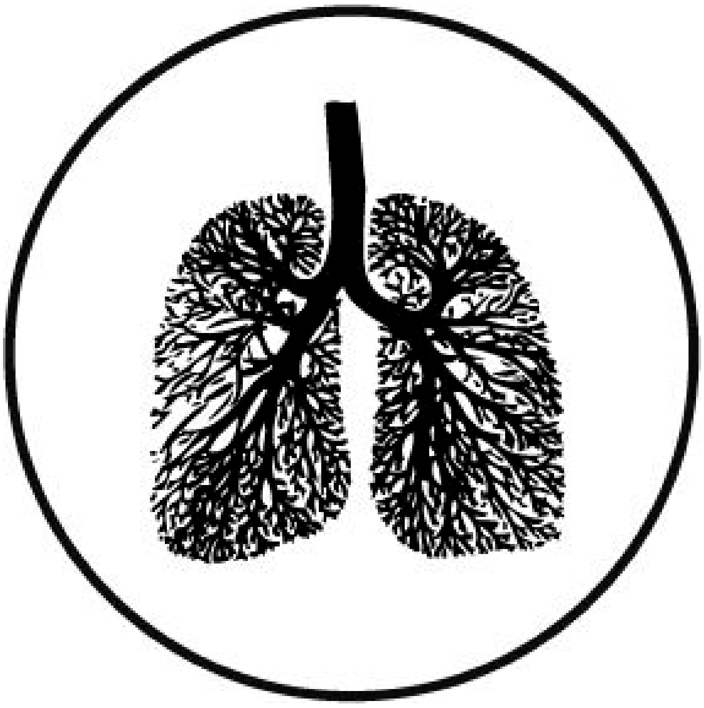
Huff and puff

Designing a device for measuring exhalation volume

Bio-Medical engineering

Human body, Respiratory system

Unit for pupils from 10-12 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: 365 minutes (plus 45 minutes optional extension activities)

Target group: 11-12 year old pupils

Description: in this unit we specifically look at biomedical engineering through a relevant scenario which challenges pupils to develop and design a biomedical instrument. The specific science aspects that are taught in this unit are the respiratory system, the concept of volume and different methods of measuring volume.

Science curriculum: this unit will relate to the science curriculum for the human body and the respiratory system, and the concept of volume and methods for measuring it.

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

Objectives, in this lesson the pupils will learn that:

- the biomedical engineer's task is to develop methods and instruments for diagnosis, treatment, rehabilitation, and follow-up;
- breathing is performed in two stages: inhalation and exhalation;
- air is a substance that takes up space and that the volume of the space can be measured;
- volume = the space taken up by a substance. The Maximal Exhalation Volume = the largest volume of air that can be expelled from the lungs after deep inhalation.
- the Engineering Design Cycle can be deployed to produce a biomedical instrument.

The lessons in this unit are:

A Preparatory lesson aimed at raising awareness of how engineering contributes to our daily lives in ways that are not always obvious.

Lesson 1, which introduces the engineering problem, its context and the engineering process.

Lesson 2, in which the 'ask' element of the engineering process leads to an investigation of the respiratory system; the concept of volume and different methods to measure it, the concept of maximal exhalation volume and important principles of measurement.

Lesson 3, which involves the pupils in applying the engineering design process (EDP) to meet the challenge. The challenge is to design a device to quantitatively measure the maximal volume of air in their lungs that can be expelled after deep inhalation (maximal exhalation volume).

Lesson 4, when it is time to evaluate the process of creating the instrument for measuring the air volume in their lungs. This is also the moment for pupils to show if they were able to meet all the criteria and to talk about how they made improvements.

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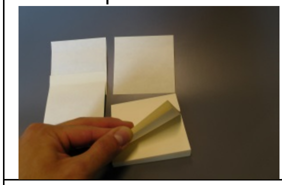
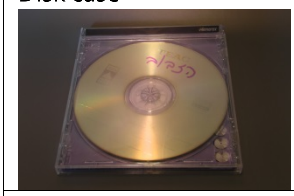
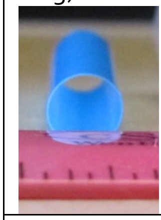
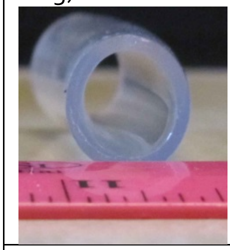
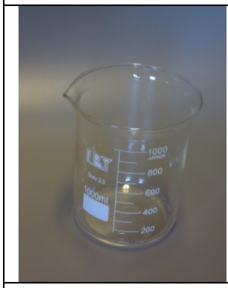
Resources

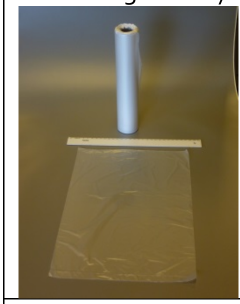
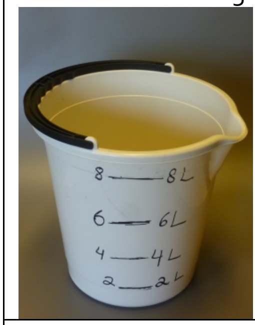
List with all the materials and quantities needed for 30 pupils.

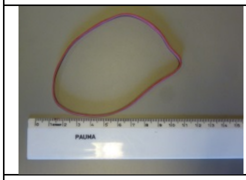
Material	Total amount	Lesson 0	Lesson 1	Lesson 2	Lesson 3	Lesson 4
'Post It' pack 	**1**	1				
Eye glasses 	**1**	1				
Eye glasses case 	**1**	1				
Opaque (from light) envelope 	**1**	1				
Sheet of paper	**1**	1				
Transparent plastic envelope for papers 	**1**	1				
Cheap jewellery	**1**	1				
Jewel box 	**1**	1				
Disk	**1**	1				
Disk case 	**1**	1				
Tea bag	**1**	1				
Glue stick	**1**	1				

Material	Total amount	Lesson 0	Lesson 1	Lesson 2	Lesson 3	Lesson 4
						
Regular mail envelope	**1**	1				
Box of tacks	**1**	1				
Scissors in their envelope 	**1**	1				
Box of toothpicks 	**1**	1				
Stapler in its envelope 	**1**	1				
peeler with its envelope 	**1**	1				
Poster of the stages of the Engineer Design Process (see Appendix).	**1**		1	1	1	1
Worksheet #1 *The Engineering Design Process*	**30**		30			
Worksheet #2 – *The respiratory system*	**30**			30		
Assessment sheet #1– *The breathing process*	**30**			30		
Assessment sheet #2 – *Volume measurement*	**30**			30		
Syringe (50 ml) 	**15**			15	4	
2 transparent soft drink bottles, one with a hole (approximately ½ cm diameter) and the other airtight.	**1**			1		

Material	Total amount	Lesson 0	Lesson 1	Lesson 2	Lesson 3	Lesson 4
						
Transparent sticky tape	**1**			1		
Scissors	**5**			1	5	
Balloons	**10**			10		
Deep transparent bowl (or plastic aquarium)	**1**			1		
Water (preferably use a room with a water tap)	a water tap			a water tap	a water tap	a water tap or about 10 litres of water
Transparent glass (from plastic or glass)	**1**			1		
Handkerchief / absorbent paper	**1**			1		
Drinking straws (diameter 4-5 mm, 4-5 cm long) 	**30**			30		
Plastic tubes (diameter 1-1.5 cm, 4-5 cm long) 	**30**			30		
Familiar food containers marked with their volume (milk bottles, soft drink bottles, cleaning materials, oil, maple syrup, ketchup bottles, etc.).	**10**			10		
measuring cup (0.2/ 0.5 /1 litre) 				1-2	3-4 of each volume	
chemistry cup (100/500/1000 ml)				7	1-2 (500 or 1000)	

Material	Total amount	Lesson 0	Lesson 1	Lesson 2	Lesson 3	Lesson 4
						
Calibrated measuring cups used in the kitchen etc.  	**5**			5	5	
Large stone or other heavy object of undefined shape.	**1**			1		
Transparent plastic container with volume about 4 litres  	**1**			1		
Wide tub 	**8**			1	8	
Flexible plastic tube, 50 cm long, diameter 1 cm. 	**1**			1		
Cut pipes whose diameter enables them to be inserted into the flexible plastic tube.  	**10**			10		
Marker	**4**			1	4	

Material	Total amount	Lesson 0	Lesson 1	Lesson 2	Lesson 3	Lesson 4
Food colouring (a bottle)	**1**			1		
Containers marked with their volume and cut at both ends (soft drink bottles of different sizes, non-toxic liquid detergent bottles and cleaning fluid bottles – 2litre and 3litre 	**4 (2 from each volume)**				4 (2 from each volume)	
Plastic bags of varying size (½ - 4litres) 	**10 of each size**				10 of each size	
Bucket with markings 	**3**				3	
Long plastic sleeves open at both ends (2.5 m long, 10 cm diameter) 	**4-5**				4-5	
Funnels (10-15 cm diameter) 	**4**				4	
Thick, wide elastic bands	**30**				30	

