts as a resonance box. It amplifies the sound. The larger the resonance box, the louder the sound.

Plenary: discuss if there is any other way the size of the box influences the sound.

- The sound from a larger resonance box gives a lower pitch than the sound from a smaller resonance box. You can use, as an example, the difference between a contrabass and a violin.

Tip - It may be difficult to hear the difference in pitch. If you have a stringed instrument available, use this during the discussion to show the difference in pitch when you tighten the string.

2.5 Exploring materials – class discussion/in pairs – 10 minutes

Tell the pupils that they need to bring the resonance box for their sound box from home. Discuss some examples of what they can bring. *Cottage cheese tray, butter tray, sturdy cardboard boxes, Pringles container, empty food cans, plastic bottles big or small.* See appendices for examples.

They have already learned that the size of the resonance box influences the sound. The bigger the box, the louder and lower the sound. They will now do an experiment to clarify that the material of a sound box also influences the sound.

Let the pupils explore in pairs the difference in sound between a paper cup and a plastic cup by making them drum the cups with their fingers. There is no worksheet for this experiment.

Possible questions:

- What can you use as a resonance box?
- Is the sound of the cups the same?
- Why is it interesting to check the sound of your possible resonance box?

Tip – Extension work: let the pupils explore how the size of the opening of the resonance box influences the sound. For example, what happens when there are holes in the resonance box? What happens if the holes are big?

2.6 Fixing strings – class discussion/in pairs – 15 minutes

Let the pupils practice different ways of fixing different strings (floss and fishing line) to a paper cup. To fix the string, a paperclip, a button or a skewer can be used. For making holes in the cup a blunt embroidery needle or perforating tool can be used. See also the photographs in the appendices.

After 10 minutes, discuss the does and don'ts. Possible questions:

- How could you fix strings to your resonance box?
- Can you give a tip to your classmates?

As the tension of the string has a major influence on the pitch of the sound, it is very important how the strings are fixed to the resonance box.

Tip – Pictures of possible fixings are given in the appendices. As the strings need to be quite tight to give good and clear sound, attaching them well is important, but sometimes also difficult. Pupils can find it hard to find ways to do this.

- *Use a button or paperclip at one side and let the string go all around.*
- *Use a skewer: roll the string around the skewer and then turn the skewer to tighten the string.*
- *Use an eye lag, which you can turn to tighten the string.*

2.7 Plenary – review learning outcomes via class discussion – 5 minutes

Repeat the results of the science experiments, if possible, with a real stringed instrument. Use it to check the learning outcomes.

- Loud sound → large vibrations.
- Soft sound → small vibrations.
- High pitched sound → fast vibrations.
- Low pitched sound → slow vibrations.
- If the vibration is large, the amplitude of the vibration is large.
- If the vibration is small, the amplitude of the vibration is small.
- A high pitched sound has high frequency vibration (lots of vibrations per unit of time)
- A low pitched sound has a low frequency vibration (fewer vibrations per unit of time)
- Sound needs a medium to travel through.
- A tight rubber band makes a high pitched tone.
- A ,looser rubber band makes a low pitched tone.
- The larger the resonance box, the louder the sound.
- The larger the resonance box, the lower the sound.

Make sure that all the questions the pupils had about the science in order to do the challenge are answered. Through the plenary discussion, review the extent to which the lesson outcomes have been met. The following lesson is about the next steps of the design cycle. This means we actually start designing and building sound generators. **Everybody needs to bring their own resonance box!** Before choosing your resonance box, think about the movie clip you are composing the soundtrack for. Bear in mind the sounds you want to make.

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Lesson 3 – Let's build!
Design and built your sound box

Duration: 90 minutes

Objectives, in this lesson pupils will

- deploy the engineering design cycle to inform their own design work;
- plan and build their sound generator in order to create an effective soundtrack using strings and a sound box;
- use some challenging materials safely.

Outcomes, in this lesson the pupils will learn

- the notion of a design challenge;
- in what ways the pitch of a sound can be changed;
- that in order to design and implement a functional solution to an engineering problem, you have to rely on the science (physical principles) which underpins the problem;
- that a sound generator can be built in various ways and the construction will be successful as long as it meets the criteria. Thus, there is not one right solution to the problem, but a range of possible solutions;
- that testing and evaluation is an important part of the design engineering process;
- to have proper regard for safety issues and to use tools in an appropriate manner.

Resources (for 30 pupils)

- ☐ smart board or computer with beamer
- ☐ internet connection (to show movie clip)
- ☐ worksheet 4, Lesson 3 - *Lets' build!*
- ☐ 5 boxes to put all the materials in (1 each group)
- ☐ 30 resonance boxes (1 for each pupil, for example cleaned food trays; cottage cheese pots, Pringles container, cans, bottles, etc.)
- ☐ 5 spools fishing thread (1 spool each group)
- ☐ 90 thick rubber bands (18 each group)
- ☐ 90 thin rubber bands (18 each group)
- ☐ 5 spools sewing thread (1 spool each group)
- ☐ 5 boxes floss (1 box each group)
- ☐ 90 buttons (18 each group)
- ☐ 75 paperclips (15 each group)
- ☐ 75 cotter pins (15 each group)
- ☐ 90 eye lags (18 each group)
- ☐ 90 ice cream sticks (also for tightening of the strings and as a bridge for the strings, 18 each group)
- ☐ 90 skewers (18 each group)
- ☐ 5 rolls tape (1 roll each group)
- ☐ 10 scissors (2 each group)
- ☐ 15 blunt embroidery needle or perforating tool (3 each group)

Preparation

- Copy Worksheet 4, Lesson 3 - *Lets' build!*
- Make sure all resources are there; it can be handy to put all the materials the pupils need per group in a box
- Collect extra resonance boxes as a reserve

Working method

- Class discussion
- Individually

Context and background

In this lesson the pupils go through the steps 'image', 'plan', create' and 'improve' of the engineering design cycle. The pupils use the science they investigated in lesson 2 to attempt to meet the challenge.

3.1 Introductory activity – What have we done so far? – class discussion – 5 minutes

Summarise with the pupils what they have done so far.

How can you get a high/low pitch sound?

What is the function of a resonance box? Does the size of the resonance box have any influence?

What is important for fixing the strings?

Which steps of the design cycle have we gone through? What step are we on now?

3.2 The challenge – class discussion – 10 minutes

The challenge is to design and make a sound generator for composing a soundtrack for a short silent movie clip. To succeed, the sound generator needs to meet certain criteria. Everybody makes their own sound generator. In groups, pupils compose a soundtrack. In lesson four, they will compose and present the soundtrack.

The criteria for the sound generator are:

– It must have 2 strings and each string must have a different pitch.
– The strings must be made of at least two different materials.

Tip - For advanced pupils the criteria could be 3 strings with a different pitch.

Tip - Although the pupils are making a string sound generator, that doesn't mean that they can't use sound effects made by something other than strings, as long as the criteria are being met. This can increase their creativity.

Tip – put the criteria on a poster or (smart) board.

Discuss with the class how the criteria, the sound generators and the soundtracks are going to be evaluated. What is the opinion of the pupils on this?

There are a few important things to consider:

– All (you and the pupils) should agree on a how the sound generators are going to evaluated. It is important that the pupils have a say in this; this increases their involvement. Take the pupils' ideas seriously.
– It is not about building a perfect sound generator right away. It is okay to do something and realise that it wasn't the best solution. The cycle is about testing and improving. Engineers do so also.
– Another important element is that the pupils understand they can learn from each other. So although they make their own sound generator, they can ask for advice and look at the work other pupils are doing.

Introduce the materials and tools

– Each group has the same amount of materials to use. Name all the materials.
– Name all the tools. Pay attention to safety and give clear examples how to use the tools and materials.
– It depends on the kind of materials you offer, but it can be that the tools and materials which are used need extra guidance and explanation. For example, making holes in cans with a bodkin. Remind the pupils about the different kind of fixings they practiced in lesson 2. It's interesting to investigate if there is a way of fixing a string which makes it

possible that the tension of the string can be changed after it is attached, as with a guitar or violin.

Tip - Pay extra attention to safety when pupils use a embroidery needle or a perforating tool to make holes in their resonance box.

3.3 Image, plan, create and improve – class discussion/individual work – 60 minutes

Start by showing the movie clip. Do the pupils know which sounds they want their sound generators to make? They thought about this in lesson 1, see Worksheet 1, Lesson 1 – *Soundtrack.*

Then the pupils can start thinking and planning their own sound box. Some pupils may also like to make a plan for building their sound box. They can do this by making a sketch or writing down the idea. They can use Worksheet 4, Lesson 3 - *Let's build* for this.

Tip - Using the worksheet is not required. It can help them, but it can also be very difficult and so therefore stop the creativity of a pupil.

Tip – Before the pupils start building, explain why it is important to fix the strings in a way that makes it possible to tighten them. This is crucial for getting sound and different kinds of pitch from their sound box.

When the pupils have planned their sound generator (after about 10 minutes), the materials for building this can be collected and they can start building. For organisation, put the materials and tools per group in a box.

Stop the activity after 15 minutes and ask the class how the building is going on. Possible questions:

- Does your idea work?
- Are you able to meet the criteria of building the sound generator?
- Could you share some tips and tricks?

Pupils can introduce their ideas to the rest of the class and exchange advice and ideas.
Then let the pupils work on their sound generator.

3.4 Evaluating the challenge – class discussion – 10 minutes

What were the criteria for the sound generator?

- It must have 2 strings and each string must have a different pitch.
- The strings must be made of at least two different materials.

Have a class discussion about the criteria and the building process the pupils went through.

- Was it difficult to meet the criteria?
- What kind of solutions did you find?
- How were you able to get high pitched tones and low pitched tones?

3.5 Plenary – review learning outcomes through class discussion – 5 minutes

Each pupil has worked to make a sound generator that meets the criteria of the challenge and which they can use for composing the soundtrack. In the next lesson, the pupils will compose their soundtrack and present it to the rest of the class. They will also talk about their experiences in the design process.

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

Duration: 60 minutes

Objectives, in this lesson pupils will
- review the engineering design cycle;
- compose and present their sound track;
- review and revise their soundtrack against success criteria derived from sound engineering.

Outcomes, in this lesson the pupils will learn
- to reflect on their work;
- that they can apply the engineering design process to solve a problem;
- a scientific understanding of sound and acoustics and their relationship to successful engineering.

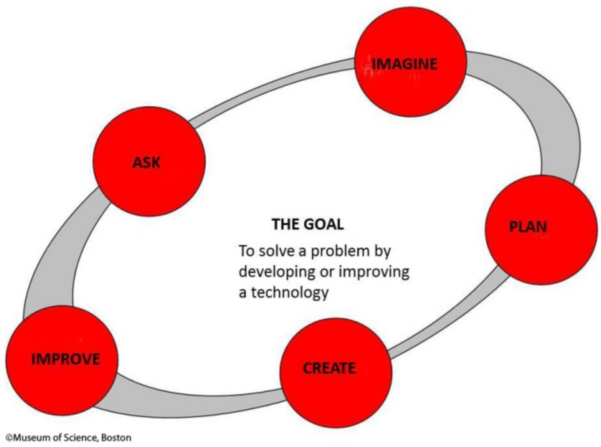
Resources (for 30 pupils)
- 30 assessment sheets
- the movie clip
- smart board or computer with beamer
- internet connection (to show movie clip)

Preparation
- Copy assessment sheets
- Make sure all sound generators are there
- Prepare to show the movie clip

Working method
- Plenary
- In groups

Context and background

In this lesson the engineering design process and the sound track is evaluated. Is the challenge met? How did the pupils apply the science they learned and how did they work with the design cycle? This is also the moment to present their solution to the problem and be proud of what they have learned and created.



4.1 Introductory activity – plenary – 5 minutes

Start this lesson by reflecting on the process of using the design cycle. You can use the assessment sheet. Ask the pupils to fill it in, or just use it as guiding questions.

4.2 Soundtrack – class discussion/in groups – 50 minutes

The sound generator is the tool for making the soundtrack. Today pupils will compose and present the soundtrack with their group. Remind them that they have already done some work on the sound track using Worksheet1, Lesson 1- *Soundtrack.*

Show the movie clip twice.

Give the pupils 15 minutes to compose and practice their soundtrack. If possible during this time, let them, play the movie clip in a loop.

After their 15 minutes of practice, each group presents their soundtrack. Possible questions that can be asked after every played soundtrack:

– Do you think the soundtrack matches the movie clip? Why?
– Is it easy to hear if the group used high or low pitched sounds?

Give all groups another 10 minutes to improve their soundtrack and let the groups present their improved soundtrack.

Tip – If possible let the pupils practice their soundtrack in different rooms. You can also give them extra time during the week to do this

4.3 Plenary – review of lesson and unit learning outcomes via class discussion – 5 minutes

What have we learned and achieved?