Material	Total amount	Lesson 0	Lesson 1	Lesson 2	Lesson 3	Lesson 4
						
Tubes for exhalation (for reasons of hygiene) – 4-5 cm long, 2-3 cm diameter) 	**30**				30	
Rags	**6**			2	6	
Various tubes 0.5m-1m length about 1-2 cm diameter	**4**				4	
worksheet #3 Imagine	**8**				8 (1 for each group)	
worksheet #4 Plan	**8**				8 (1 for each group)	
Assessment sheet #3 *Final assignment after Completing the Challenge*	**30**				30	
Short film demonstrating the spirometer: http://www.youtube.com/watch?v=LeXgXKIyRAo&feature=related	**1**					1
Computer	**1**					1
Screen/projector	**1**					1
Measuring instrument built by the pupils	**5-8**					5-8
Assessment sheet #4 *The Engineer Design Process – Summary of the ENGINEER unit*	**30**					30

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

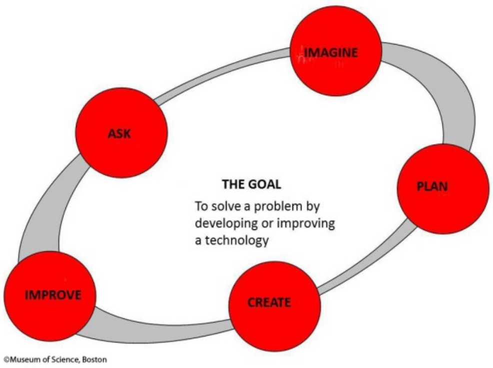
- Collect together a range of different envelopes and packages
- Print copies of worksheet 1 if using
- Collect pictures for introductory activity

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 th e 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.

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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

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

Duration: 50 minutes

Objectives: in this lesson pupils will learn:

- the nature of biomedical engineering and its importance to medicine;
- the engineering design process can be used to create important scientific instruments;
- that biomedical engineering can help to resolve medical problems of relevance to their everyday lives.

Resources (for 30 pupils)

- ☐ 1 poster that indicates the stages of the Engineer Design Process.
- ☐ 30 worksheets Lesson 1 Worksheet 1 '*The Engineer Design Process*.
- ☐ 10 glasses

Preparation

- Make copies of the worksheets.
- Collect 10 different eyeglasses.

Working method

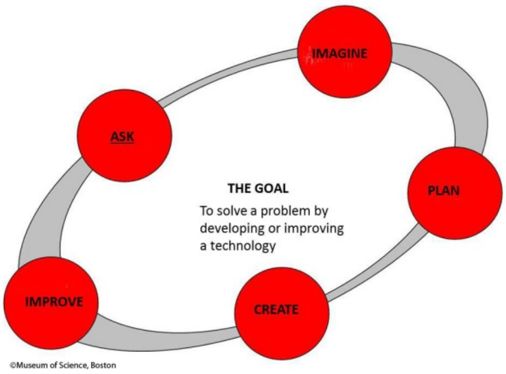
- Plenary discussions and demonstrations
- Individual work

Key ideas in this lesson

- Technical tools are the result of a process that involves several stages. This is known as the Engineering Design Process.
- The biomedical engineer's task is to develop methods and instruments for diagnosis, treatment, rehabilitation, and follow-up.

Context and background

The lesson deals with defining the engineering need and presents the pupils with the challenge of the unit: to design a device to quantitatively measure the maximum volume of air in their lungs that is used for breathing (maximal exhalation volume). The pupils are exposed to the field of bio-medical engineering and the EDP by participating in a workshop dealing with familiar biomedical instrument – eyeglasses.



1.1 Introductory activity - whole class discussion - 20 minutes

In the previous lesson we learned what engineering is and what engineers do. Engineering is not one field, there are many fields like: electrical engineering, construction engineering, civil engineering etc... in our unit we will focus on biomedical engineering.

Has anyone heard about this field of engineering? You can write the pupils' answers on the board. *Biomedical engineering is a multi-disciplinary field which applies the knowledge and tools of various spheres of engineering. The biomedical engineer's task is to develop methods and instruments for diagnosis, treatment, rehabilitation, and follow-up. In their work they combine knowledge from various engineering and science fields (especially medicine).*

An example of the work of a biomedical engineer – making glasses:

In order to understand the work of the biomedical engineer better, the class will take a deep look into a common and well known biomedical device – glasses.

Pass around a few pairs of glasses. Let the pupils examine the different parts of the glasses and the various materials that the glasses are made of. They can also be given the chance to try the glasses on for a short while. This will give them a sense of what it's like to see objects out of focus or distorted.

- What need do the glasses solve? *Glasses are used to correct vision impairment: nearsightedness, farsightedness astigmatism and more.*
- What do engineers need to know in order to solve vision impairment?
    - *Ophthalmology and the physiology of the eye.*
    - *Optics – to match a type of lens (concave, convex etc.) to the specific vision impairment.*
    - *Materials engineering – to make the glasses from materials that are as durable, strong, light weighted and cheap as possible.*
    - *Ergonomics and design – to plan comfortable and durable glasses.*

Engineers also have to take into account all sorts of other parameters like budget, time, materials available, workforce...

After the initial **gathering of data**, a development team of engineers and other experts get together and **come up with ideas** to solve the specific vision impairment, for instance: near-sighted (myopia). After reaching an agreed upon solution, for example: light weighted glasses with concave lenses, they **plan** a prototype, **build it and test it**. If the prototype isn't satisfactory – breaks easily, makes far away objects look out of focus or pinches the nose – then the development team try to **improve** the glasses until they get a satisfactory product. For example, they can design glasses with multifocal lenses made out of durable plastic.

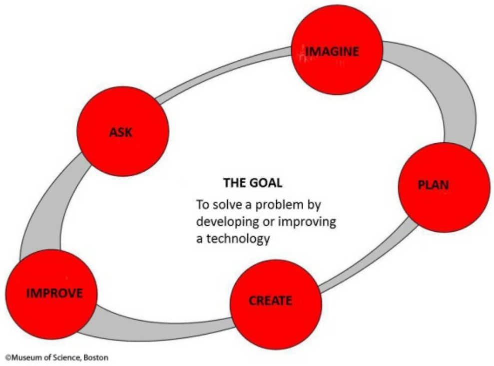
The design process for the production of glasses isn't as simple and straight forward as the example above indicates. Sometimes there's a need to go back, gather more information, build more prototypes or come up with better ideas.

Tip – You can find more information about biomedical engineering here:
http://www.mada.org.il/en/about/engineer/challenge/about-biomedical-engineering

1.2 Presenting the Engineering Design Process - whole class discussion - 5 minutes

The teacher presents the Engineering Design Process – a common process engineers use when they develop a product - a technological instrument. In the next lessons, the pupils act as engineers and undertake the whole process in order to solve a problem.

Engineering Design Process



The goal: defining the problem and the need
Ask: Finding out information
Imagine: suggesting ideas and choosing the best solution
Plan: planning and developing the chosen solution
Create: create a prototype
Improve: testing, evaluation and improvement

Tip- It is recommended that you use a poster or other methods to illustrate the stages of the design process throughout the teaching unit. In each lesson you should indicate the stages you are focusing on.

Tip- It is important that the pupils understand that the process is not necessarily linear. At any point it is possible to go back to any of the previous stages.

1.3 Defining the challenge - telling a story and whole class discussion - 15 minutes

Case presentation: t**he teacher reads the pupils a story** – See appendix *How can we help Yael? A surprising challenge on the annual school trip*

The teacher tells the pupils the Goal (the challenge): **to design a technological instrument that can measure maximal exhalation volume** that will help the doctor to diagnose Yael's medical problem.

Tip- A medical diagnosis is carried out by a doctor. It includes several stages: describing symptoms and what the patient feels, a manual examination by the doctor, the use of technological instruments to locate the source of the problem and/or to measure various parameters in the body.

Group discussion: Yael's problem is in the respiratory system, which part can it be? Which problems or illnesses are you aware of that relate to the respiratory system? At this point we expect the pupils to make various suggestions but there is no need to identify the right answer.

1.4 Filling in worksheet The Engineering Design Process - individual work - 5 minutes

The teacher distributes **Lesson 1 worksheet 1** The Engineering Design Process which the pupils fill in.

1.5 Conclusion - plenary - 5 minutes

After completing the worksheet, the teacher asks one of the pupils to present the goal and writes the challenge on the board: ***to design a biomedical instrument that measures maximal exhalation volume*.**

The teacher tells the pupils that from now they will act as engineers and in the next lesson they will start with the ASK stage - asking questions and gathering information that will help them to do the challenge.

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Lesson 2 – What do we need to know?
Finding out about Air, the respiratory system and the concept of volume

Duration: 120 minutes (135 with additional activity)

Objectives: in this lesson pupils will learn about:

- the structure of the respiratory system: respiratory apertures;
- the stages of the breathing process (inhalation and exhalation);
- the concept of volume and ways of measuring it, including the exhalation volume of the lungs.

Resources (for 30 pupils)

- 30 assessment sheet 1– *The breathing process*
- 30 assessment sheet #2 – *Measurement of volume*
- 15-30 syringes
- 2 transparent soft drink bottles, one with a hole
- 1 transparent sticky tape
- 1 scissors
- 10 balloons
- 1 deep transparent bowl
- 1 transparent glass
- 1 handkerchief
- 30 drinking straws (diameter 4-5 mm, 4-5 cm long)
- 30 plastic tubes (diameter 1-1.5 cm, 4-5 cm long)
- Familiar food containers marked with their volume (milk bottles, soft drink bottles, cleaning materials, oil, maple syrup, ketchup bottles, etc.)
- 1-2 measuring cups (100/500ml/1litre)
- 7 chemistry cups (100ml)
- 5 calibrated measuring cups used in the kitchen etc.
- 1 large stone or other heavy object of undefined shape.
- 1 transparent plastic container with volume about 4 litres
- 1 flexible plastic tube, 50 cm long, diameter 1 cm.
- 10 cut pipes whose diameter enables them to be inserted into the flexible plastic tube.
- 1 marker

Preparation

- Make copies of worksheet #2 and assessment sheets #1 and #2.
- Organise all the materials and the equipment.
- Build a model to illustrate the breathing process (resources & instruction in the appendix).
- Watch the Video clips:
  The handkerchief that doesn't get wet http://www.youtube.com/watch?v=9N5rkI61o-U&feature=youtu.be
  Archimedes' Principle 1 http://www.youtube.com/watch?v=Ryx1ELGJqeA&feature=youtu.be
  Archimedes' Principle 2
  http://www.youtube.com/watch?v=KYkh-9-Qs1M&feature=youtu.be
  Measuring exhalation volume
  http://www.youtube.com/watch?v=cnewH2HUbBw&feature=youtu.be

Working method

- Whole class discussions and demonstrations.
- Working in groups of 4-5 pupils.
- Individual work.

Key ideas in this lesson

- Air is a substance that takes up space and can be felt.

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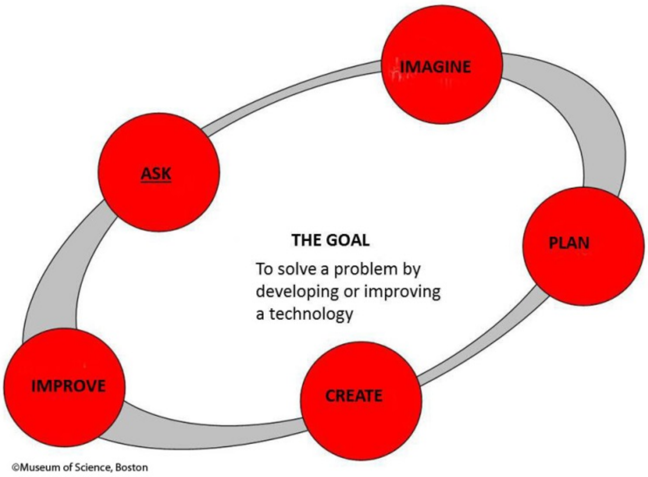
- The act of breathing has two stages: Inhalation – the intake of air into the lungs through expansion of chest volume - and exhalation – the expulsion of air from the lungs through contraction of chest volume.
- Various factors such as dust particles and air pollution can cause constriction of the air passages (trachea and bronchi). The constriction causes a decreased volume of air through the air passages, resulting in asthma.
- Volume = the space taken up by a substance.
- Maximal exhalation volume = the largest volume of air that can be expelled from the lungs after deep inhalation.

Context and background

The lesson includes scientific material to help pupils solve the challenge, by performing experiments that demonstrate the scientific principles upon which the respiratory process is based, and experiments on volume, focusing on exhalation volume.



2.1 Introductory activity - whole class discussion - 5 minutes

The teacher tells the pupils that in this lesson they will learn scientific ideas that will help them to solve the challenge – to design an instrument to measure the lungs volume (the exhalation air volume).

What information do we need before starting the challenge?

The teacher listens to the pupils' answers and writes them on the board.

- *Information about the structure of the respiratory system (organs like – lungs, trachea etc.)*
- *Information about how the respiratory system works*
- *Elements that can affect the functioning of the respiratory system*
- *Other suggestions by the pupils*

The teacher tells the pupils that they will learn these topics in this lesson and indicates on the EDP poster the stage the pupils are at: The stage of gathering information – the Ask stage.

2.2 What do we breathe? - whole class discussion - 10 minutes

What do we breathe? *Air* Can air be seen? Can we feel it?

Pupils suggest how we can feel air: wind, expulsion of air from the lungs etc. The teacher distributes a syringe for each pupil or for each pair of pupils and asks them to fill the syringe with air and then to press the plunger down and deflate.

2.3 Air takes up space - individual experience, in pairs - 5 minutes

The pupils are asked to do more experiments with the syringe:

To fill the syringe with air; To block with their finger the opening of the syringe and to press the plunger down thereby compressing the air. Is it possible to press the plunger to the end of the syringe? *No, it's not possible, the air takes space. It can be compressed but it still takes space.*

2.4 Air takes up space - inflating balloons in bottles – demonstration - 15 minutes

Inflating balloons in a "sealed" bottle and a bottle with a hole.

Two transparent bottles with balloons each having a hole in the base of each bottle, and sticky tape covering the hole of one bottle. Two children are asked to blow up the balloons.

What happens?The pupil with the open bottle will succeed in inflating the balloon.

The pupil with the sealed bottle will not succeed in inflating the balloon.

Why does this happen? Why does one pupil manage to inflate the balloon while the other does not succeed?

Pay attention to the pupil's answers, and invite more pupils to attempt to inflate the balloon.

How can we test and verify the explanations?

Listen to the pupil's answers, and try to carry out their suggestions. Then open the hole in the sealed bottle and once again try to inflate the balloon.

Explanation: since the air in the bottle takes up space, when the hole is closed the air around the balloon has no place to escape, so it is more difficult to inflate it. When the hole is opened, it is possible to enlarge the volume of the balloon because the air in the bottle can be pushed out through the hole.

2.5 Optional extension activity: air takes up space - the handkerchief – demonstration

How can a dry handkerchief be inserted into a full container of water without it getting wet? If the teacher chooses to do this experiment it will add 15 minutes to the lesson.

Listen to the pupils' suggestions; try to carry them out, and discuss what happens with them. Finally (possibly a pupil will suggest this), place the handkerchief in the bottom of a cup, turn the cup over and immerse it in an aquarium. When the cup is removed, the (dry) handkerchief can be shown to the class.

Explanation: the air in the cup "takes up space" and prevents water from entering and wetting the handkerchief.

2.6 The respiratory system - individual work and discussion - 15 minutes

The pupils will need a basic understanding of the respiratory system: that air is taken in through our nose to the lungs where it oxygenates the blood. Carbon dioxide is expelled from the lungs, the movement of which is controlled by the diaphragm. If the process is not working properly we will get very poorly which is why the doctor is worried about Yael

The teacher can show this in the form of a poster – see appendix

2.7 The breathing process – inhalation/exhalation – demonstration/discussion - 10 minutes

How does air enter our lungs? In order to answer the question, the teacher gives the pupils an activity:

Close your eyes, let your body relax, take a deep breath, and draw the air into your lungs. Breathe out.

What did we do that let us breathe in and out?

We activated our chest and diaphragm muscles.

What happens when we inhale?

1. *When the diaphragm (the muscle separating the thoracic cavity from the stomach cavity) contracts, it stretches/ descends, causing the chest muscles to elevate the ribcage.*
2. *Chest volume expands.*
3. *Air pressure in the lungs decreases.*
4. *Outside air, which has a higher pressure in comparison to the air pressure in the lungs, enters the breathing passages and the lungs.*

You can go on filling your lungs until there is no more room.

What happens when we exhale?

As we start to exhale, the air pressure in the lungs is relatively higher than the outside air.

1. *The muscles of the respiratory system relax – the diaphragm curves, the thoracic muscles return to their former position, and the ribs attached to these muscles descend once again.*

2. *Chest volume decreases due to the force of gravity.*
3. *Air pressure in the lungs increases.*
4. *Air is expelled from the lungs towards the outside air, which has a lower pressure.*

2.8 Respiratory system - individual experiment and whole class discussion - 20 minutes

What can affect the flow of air in the respiratory system?