Refer to the preparatory lesson and check if pupils still recognise 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.

Engineers who solve problems related to sound are called acoustic engineers. Our investigation on sound helped us to build a sound generator. Can you think of more problems that acoustic engineers solve?

– Solutions about unwanted sounds, like sound barriers or sound-proof rooms for making music.
– Developing a concert hall with good acoustics.
– Developing solutions to minimize the sound produced by cars.
– Solutions for navigation, like sonar or echo location.
– Ultrasound for medical diagnostics.
– Optimising the sound that musicians make.

The main tasks undertaken by acoustical engineers are to try to control sound. This can mean reducing it, or using it for a useful purpose.

Appendices

Story to set the context - Let's hear!

The challenge is to design and make a simple string sound generator that the pupils will use to compose a soundtrack for a short movie clip. The movie clip has no sound; it has accidently been deleted. Can the pupils help the teacher by making a soundtrack with their own designed and made string sound generator?

There are some possibilities for the movie clip, choose one of the following options:

1. Select a movie clip of about 50 seconds. This can be a cartoon, or a movie in your own language, or a clip that suits a particular topic being taught in school, for example, space or wildlife. Watch with the sound off.
   On http://movieclips.com there are a lot of clips. For example use a part (0.40 - 1.35 seconds) of the clip of the movie 'Modern times' with Charlie Chaplin http://cli.ps/xruv.
   Or the ice scene from Bambi (0.0 – 0.50 seconds) http://cli.ps/hGMo.
   Or a Rube Goldberg machine, like the http://youtu.be/qybUFnY7Y8w (OK Go - This Too Shall Pass)

2. Use a pre-recorded video created by your pupils to suit a topic being taught at school;

3. Let the pupils select their own movie clip/cartoon. Make sure that the movie clips are age appropriate.

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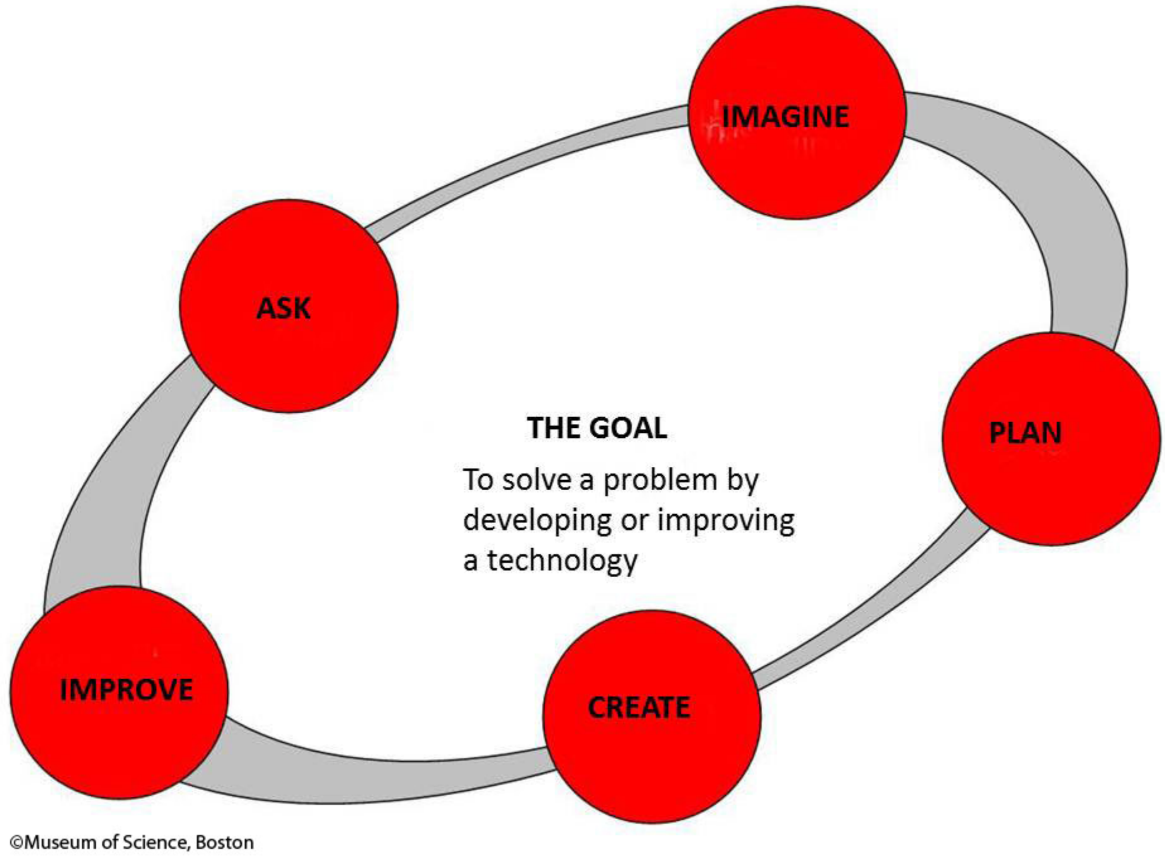
Engineering design cycle



Design cycle	Questions
Ask	What is the problem? What do you need to know? (knowledge and restrictions).
Imagine	What are some solutions? Brainstorm ideas. Choose the best one.
Plan	Draw a diagram. Make a list of materials you'll need.
Create	Follow your plan and create it. Test it out!
Improve	Make your design even better. Test it out!

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Worksheets and answer sheets

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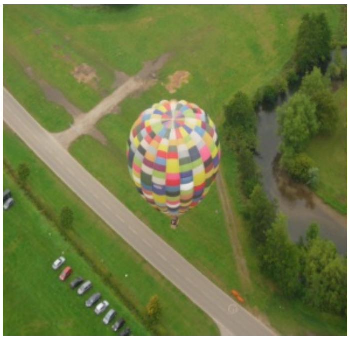
Worksheet 1 Lesson 0 – Engineering?











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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.

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Worksheet 1 Lesson 1 – Soundtrack

Date:

Group members:

1.	....	4.	....
2.	....	5.	....
3.	....	6.	....

What kinds of sounds do you all want to make in the soundtrack? And why?

....

....

....

At which part of the movie clip do you want to make what sound?

....

....

....

Who is going to do what effect? Everyone has different qualities and preferences. Divide the roles

Group member 1 does: ....

Group member 2 does: ....

Group member 3 does: ....

Group member 4 does: ....

Group member 5 does: ....

Group member 6 does: ....

What do we need to know to meet the challenge?

....

....

....