Pupils make suggestions and the teacher adds more information.

Dust particles, smoke, soot, etc. that enter the breathing passages and settle along its sides can cause them to constrict. (If a large foreign object penetrates the breathing passages it can cause asphyxiation – the inability of air to reach the lungs).

Other factors that can affect the flow rate of air can be narrowing of the passages as the result of spasms in the muscles covering the passages of the respiratory system; fluid absorption in the tissues; swelling; and the production of phlegm.

Breathing difficulty that comes from asthma is caused by narrowing of the passages in the respiratory system.

To illustrate the concept of flow rate and factors influencing it in the respiratory system, the pupils can conduct the following simple experiment: Pupils should try to extract or insert air through tubes of varying diameter in the same length. Ask them to take a deep breath and then to exhale all the air at once through the tube. They will see that it takes more effort and more time to transfer air through a tube with a narrow diameter than one with a wider diameter (it's possible to measure the time with a clock / stopwatch). The experiment demonstrates the transfer of air through healthy respiratory pathways compared to the transfer of air through narrow respiratory pathways. The narrower the tube, the harder it is to pass air into the lungs and out again.

Tip -It is recommended that you collect the tubes from the pupils after the activity. They can distract them and interfere with the continuation of the lesson.

Tip – If pupils mention the asthma inhaler the teacher can tell them that the inhaler (the medicine that is released from it) causes a decrease in swelling of the breathing tubes. Since the swelling causes narrowing of the respiratory system, its reduction enables the tubes to expand back and allow normal breathing.

Tip – Maximal Exhalation Volume = the volume of air that is expelled from the lungs after maximal inhalation.

2.9 What is volume and how can it be measured? – discussion - 5 minutes

In order to conduct the challenge we need to gather additional information about the concept of volume.

What is volume and how can we measure it?

After listening to the pupils' answers, the teacher explains the definition of volume and writes it on the board - *Volume = the space taken up by a substance*.

Volume is generally measured in litres or cubic centimetres (1 cm x 1 cm x 1 cm). One litre = 1000 cubic cm.

Measurement results are indicated on the measuring instrument in appropriate units of measurement. When designing a measuring instrument it is essential to provide markings that show the appropriate measurement. For example: A ruler is marked in intervals of centimetres and millimetres; a thermometer is marked in intervals of 0.1 degrees Celsius and a measuring cup is marked in intervals of 0.1 litres.

2.10 Identify the volume of various containers – working in groups - 5 minutes

The teacher shows the class various containers marked with their volume. Distribute containers that pupils recognise from home – oil, maple syrup, ketchup, soft drinks etc., and ask the pupils to write down the volume of each one.

Tip – For outstanding pupils it's possible to give one more container to weigh instead of determining the volume. You can have a discussion emphasising the difference between them.

2.11 Experiment about measuring the volume of liquids – working in groups - 15 minutes

The teacher shows the pupils various instruments for measuring volume – measuring cup, syringe, chemical cup, calibrated measuring cups used in the kitchen, etc.

After showing the instruments each group receives a syringe 50 ml, filled with water (up to the end) and a chemical cup 100/200 ml or measuring cup 1 liter/2 liter.

The pupils will notice that the same amount of water (10 ml) takes up the same volume – both in the narrow instrument (the syringe) and in the wide instrument (the chemical cup) – although they look quite different.

2.12 Measurement of solids – demonstration – 10 minutes

One of the methods to measure the volume of a solid is based on the fact that when a solid object is immersed in liquid, the liquid level rises. The displaced volume of liquid is equal to the volume of the object.

At this point the teacher can briefly describe Archimedes' discovery, focusing on how immersion in the bathtub caused the level of water to rise.

It is suggested that the teacher lets a solid object with an undefined shape (a stone, a lump of modeling clay, etc.) sink in a transparent container of water, so the pupils can see what happens to the water level (mark the initial level of water with a marker). If the container is filled to the brim, the overflow can be collected in a measuring cup and its volume can be measured.

If the container is marked with volume measurements, you can see the desired volume. It must be emphasized that the object has taken the place of the water that spilled out – this "place" is equal to the volume of the object.

Tip – it's recommended that the teacher watch the video clips illustrating experiments on Archimedes' principle before doing it for the first time in front of pupils.
http://www.youtube.com/watch?v=KYkh-9-Qs1M&feature=youtu.be
and http://www.youtube.com/watch?v=Ryx1ELGJqeA&feature=youtu.be

Tip – it's recommended that you use coloured water in these experiments.

2.13 Conclusion – plenary – 5 minutes

The teacher tells the pupils that in lesson 2 they gathered information (the Ask stage) to help them solve the challenge. They have learned about the respiratory system, the concept of volume, what is the meaning of the maximal exhalation volume, and how to measure volume of liquids and solids. The assessment sheets can be distributed at the end of the lesson as homework, or as part of the lesson (it takes 15-20 minutes to fill in and check). Assessment sheet 1, Lesson 2 The breathing process deals with the process of breathing and factors that can affect the flow of air in the respiratory system; connect this to the challenge. Assessment sheet 2 lesson 2 assesses pupils' understanding of measuring volume

Tip – This activity can be used as a conclusion or as homework.

Tip –It is recommended that at this stage of the lesson you repeat Yael's problem /need, and describe the challenge the pupils face: Yael wants to know why she has difficulty breathing, so we have to help her get a diagnosis. The pupils' challenge is to design a biomedical instrument that measures the volume of air that can be expelled from the lungs by exhalation (as mentioned in the story).

Lesson 3 – Let's build!
Design your instrument for measuring maximal exhalation volume

Duration: 110 minutes

Objectives: in this lesson the pupils will learn:

- how to design an instrument for measuring exhalation volume by using a range of tools and materials;
- to apply the science knowledge and understanding gained in lesson 2 to design a biomedical instrument;
- to deploy the Engineering Design Process to effectively structure their work.

Resources (for 30 pupils)

- ☐ 3-4 measuring cups (0.2L + 0.5L +1L)
- ☐ 2 chemistry cups (500 and/or 1000ml)
- ☐ 5 calibrated measuring cups used in the kitchen etc.
- ☐ 4 markers
- ☐ 4 containers marked with their volume and cut at both ends (2 containers from each volume – 3L and 4L).
- ☐ 10 plastic bags of varying size (½ - 4litres)
- ☐ 3 bucket with markings
- ☐ 4-5 long plastic sleeves open at both ends (2.5 m long, 10 cm diameter]
- ☐ 4 funnels (10-15 cm diameter)
- ☐ 30 thick, wide elastic bands
- ☐ 30 tubes for exhalation (for reasons of hygiene) – 4-5 cm long, 2-3 cm diameter
- ☐ 1 Poster that indicates the stages of the Engineer Design Process
- ☐ 5 scissors
- ☐ 4 syringes (50 ml)
- ☐ 6 rags
- ☐ 4 various tubes 0.5m-1m length about 1-2 cm diameter
- ☐ 8 wide tubs (bowls)
- ☐ worksheet #3 *Imagine*
- ☐ worksheet #4 *Plan*
- ☐ Assessment sheet #3 *Final assignment after Completing the Challenge*

Preparation

- Make copies of worksheets #3 *Imagine* and #4 *Plan* and assessment sheet #3 *What did we do in lesson 3?*
- Organise all the materials and the equipment on a central table.
- Organise a space to save the pupils' instruments for the next lesson.

Working method

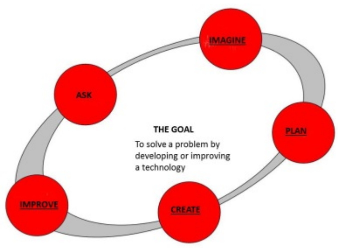
- Working in groups of 4-5 pupils

Key ideas in this lesson

- Teamwork includes collaboration and brainstorming, important for the Engineer Design Process.
- The Engineer Design Process involves trial and error.

Context and background

In this lesson the pupils go through the steps 'image', 'plan', create' and 'improve'. The pupils use the science they have investigated in the previous lesson as they try to meet the challenge.



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3.1 Introductory activity – whole class discussion – 10 minutes

The teacher reminds of the aim to help Yael by *designing and building an instrument to measure the volume of air exhaled after deep inhalation. (Results must be repeated 3 times to try to ensure a consistent outcome)*

The teacher indicates, on the EDP poster, the Goal and the Ask stages the pupils have undertaken and the stages they need to carry out in this lesson – Imagine, Plan, Build and maybe Improve.

3.2 Measuring exhalation volume (apparatus built by the teacher) – demonstration – 20 minutes

The teacher reminds the pupils that up to now they have learned methods to measure the volume of liquids and the volume of solids. Is it possible to use similar methods to measure the volume of air?

Let the pupils think about it and don't give an answer. It will be of help later when solving their challenge.