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Worksheet 2 Lesson 2- Experiments with a ruler
Page 1

Name:
Date:

You now know that sound is a vibration. How do you make a high pitched sound or a low pitched sound? When is a sound loud or soft? You can investigate this with a ruler.

What do you need?

- Ruler (not wooden)

To work!

1. Place the ruler on the table. Let the ruler stick out 10 centimetres over the edge of the table.
2. Hold the ruler in place with one hand pushing on the
3. Pull the sticking out part of the ruler down with a finger of your other hand and release .

   This is called plunking.

   What do you hear when you plunk the ruler?

   ....

   What do you see when you plunk the ruler?

   ....

4. Plunk the ruler hard first and then soft. Do you hear a difference? Circle the correct underlined word.

   If I plunk the ruler hard, the sound gets higher/lower/louder/softener.

   If I plunk the ruler soft, the sound gets higher/lower/louder/softener.

Worksheet 2 Lesson 2- Experiments with a ruler
Page 2

5. Let the ruler stick out 20 centimetres over the edge of the table. Plunk the ruler.

   Do the same but now with 7 cm over the edge of the table.

   What happens with the pitch if the part of the ruler that vibrates gets smaller?

   O the pitch gets higher.

   O the pitch gets lower.

   What happens if the part of the ruler that vibrates gets smaller?

   O the ruler vibrates faster.

   O the ruler vibrates slower.

6. Circle the right underlined word.

   When I plunk the ruler hard, the vibration is <u>large/small</u>.

   When I plunk the ruler soft, the vibration is <u>large/small.</u>

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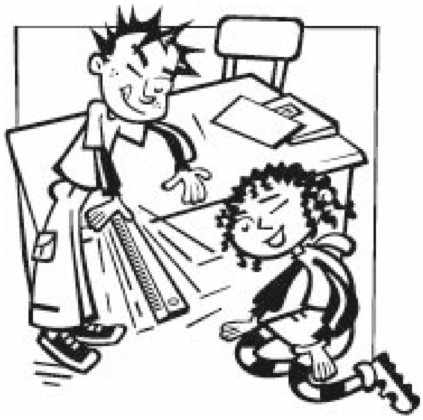
Answer worksheet 2 Lesson 2- Experiments with a ruler

Name:
Date:

You now know that sound is a vibration. How do you make a high pitched sound or a low pitched sound? When is a sound loud or just soft? This you can investigate with a ruler.

What do you need?

- ruler (not wooden)
- table



To work!

1. Place the ruler on the table. Let the ruler stick out 10 centimetres over the edge of the table.
2. Hold the ruler in place by with one hand pushing on the ruler.
3. Pull the sticking out part of the ruler down with a finger of your other hand and release . This is called plunking.

   What do you hear when you plunk the ruler? **A sound**

   What do you see when you plunk the ruler? **The ruler goes up and down, it vibrates.**

4. Plunk the ruler hard first and then soft. Do you hear a difference? Circle the right underlined word.

   When I plunk the ruler hard, the sound gets higher/lower/**louder**/softener.
   When I plunk the ruler soft, the sound gets higher/lower/louder/**softener**.

5. Let the ruler 20 centimetres over the edge of the table protrude. Plunk the ruler.
   Do the same but now with 7 cm over the edge of the table.

   What happens with the pitch if the part of the ruler that vibrates gets smaller?
   o the pitch gets **higher**.
   o the pitch gets lower.

   What happens if the part of the ruler that vibrates gets smaller?
   o the ruler vibrates **faster**.
   o the ruler vibrates slower.

6. Circle the right underlined word.
   When I plunk the ruler hard, the vibration is **large**/small.
   When I plunk the ruler soft, the vibration is large/**small**.

Worksheet 3 Lesson 2 - Rubber band and paper cup
Page 1

Name:
Date:

What do you need?

- 2 paper cups
- thin rubber band
- scissors
- ruler
- eventually 2 boxes made of the same material; a small box and a large box

To work!
The experiment, part 1

1. Press the rubber band against the underside of a cup.
2. Hold the cup about 10 centimetres from your ear, or the ear of a classmate.
3. Pull the rubber band a very slightly tight and plunk the rubber band.
4. Pull the rubber band tight and plunk it.

What happens with the pitch sound if the rubber band is tighter?

....

5. Circle the right underlined word.

A tight rubber band makes a <u>high/low</u> pitched tone.

A loose rubber band makes a <u>high/low</u> pitched tone.

The experiment, part 2

6. Take the other paper cup and cut away a large part of the upper part. You need a small cup of about 3 centimetres high.
7. Press the rubber band against the underside of the cup.
8. Hold the cup about 10 centimetres from your ear or the ear of a classmate.
9. Pull the rubber band tight and plunk the rubber band.

Worksheet 3 Lesson 2 - Rubber band and paper cup
Page 2

10. Do this again with the large cup. Do you hear a difference?

    Is the sound from the small cup as loud as from the large cup?

    ....

11. Circle the correct underlined word.

    The sound from the large cup is <u>louder/less loud</u> than the sound from the small cup.

Learning more

Does the size of the resonance box influence the pitch of the sound?
What do you think?

- o Yes, the larger the resonance box, the lower the sound.
- o No, the size of the box does not influence the pitch.

Let's find out!

12. Take 2 boxes made of the same material, a small box and a large box.
13. Put them on the table and drum them in turn. Compare the sound of each box.
    Do you hear a difference in pitch? Circle the correct underlined word.

    A small box gives a <u>higher/ lower</u> pitched sound than a large box.

    Did you make the correct prediction?

Answer worksheet 3 Lesson 2 - Rubber band and paper cup

Name:
Date:

What do you need?

- 2 paper cups
- thin rubber band
- scissors
- ruler
- eventually 2 boxes made of the same material; a small box and a large box

To work! The experiment, part 1

1. Press the rubber band against the underside of a cup.
2. Hold the cup about 10 centimetres from your ear or the ear of a classmate.
3. Pull the rubber band very slightly tight and plunk the rubber band.
4. Pull the rubber band tight and plunk it.
   What happens with the pitch sound if the rubber band is tighter?
   The sound has a higher pitched tone.

5. Circle the right underlined word.

   A tight rubber band makes a **high**/low pitched tone.
   A loose rubber band makes a high/**low** pitched tone.

The experiment, part 2

6. Take the other paper cup and cut away a large part of the upper part. You need a small cup of about 3 centimetres high.
7. Press the rubber band against the underside of the cup.
8. Hold the cup about 10 centimetres from your ear or the ear of a classmate.
9. Pull the rubber band tight and plunk the rubber band.
10. Do this again with the large cup.
    Do you hear a difference? Is the sound from the small cup as loud as from the large cup? **No**.
11. Circle the correct underlined word.