The pupils then watch a method for measuring the largest volume of air that can be expelled from their lungs after deep inhalation (= *The Maximal Exhalation Volume)* using an apparatus built by the teacher. The teacher ensures that all the children can see the demonstration and then shows how the exhalation volume is measured.

How to carry out the experiment:

1. Fill the bowl with water to a height of 10 cm
2. Fill the plastic container to the top
3. Cover the opening of the plastic container with your hand so that no water spills out, then turn it upside down inside the bowl so that the opening is under the water
4. Insert one end of the flexible tube into the plastic container, below the water level. Make sure the tube is not bent or blocked
5. Insert the small narrow pipe into the other end of the tube
6. Take a deep breath. Now blow as hard as you can through the narrow pipe(straw) so that the air you breathe out goes into the container
7. Estimate the amount of air expelled by estimating the volume of air that has taken the place of the water expelled from the container.
8. Is the volume of air that you expelled equal to approximately half the volume of the container? Or one third of its volume?
9. This experiment is carried out without calibrating the container. Once the pupils realise that it is possible to "approximately" measure volume, the teacher can ask: How can we know precisely how much air was expelled? The teacher can let the pupils answer and

then sum up the discussion and say that the apparatus must be calibrated so that the volume can be measured precisely.

Measurement results are indicated on the measuring instrument in appropriate units of measurement. When designing a measuring instrument it is essential to provide markings that show the appropriate measurement and also to use a measurement instrument with a measurement range suitable for the size you want. If you want to measure the length of your notebook you will use a ruler, but if you want to measure the distance between your home and the school you won't use a ruler, but ......

In the same way, when you need to measure the volume of air in a small balloon you probably will not use the same apparatus as the one that will measure the air volume of your lungs.

Tip –It's recommended the teacher watch a video clip which illustrates the experiment before doing this experiment in front the pupils
http://www.youtube.com/watch?v=cnewH2HUbBw&feature=youtu.be

Tip - The lungs are never completely emptied. There is always a residual volume of air. The air left in the alveoli and the broncheoli prevents them from sticking together

3.3 Carrying out the challenge – working in groups – 75 minutes

The class is divided into working groups and the teacher emphasises the importance of teamwork – listening to the ideas of other group members and collaborating as a team. The teacher presents the materials and equipment available to the pupils needed to meet the challenge.

The teacher writes the group work stages on the board:

1. Group discussion, raising suggestions and ideas (at least 2) until they settle on one solution – use **worksheet 3 Lesson 3 Imagine** – 5-7 minutes
2. Planning and development of the chosen solution - use **worksheet 4, lesson 3** Plan-5 minutes
3. Obtaining the teacher's approval to start – 2 minutes
4. Taking the materials from the central table – 2-5 minutes
5. Creating the instrument and testing it – 45 minutes
6. Organising and cleaning the room – 10 minutes

The pupils will then use resources provided to initially plan their instrument and then build it. Each stage of the process is checked by the teacher to help the children to be successful

Tip – Be sure to follow rules for maintaining hygiene while building and using the prototype.

3.4 Conclusion – plenary – 5 minutes

After the groups have carried out the challenge, the teacher reviews all the design stages. The teacher undertakes revision of the stages – Ask; Plan; Create and marks each stage on the poster.

The teacher concludes the lesson by relating, in a general way, to the manner in which the whole class has cooperated in groups, shown creativity, worked through trial and error and experienced the failures and disappointments that are 'built in' the engineers' work.

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The teacher tells the pupils that the next lesson will be devoted to testing and evaluating each of the instruments that were built and presenting them to the other groups.
Finally, the teacher distributes **assessment sheet 3** *Final Assignment after Completing the Challenge a*s a homework assignment.

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

Duration: 85 minutes (plus 30 minutes with extension activity)

Objectives: in this lesson the pupils will learn:

- that there are various solutions that can be used to solve an engineering challenge, deploying a variety of scientific principles;
- to evaluate the instruments they designed and built according to given criteria;
- that collaborative endeavour can produce valuable achievements.

Resources (for 30 pupils)

- Measuring instruments built by the pupils.
- Extension activity: Short film demonstrating the spirometer: http://www.youtube.com/watch?v=LeXgXKIyRAo&feature=related
- Computer
- Projector/screen
- Poster of the EDP
- Assessment sheet 4 *The Engineer Design Process – Summary of the ENGINEER unit*

Preparation

- Upload the video on the computer or web connection.

Working method

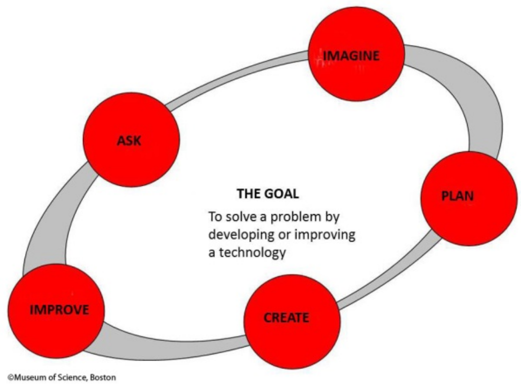
- Whole class discussion
- Working in groups
- Groups presentations

Key ideas in this lesson

- Accuracy, reliability and ease of use are important factors in designing and building measuring instruments.
- Maximal exhalation volume = the largest volume of air that can be expelled from the lungs after deep inhalation.
- (If included)A spirometer is a biomedical instrument used to diagnose respiratory problems. In comparison to the instruments that the pupils have built, the commercial spirometer is more accurate and can provide additional lung functioning measurements.

Context and background

In this lesson pupils will examine and present to the class the measuring instruments they designed and built in the last lesson. Based on their experience with the instruments they built, the pupils will discuss and raise suggestions for improvements. The pupils will become familiar with biomedical instruments used by physicians to diagnose breathing problems. The lesson ends with a summary of the whole unit, closing the circle and going back to the first lesson, the story of Yael, and the introduction to the field of biomedical engineering.



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4.1 Introductory activity – whole class discussion - 5 minutes

The teacher reviews the assessment sheet the pupils have completed at home. Relate back to the EDP stages in which the pupils were engaged in lesson 3, by pointing them out on the EDP poster. Refer again to the trial and error procedure and to the failures and the disappointments, as well as success, are 'built into' the engineers' work.

4.2 Utilizing and preparing a presentation – working in groups – 20 minutes

Using the instruments they built, the pupils can measure their own exhalation volume after taking a deep breath (Maximal exhalation volume). They need to pay attention to the criteria put forward at the outset: to quantitatively measure lung volume 3 times, obtaining a similar result each time. They should write down their results in their notebooks.

Each group prepares a short presentation (2-3 minutes each) on the instrument they have developed.

4.3 Presenting the instruments – group presentations – 40 minutes

Each group presents its instrument to the class and demonstrates how it works.

The pupils should relate to the following issues during their presentations:

– The scientific principal on which the solution is based.
– Other solutions raised in the early stages of the design.
– The criteria issued at the outset: accuracy (degree of maximal error which may be between the measured size and the actual size), reliability (the ability to repeat and reproduce results).

During their presentations, the teacher should guide the pupils' conceptualisation of the scientific principles used and relate these to causes of differences in their results.

What can be the cause for differences in pupils' results?

Differences in exhalation volume can only be caused by gender, age, and height.

There should be no significant differences in measurement results, but if there are, it should be emphasised that they are not caused by a defect, but by one of the following:

1. *Differences related to measurement:*
   a. *Using different methods of measurement with differing degrees of reliability.*
   b. *Inaccuracy of measurements caused by the quality of the instrument.*
2. *Differences arising from personal differences in:*
   Height; Gender; Age

Contrary to what is commonly believed, there is no difference in lung volume and functioning between healthy humans who are physically fit and those who are not. Nevertheless, some lung diseases, which are very rare among children, can affect lung volume.

Tip – Since some measuring instruments require the use of water, it's recommended that the presentation takes place at a central table.

4.4 Improvement of the measuring instruments – whole class discussion - 10 minutes

Ask the pupils:

– Did you always achieve the same measurement results, or were there large differences between them? (This was the main requirement for the instrument).
– How can you improve the measuring instrument that you built?

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– Was your instrument easy to operate and reset?

The teacher can write the criteria on the board by which the pupils can assess the quality of the instrument. The pupils can raise suggestions and the teacher can add comments as needed.

Suggestions for criteria for improvement of the instruments:

- *Operating method – ease of use and time required to use it again.*
- *Accuracy of measurement (compared to the volume of normal lungs, according to the literature).*
- *Aesthetic appearance of the instrument.*

4.5 Extension activity: the spirometer – whole class discussion – 30 minutes

The teacher will judge on the basis of their pupils' interest and understanding whether to extend the unit into this commercial application of biomedical engineering.