    The sound from large cup is **louder**/less loud than the sound from the small cup.

Learning more

Does the size of the resonance box influence the pitch?

What do you think? **Every answer is right; it is what the pupils think**.

- Yes, the larger the resonance box, the lower the sound.
- No, the size of the box does not influence the pitch.

Let's find out!

12. Take 2 boxes made from the same material; a small box and a large box.
13. Put them on the table and drum them in turn. Compare the sound of each box.
    Do you hear a difference in pitch? Circle the correct underlined word.

A small box gives a **higher**/ lower pitched tone then a large box.

Did you make the correct prediction?

Worksheet 4 Lesson 3 - Let's build!

Name:
Date:

Imagine and plan

You have seen the materials you can use. Also you have thought about how you want to build your sound box. Try to write down your idea. Think of naming things like: shape, size, materials

……

……

……

……

If you want to you can also draw your idea.

Write down a list of materials you want to use

1. ………………………………………

2. ………………………………………

3. ………………………………………

4. ………………………………………

5. ………………………………………

Improve

Did you improve something?

……

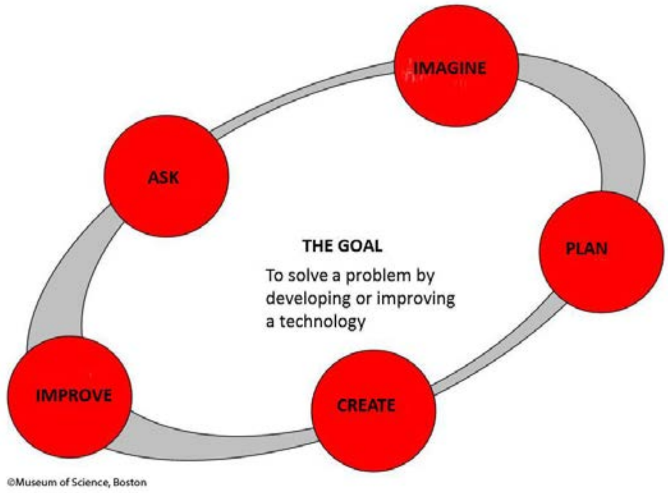
……

……

Assessment sheet Lesson 4 - Engineering design cycle

Name:
Date:

During the lessons you have carried out many different activities. Each of these activities is connected to a step in the engineering design cycle. Write, for each activity, the step of the design cycle which each belongs to.

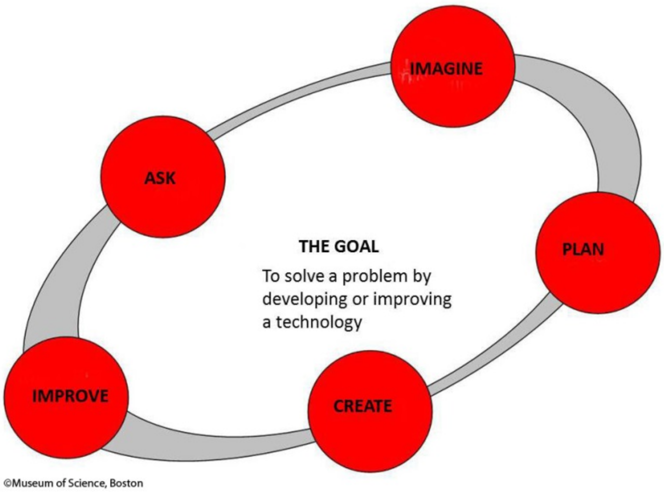


Activity	Step in the engineering design cycle
Thinking about what you need to know in order to design and create your sound generator.	
Building your sound generator	
Testing the sound generator and changing something.	
Doing experiments to investigating how to make the pitch of a string higher.	
Brainstorming ideas and solutions.	
Choosing which idea you want to build.	
Thinking about the materials you want to use.	

Answer assessment sheet Lesson 4 - Engineering design cycle

Name:
Date:

During the lessons you have carried out many different activities. Each activity was connected to a step in the engineering design cycle. Write, for each activity, the step of the design cycle which it belongs to.



Activity	Step in the engineering design cycle
Thinking about what you need to know in order to design and create your sound generator.	Ask
Building your sound generator	Create
Testing the sound generator and changing something.	Improve
Doing experiments to investigating how to make the pitch of a string higher.	Ask
Brainstorming ideas and solutions.	Imagine
Choosing which idea you want to build.	Plan
Thinking about the materials you want to use.	Plan

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Possible resonance boxes

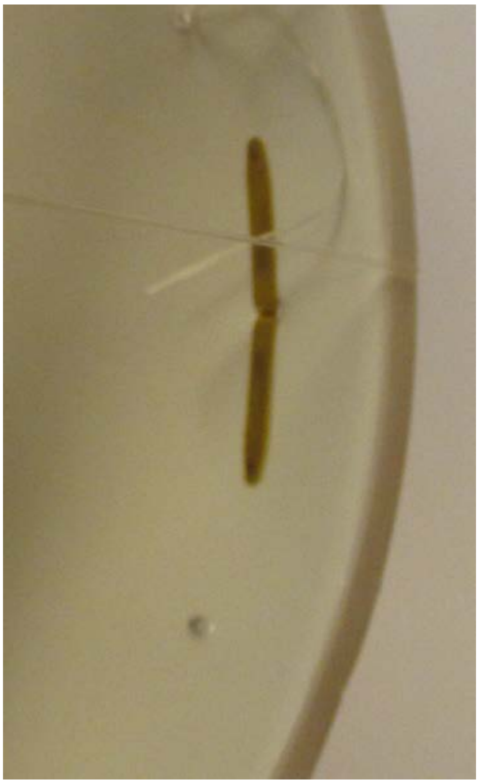
Tips and tricks about fixing a string

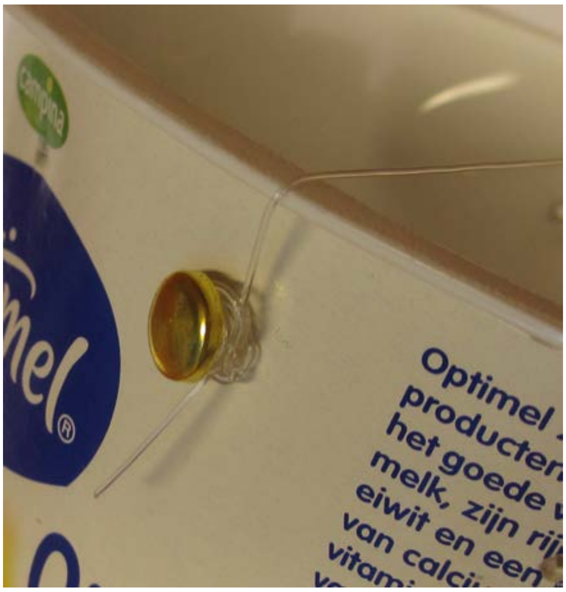
Here are examples of how strings can be attached to the resonance box.

Make a hole in the sound box and pull the string through the hole and tie a knot. Tie the string, because the button is bigger than the hole in the sound box and the string can't get loose.

The same as with the button but with a paperclip.

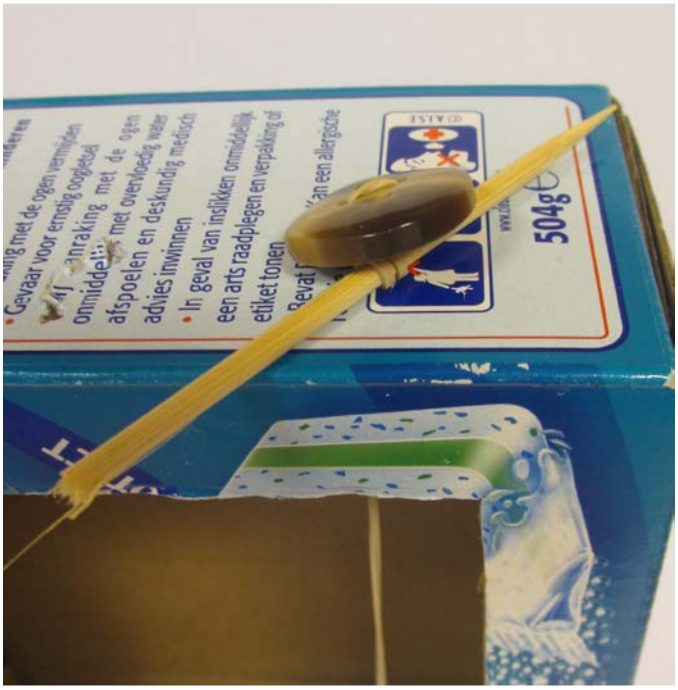
If you use an eye lag, tighten the string around it. Then when you screw the eyelag, you tighten the string.

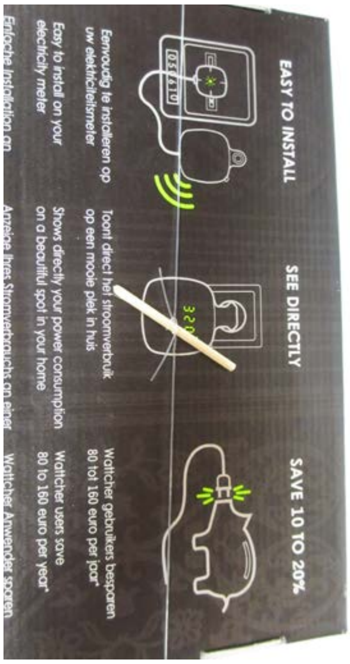




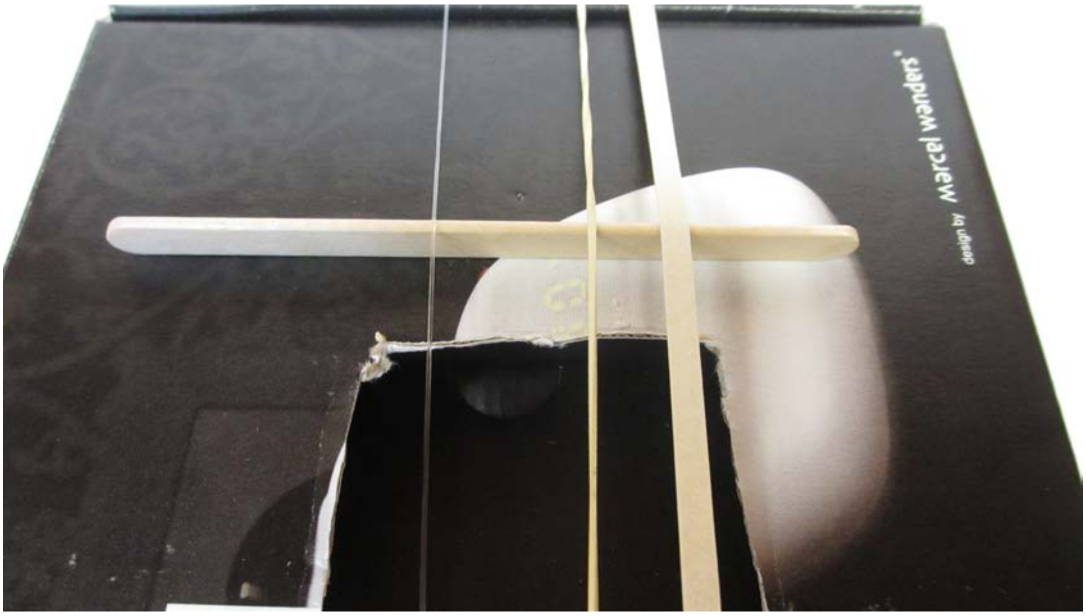
A cotterpin can be used to fasten the string to the resonance box.

Use a (part of) a skewer to tighten the string. Put a skewer between the button and the string. If you twist the skewer a few laps you tighten the string. Make sure you attach the skewer with tape or it will turn all the way back.





Use an ice cream stick as a bridge. By using a bridge the strings do not touch the resonance box and the sound is louder.



Pictures of the resources

For the strings

– fishing thread
– thick rubber bands
– thin rubber bands
– dental floss
– sewing thread

For the resonance box

This can be empty and cleaned sturdy food trays, for example:

– cottage cheese tray
– butter tray
– sturdy cardboard boxes
– Pringles container
– empty food cans
– plastic bottle (big or small)

For attaching the strings

– buttons
– paperclips
– cotter pins
– eye lag
– ice cream sticks, also for tightening of the strings and can function as a bridge for the strings
– skewers, also for tightening of the strings

Tools

– blunt embroidery needle or perforating tool

Science notes for teachers about sound and acoustic engineering

Some key science concepts involved in Lesson 2
• sound is a vibration • types of sound – high/low/loud/soft • sound needs a medium through which to move • sound travels as a wave • sound moves at different speeds through different media • sound is heard when vibrations cause the eardrum to vibrate • the pitch of a sound can be high or low • rapid vibrations can produce a high- pitched sound and slower vibrations produce a low- pitched sound • loud sounds are produced by large vibrations, soft sounds are produced by small vibrations • the pitch and loudness of a sound can be changed with a resonance box

Sound - is a vibration that travels through a medium (such as air or water). A ***vibration*** is backwards and forwards movement produced by a vibrating force. Vibrations to travel outwards in all directions from the source through the surrounding medium; they are transmitted through the medium.