The teacher tells the pupils they have built an instrument for measuring maximal exhalation volume, one of the components of lung volume. It is known that lung volume depends on gender, height and age, except in cases of rare lung diseases. As they have learned in the first lesson, Yael suffers from shortness of breath. Since it is unlikely that this is caused by a rare lung disease, the instrument they built is not sufficient to diagnose her problem. Biomedical instruments in clinics are capable of measuring additional data, such as lung volume under different situations, and the rate and amount of time required to take air into the lungs or to expel air from the lungs. By weighing up all these figures the doctor can obtain information about the functioning of the lungs and make a diagnosis of the problem. These measuring devices are designed and built by engineers who work in biomedicine. One such instrument, used for measuring lung volume, is the **spirometer**.

The teacher shows the pupils a short video showing the importance of the spirometer and how it works: http://www.youtube.com/watch?v=LeXgXKIyRAo&feature=related

The teacher accompanies the video with explanations.

The spirometer – an instrument used to measure lung function

This biomedical instrument measures lung volume. It is used to diagnose breathing difficulties such as airflow obstruction, and problems of airflow rate (the volume of airflow in a timed interval) such as asthma and other pulmonary diseases.

During the examination, the patient exhales strongly into the instrument. Various lung volumes are measured and calculated. The doctor deciphers the results to determine whether there is a problem, and if so, what it is.

The tests include measurement of maximal exhalation volume after taking a deep breath and "normal" exhalation volume. (These measurements were also tested by the instruments built by the pupils).

The spirometer utilises a variety of sensors and devices that measure data and translate them into electrical signals. It can be pointed out that since we do not have enough information about the field of biomedical engineering, and we do not have suitable technological resources, the *instrument that the pupils built cannot perform most of the measurements and calculations undertaken by commercial instruments and of course, it is not as accurate when compared to commercial spirometers.*

4.6 Conclusion – plenary and individual work - 10 minutes

The teacher distributes the assessment sheet 4 *The Engineer Design Process – Summary of the ENGINEER unit to the pupils*.

After each pupil completes the assessment sheet individually, the teacher and the pupils check the responses, together while discussing and indicating the stages on the EDP poster.

Tip – Background information about measurement can be found in the appendix and also here: http://www.mada.org.il/en/about/engineer/challenge/measurement?from=ref-inpage

Appendices

Story to set the context - How can we help Yael?

A surprising challenge on the annual school trip

"Yael, you're next!"
Yael stood up and walked to the doctor's office, feeling slightly nervous. The doctor smiled and asked her to sit down.
"Hello, Yael, my name is Michal and I'm a doctor. I specialise in the respiratory system. How can I help you?" Yael was very surprised that the doctor was asking her questions instead of examining her.
"It all started two weeks ago," explained Yael. "We were playing ball during recess and in the middle of the game I started having pains in my chest. I had to stop playing to catch my breath, and when I inhaled, there were wheezing sounds in my throat.
"A few days ago," she continued, "when I was on our way to the grocery store with my friends, a bus drove by sending out clouds of black smoke. Everyone started coughing, but I coughed more than anyone else."
The doctor listened carefully, and then said, "I understand that you have breathing difficulties. We'll have to find out what's causing them."
Yael was alarmed. "But I'm going on a school trip tomorrow. I don't want to miss it!"
The doctor smiled. "Don't worry, Yael. We just have to carry out a simple check, something you can do by yourself during the school trip. I can see that you're mature and responsible and I'm sure you can manage it."
That made Yael feels much less nervous. In fact she was quite proud that the doctor thought she was mature and responsible. "What do I have to do?" she asked.
"I'm going to give you an instrument to measure the maximal exhalation volume you can expel from your lungs, and I'll also give you a little notebook. Every day for a week I want you to take a deep breath and expel it as hard as you can into the measuring instrument, and then write down the result. We'll meet again in a week and you'll show me what you wrote in the notebook. The results can help us diagnose your problem."
That didn't sound scary at all. Yael took the measuring instrument and the notebook. "Don't worry, doctor," she said, "I'll record the results exactly like you said. You can count on me."
The doctor smiled again and said goodbye. Yael's mother was waiting outside. Yael showed her the measuring instrument and the notebook and explained what the doctor had told her to do.

* * * * * * * * * *

The next morning Yael woke up early to prepare for the trip. Of course she remembered what the doctor had told her. She packed the measuring instrument and the notebook, and she didn't forget to take something to write with so she could record the results. Then she hurried to school with her big backpack to show her friends her new measuring device. Just then the bus arrived and all the children climbed aboard. Yael quickly shoved the instrument on top of everything else and placed her bag in the large baggage compartment. Then she ran to find a seat next to her best friend, Avigail.

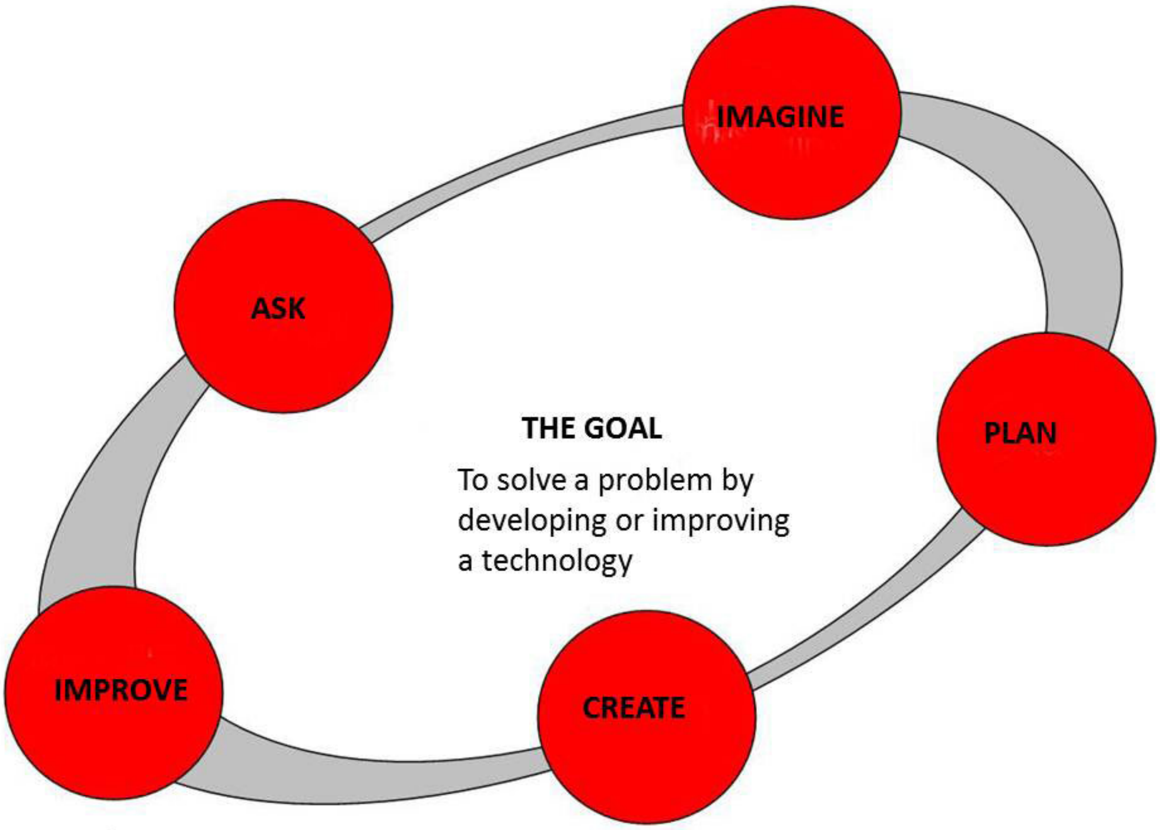
* * * * * * * * * *

The trip was lots of fun. When they stopped, the guide asked everyone to take out their water bottles and drink plenty of water. But when Yael opened her bag to look for her water bottle she discovered, to her horror, that the measuring instrument was broken. It must have been squashed against the other bags while the bus was moving. Nearly in tears, Yael carefully took out the pieces, one by one. How would she measure her exhalation volume? The doctor would be so disappointed.

"Don't be upset, Yael," said Avigail, as all her friends gathered round. "We'll help you find a solution. Didn't you say the doctor wants you to measure your maximal exhalation volume? I'm sure we can find some way to do so, even without the instrument the doctor gave you."

Note to the teacher: at this stage you should tell the pupils that in the coming lessons they will help Yael find a way to measure her maximal exhalation volume, using simple materials that the children brought on their trip.