Hearing - when vibrations reach the ear, they cause the eardrum to vibrate. The sounds are amplified within the ear (understanding details of the anatomy are not essential for this unit), and messages are sent via the auditory nerve to the brain where they are interpreted (i.e. 'heard'). If you whistle on a flute, for example, blowing makes the air inside the flute vibrate. People sitting all around can hear it because the vibrations travel outwards from the flute through the surrounding air and eventually reach individuals' eardrums.

Sound wave - as a source of sound vibrates, it causes vibrations of the particles that make up the surrounding medium. The backwards and forwards movement of particles (vibrations) travel through the medium and, as they do so they create areas where particles are crowded together (**compressions**) and areas where particles are spread out and are further apart (**rarefactions**) thus creating waves of pressure (**sound waves**). You can see an animation of this at:
http://www.acs.psu.edu/drussell/Demos/waves-intro/waves-intro.html

Three characteristics describe a sound wave:

frequency -the number of waves that pass a point in every second –measured as cycles per second called Hertz (Hz)
wavelength -the distance from the crest of one wave to the crest of the next wave
amplitude- a measure of the size of the wave

Frequency - the number of vibrations in one time unit.
The human ear can hear sound between 20-20.000 Hz. That means that 20 Hz is the lowest sound you can hear and 20.000 Hz is the highest. This also depends on age and health. In general, children can hear higher sounds than adults so there are sounds that the pupils in your class can hear, which you can't. Some animals can hear and produce much higher or much lower sounds than humans can hear. A dog, for example, can hear sounds of 15-50.000 Hz. A bat can hear sounds of 100-100.000 Hz, while the song of the Humpback Whale is 20-24Hz.

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Pitch - depends on frequency. A high -pitched sound has a high frequency, and a low- pitched tone has a low frequency. The pitch of a sound depends on the frequency of the sound waves which is determined by the rate of vibration. The higher the frequency, the greater the number of vibrations per unit of time. A higher frequency (so faster vibrations), produce a higher-pitched sound than sound with slower vibrations. Frequency is measured in vibrations per second or Hertz (Hz). The higher the frequency of a sound, the shorter the wavelength. This influences the way a sound moves (see *How sound waves behave* - below).

Amplitude - the size of a wave. The amplitude determines the loudness of the sound. A large amplitude produces a loud sound, and a small amplitude produces a soft or quiet sound. You can illustrate this if you plunk a ruler (see *Experiment with a ruler* in Lesson2). A big vibration produces a louder sound than a small vibration. Sound intensity is measured in decibels (dB). It is a logarithmic scale. A difference of 10 dB between the intensity of two sounds, means that one sound is 10 times louder than the other. Human speech ranges between 40 dB (whispering) and 80 dB (shouting). How sensitive your ear is to a sound depends on the frequency of the sound. The human ear is most sensitive to sounds with a frequency of about 4.000 Hz. The highest note on a piano is around 4.000 Hz. There are very loud sounds that your hearing doesn't register at all. For example, the sounds bats make are 130 dB, but we can't hear them because the sound is too high to hear for our ears.
A few examples of different sounds on the dB scale:

- whispering 40 dB
- conversation 60 dB
- shouting 80 dB
- risk of hearing damage 85 dB
- pneumatic hammer 100 dB
- jet engine at 10 m 120 dB (or class full of shouting children)
- pain threshold 130 dB
- rock concert close to the speakers 150 dB
- heavy artillery fire 180 dB

Medium - sounds need a medium to travel through. If there is no medium, there is nothing to vibrate. The medium can be air or water, but also solid materials such as wood. When swimming under water you still can hear things. Wood is also a good medium; put your ear against the table and tap the table. Can you hear it? When we talk of the speed of sound, we usually mean the speed of sound through the air. However, sound travels at different speeds in different media. In air, the speed of sound is approximately 343 metres per second (1235 km/h); this varies depending on the humidity and temperature of the air. In water, the speed of sound is faster (1500 m/s). Sound in water travels much further than through air. For example, whales can hear each other call over distances of hundreds of miles. Sound cannot travel in a vacuum, because there is nothing to travel through. So movies in which you hear a big bang when something explodes in space are not scientifically correct.

Acoustics* -** is the science that studies mechanical waves. A ***mechanical wave is a wave that needs a medium to travel as it is propagated through the oscillation of particles. The application of acoustics is, for example, in the audio and noise control industries. The characteristics of a room or auditorium determine if the sound is heard well. Things that have to be taken into account are reflection of vibrations, absorption of vibrations, resonance and distance (people in the back want to hear it too).

How sound waves behave

When sound waves encounter an obstacle, several things can happen. This knowledge can be used when designing a concert hall or theatre:

- ***Absorption***. When an obstacle is made of a soft, porous material (e.g. foam or cotton wool) a lot of energy from the sound waves is absorbed. This causes smaller differences in pressure in the sound wave and a muffling of the sound. This is used in recording studios for example, where the walls, floor and ceiling are covered with soft, porous materials to reduce echo and other sounds that don't belong on the recording. Also there is less noise in a room with a carpet on the floor than in a room with a hard floor, because a carpet absorbs sound.
- ***Reflection***. When sound encounters a hard surface (e.g. rock or concrete) it is reflected and the waves bounce back to the source. This is the cause of echo and reverberation. Sounds are louder in a room with materials that reflect sound (for example, a bathroom with tiles on the floor and walls) than they are outside. This is because of the reflection of the sound against the tiles. You could say that the amount of sound energy reaching your ears is higher, because one sound reaches your ears several times.
- ***Diffraction***. Sound waves can move around objects. For example when there is an obstacle between you and a source of sound, you can still hear it.

The frequency and, therefore the pitch, influence the way sound moves in a space. And also how it is absorbed, reflected or diffracted. High sounds are more easily absorbed and scattered than low sounds. Low sounds are more penetrating. That is the reason that when there is a concert or large party at a distance you can only hear the low noises, such as base notes and drumbeats. The higher sounds are either absorbed or scattered between the source and you.

When designing and making musical instruments, different materials are used depending on their absorbing or reflecting properties. Also the shape and size of the space in which the vibrations are produced influences the sound. In general, the larger the instrument, the lower the pitch of the tone it produces. This is because a larger instrument can produce sounds with a longer wavelength and therefore lower sounds. For example, an organ pipe has a length of half the wavelength of the pitch it produces. So the longer the organ pipe, the lower the pitch of the tone it makes.

A common explanation of ***mechanical resonance*** is given by the example of pushing a swing. When the push is provided in accordance with the movement of the swing, then the result is bigger swing. If the same push is not given at the correct point, the impact on the swing may be relatively small or it may even reduce the movement if it acts against the direction. ***Acoustic resonance*** is a phenomenon in which the sound waves produced by the acoustic system can be enhanced when the frequency of the sound approaches a natural vibration frequency of the system. Acoustic resonance is extremely important for the makers of acoustic instruments. In a wind instrument, like a saxophone, for example, the musician blows against the reed of the mouthpart creating a vibration. When the frequency of the vibration of the reed matches the natural frequency of vibration of the column of air within the body of the instrument then resonance occurs to produce a loud sound. In Lesson 2.5 the pupils will explore the making of a resonance box to amplify the sound they make.

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Some pupils' ideas about the science of sound and engineering

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.

Children's ideas about sound

Most children struggle with the abstraction level of sound. Early conceptions of sound may involve children not recognising that sound has a source, whereas later conceptions may entail ideas about sound as a physical entity with properties like volume or weight and that sound can be pushed by water or air(1). Some children also think that sound can be contained in something. In a research study by Haim, Eshach & Schwartz (2006), a student said: 'Voice is like bubbles of noise. Like small balls. Inside the balls there is a noise. When those balls open the voices comes out.' (1). Children need to have the opportunity to experience sound as a vibration, to identify vibrating sources where this is not immediately obvious (such as in Lesson 2.1 where children 'feel' the vibrations in the throat while speaking).While children may use the word 'vibration' they may not fully understand that this is a movement backwards and forwards (a shake) with no net movement from a position.

Even when children appreciate that sound is caused by a vibration, they may think that an entity (called sound) that is *different from* the vibration has been produced (2). In activities relating to sound travelling, it is, therefore, important to ensure that children understand that sound is a vibration, and that it is the vibration that travels through the medium. It is helpful to draw attention to where this can be experienced, such as the vibrations that can be felt (as well as heard) when a metal table leg or wooden table top is struck. Activities that involve children passing on a 'vibration' are useful in helping to develop this idea. It is also important to make a connection between vibrations travelling through the air (or other media) and entering the ear, making the ear drum vibrate.

Children's ideas about sound travelling

The concept of sound needing a medium in which to travel is difficult. Children around 7 years often think that sound travels without a medium, the sound 'escapes' from cracks and holes as pupils say (1,3). Many children think that sound can travel through a space without air (like a vacuum or in space)(2). This is something children see and hear in the movies and games they watch and play. Piaget discovered that children around 11 years have a notion that sound travels through a medium and that vibration are involved. In the Space report (3) a 10 year old boy answered when asked if he could explain how sound travelled 'It doesn't mean like I travel in a car it means – oh I don't know – but it's not travelling in a car or like me on a bike – it is something else.' Children may also think that sound travels in one direction from the source (from the source to the ear of the person who hears the sound).

Children's ideas about sound waves

The notion of sound waves is problematic. Some children think that sound waves are similar to waves in the sea (2,3). In daily life, the term 'wave' is not the same as the way science uses the term; in fact there are different types of waves in science. The slinky demonstration in Lesson 2.2 allows children to think about the difference between water waves and sound waves in terms of movement. Providing a push sends a wave of

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vibration (forwards and backwards movement) down the slinky when it is held at both ends. Children will need to observe that the slinky returns to its original position once a wave has passed. It is important to point this out to so that they begin to recognise that a wave is a region of compression moving along the slinky. This is a challenging idea and the teacher may have to tolerate children's partial understanding of it.

Children's ideas about changing sounds

For children it can be difficult to hear the change in a pitch when the loudness of a sound also changes. Verbalising this is very difficult. Common ideas are that hitting an object harder changes the pitch of the sound produced and loudness and pitch of sounds are the same things (2,5). It is important in Lesson2.3 and 2.4 to ensure that the children understand what is meant by loud/soft/high- pitched sound and low- pitched sound through *direct* experience. This is an area of learning that works well with musical instruments and exploring how to change the pitch of familiar instruments will support learning. For instance, in playing a flute, the pitch is changed by opening or closing the air holes. This changes the size of the column of air to be vibrated (a small column of air produces a high pitch and a large column of air a low pitch). It is often thought that the sound of a flute is produced by the vibration of the material of the flute and not vibrations of the air inside (2).

The terms 'amplitude' and 'frequency' are challenging for most children of this age. The teacher should consider carefully children's level of understanding of sound prior to introducing them. *Large/small* and *fast/slow* vibrations of a ruler or elastic band (Lessons 2.3 and 2.4) would provide a useful working description for many pupils.

Finally, children are likely to have limited experience and knowledge of resonance. This is a complex scientific idea and the intention in this unit is not to develop a full scientific explanation of it. At this stage resonance is best understood through exploring the making of resonance boxes (Lessons 2.4,2.5,2.6)

1: Eshach, H. & Schwartz, J.L. (2006). Sound Stuff? Naïve materialism in the middle-school students ' conceptions of sound. *International Journal of Science Education, 28 (7)*, 733-764.

2. *Nuffield Primary Science Process and Concept Exploration Ages 7-12 Teachers' Guide: Sound and Music* (1995) Nuffield : London.

3: Hapkiewicz, A. (1992). Finding a List of Science Misconceptions. *MSTA Newsletter, 38 (Winter'92)*, pp. 11-14.

4: Watt, D. & Russell, T. (1990). *Primary Space Project Research Report. Sound*. Liverpool University Press: Liverpool.

5: Periago, C., Pejuan, A., Jaén, X., & Bohigas, X. (2009). *Misconceptions about the Propagation of Sound Waves*, Departament de Física i Enginyeria Nuclear, Universitat Politècnica de Catalunya.

6: Author unknown, Operation Physics Elementary/ middle school physics education outreach project of The American Institute of Physics (1998). *Children's Misconceptions about Science*, obtained on 09-07-2012, http://www.eskimo.com/~billb/miscon/opphys.html

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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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