Engineering Design Cycle



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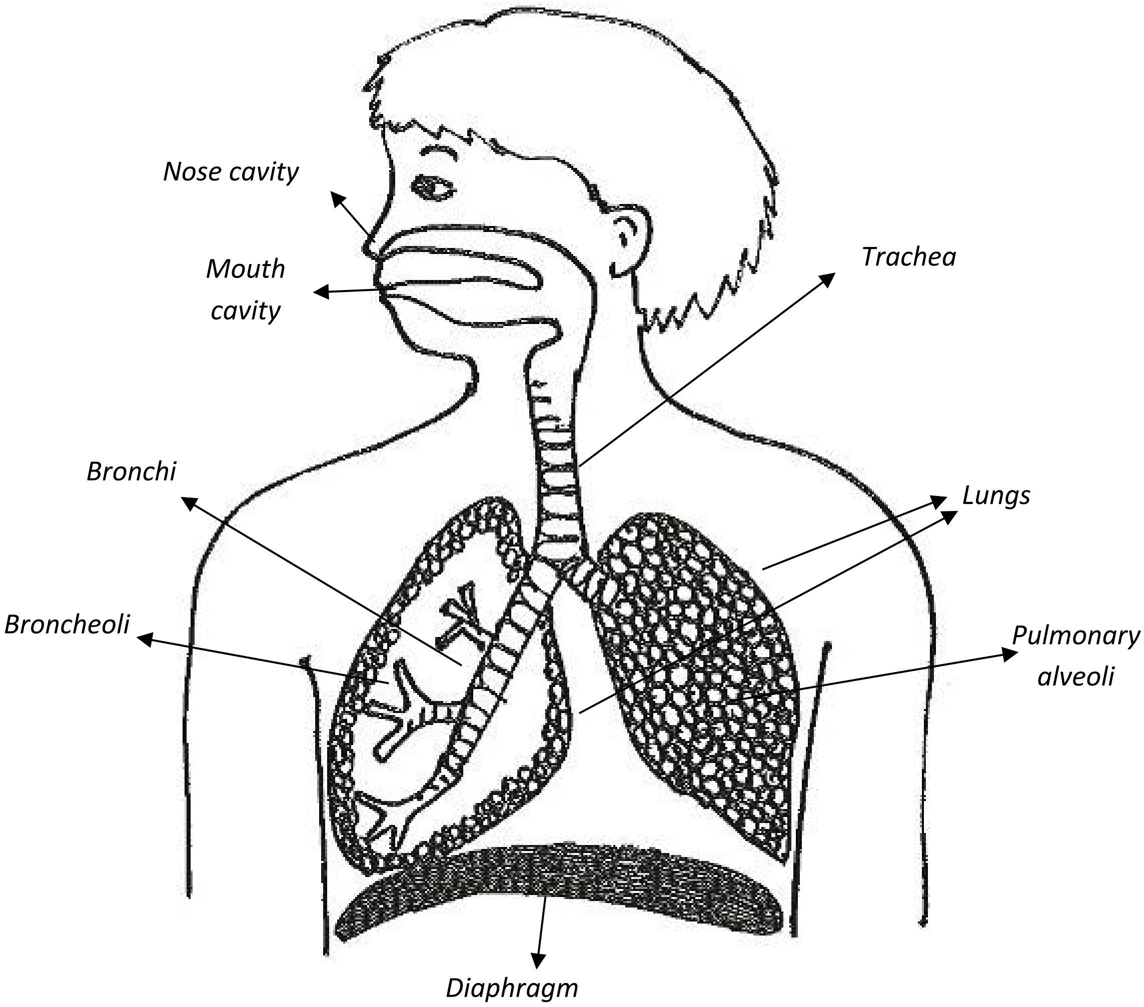
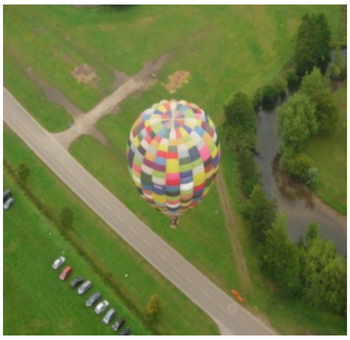
The Respiratory System



Worksheets and answer sheets

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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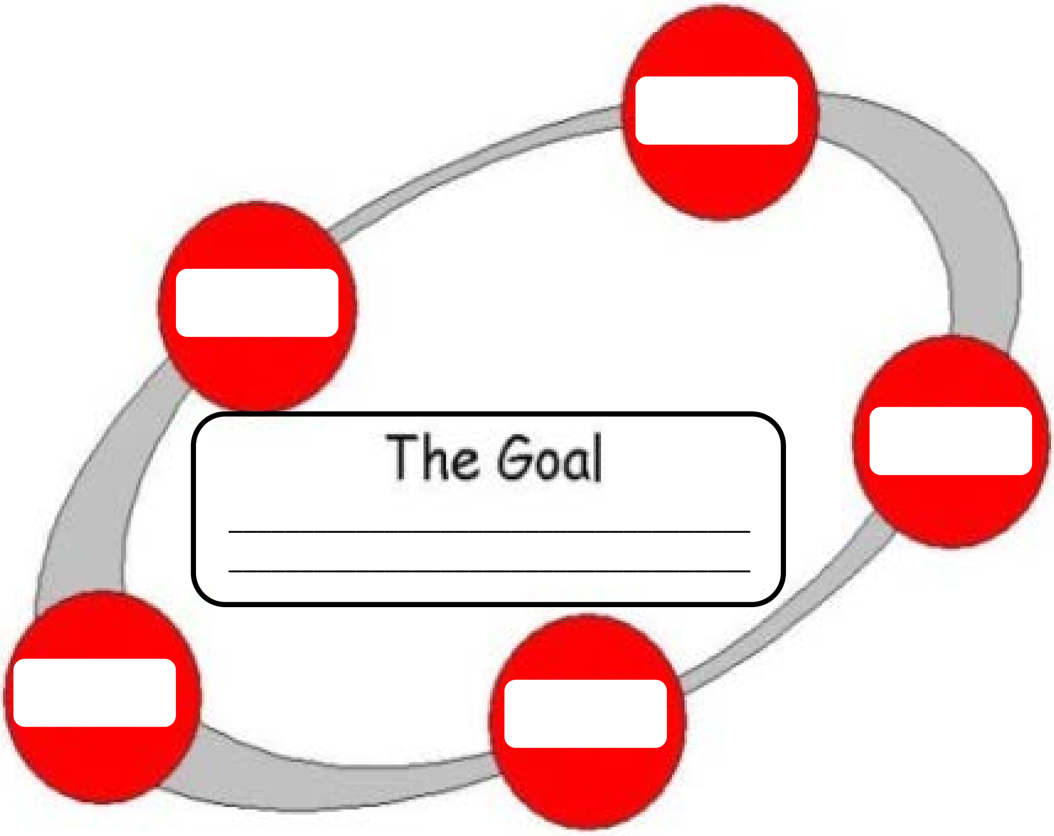
Worksheet 1 Lesson 1- The Engineer Design Process

Name: ....

Date: ....

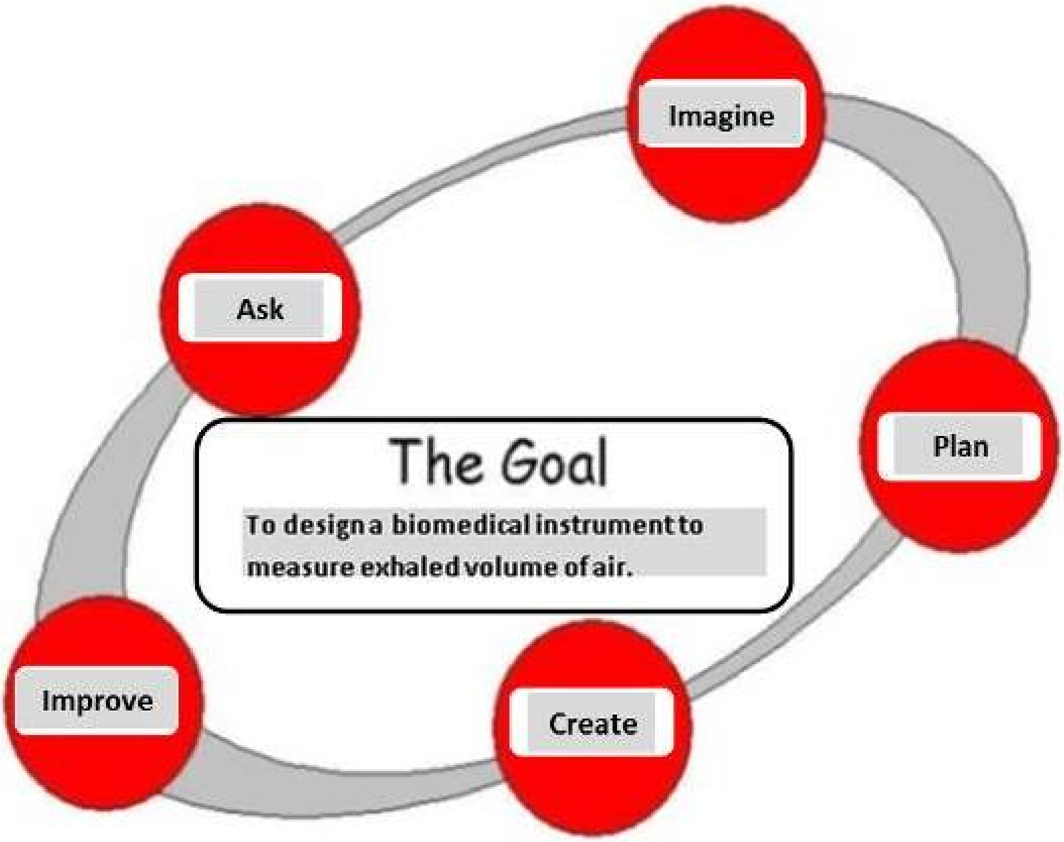
Fill in the blank spaces.



Answer sheet Worksheet 1 Lesson 1 - The Engineer Design Process

Name: ....

Date: ....



Assessment sheet 1 Lesson 2- The Breathing Process

Name: ....
Date: ....

1. **Arrange the stages of the breathing process in order:**

Stages of inhalation:

- ☐ The volume of the chest increases
- ☐ Contraction of the diaphragm and the chest muscles
- ☐ External air, which is at a greater pressure than the air in the lungs, goes into the airways and the lungs.
- ☐ The air pressure in the lungs decreases

Stages of exhalation:

- ☐ The diaphragm and the chest muscles relax and the ribs descend
- ☐ The volume of the chest decreases
- ☐ Air exits the lungs towards the external air, which is at a lower pressure
- ☐ The air pressure in the lungs increases

2. **Mark the factors that can influence the passage of air through the airways**
   - ☐ Dust particles
   - ☐ Smoke
   - ☐ Mucus
   - ☐ All of the above

3. **Find 8 words related to breathing:**

a	i	b	e	d	k	s	i	l	s
s	j	e	x	h	a	l	n	u	n
t	k	j	h	x	d	u	h	n	z
m	d	i	a	p	h	r	a	g	m
a	j	v	l	f	x	g	l	s	f
g	t	r	a	c	h	e	a	i	r
q	a	s	t	h	m	a	t	b	c
v	s	d	i	a	p	h	i	a	m
c	z	m	o	u	t	h	o	i	k
b	k	i	n	h	a	l	n	o	n

Answer sheet - Assessment sheet 1 Lesson 2- The Breathing Process

Name: ....
Date: ....

Arrange the stages of the breathing process by order:

Stages of inhalation:

☐ **2** The volume of the chest increases
☐ **1** Contraction of the diaphragm and the chest muscles
☐ **4** External air, which is at a greater pressure than the air in the lungs, goes into the airways and the lungs.
☐ **3** The air pressure in the lungs decreases

Stages of exhalation:

☐ **1** The diaphragm and the chest muscles relax and the ribs descend
☐ **2** The volume of the chest decreases
☐ **4** Air exits the lungs towards the external air, which is at a lower pressure
☐ **3** The air pressure in the lungs increases

1. **Mark the factors that can influence the passage of air through the airways**
   - ☐ Dust particles
   - ☐ Smoke
   - ☐ Mucus
   - ■ All of the above
2. **Find 8 words related to breathing:**

a	i	b	e	d	k	S	i	l	s
s	j	e	x	h	a	L	n	u	n
t	k	j	h	x	d	U	h	n	z
m	d	i	a	p	h	R	a	g	m
a	j	v	l	f	x	G	l	s	f
g	t	r	a	c	h	E	a	i	r
q	a	s	t	h	m	A	t	b	c
v	s	d	i	a	p	H	i	a	m
c	z	m	o	u	t	H	o	i	k
b	k	i	n	h	a	L	n	o	n

Assessment sheet 2 Lesson 2- Measuring Volume

Name: ....
Date: ....

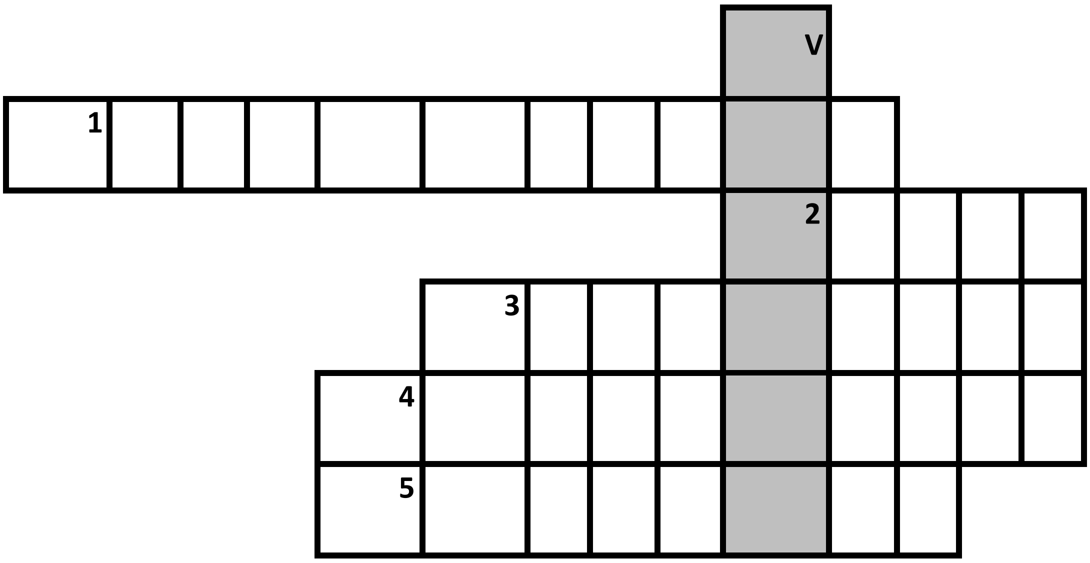
1. Uri was making a cake for his sister's birthday. He was quickly putting all the ingredients into a bowl, until he stumbled upon a problem – the recipe said to add 1 millilitre of vanilla extract and he couldn't decide which measuring instrument to use. Can you help Uri find the best measuring instrument?
   - ☐ A 50 ml syringe
   - ☐ A 20 ml graduated cylinder
   - ☐ A 30 cm ruler
   - ☐ A 5 ml syringe

2. The nurse in the clinic that treated Yael wants to order a device for measuring the maximal exhalation volume of Yael. The measuring range of each device was different. Help the nurse pick the most suitable device. Explain your answer.
   - ☐ 0-4 ml
   - ☐ 0-40 ml
   - ☐ 0-4 litres
   - ☐ 0-40 litres

....
....
...

3. Marking graduations on a measuring device, according to the physical measurement we want to access, is called:
   - ☐ Calibration
   - ☐ Arranging
   - ☐ Grading
   - ☐ Notation

4. Complete the crossword and find an important concept you have learned today in class. The answer is in the grey boxes.



Definitions:

1. The process in which we perform adjustment between the measurements indicated by a sensor or a measuring equipment and the physical measurement we want to access ____________________
2. A unit for the measurement of volume ________________
3. A ruler, a graduation cylinder and a thermometer are examples of ___________________ instruments.
4. A well-known Greek scientist and engineer, who discovered a method for the measurement of the volume of solids ________________
5. A person who uses his or her creativity and understanding of materials, tools and science to design things that solve problems _________________.

Answers sheet - Assessment sheet 2 Lesson 2- Measuring Volume

1. Uri was making a cake for his sister's birthday. He was quickly putting all the ingredients into a bowl until he stumbled upon a problem – the recipe said to add 1 millilitre of vanilla extract and he couldn't decide which measuring instrument to use. Can you help Uri find the most fitting measuring instrument?
   - ☐ A 50 ml syringe
   - ☐ A 20 ml graduated cylinder
   - ☐ A 30 cm ruler
   - ■ A 5 ml syringe

2. The nurse in the clinic that treated Yael wants to order a device for measuring the maximal exhalation volume of Yael. The measuring range of each device was different. Help the nurse pick the most suitable device. Explain your answer.
   - ☐ 0-4 ml
   - ☐ 0-40 ml
   - ■ 0-4 litres
   - ☐ 0-40 litres

3. Marking graduation on a measuring device according to the physical measurement we want
   ■ access is called:
   - ☐ Calibration
   - ☐ Arranging
   - ☐ Grading
   - ☐ Notation

4. Complete the crossword and find an important concept you have learned today in class. The answer is in the grey boxes.

									v				
1 c	a	l	i	b	r	a	t	i	o	n			
									2 l	i	t	r	e
					3 m	e	a	s	u	r	i	n	g
				4 a	r	c	h	i	m	e	d	e	s
				5 e	n	g	i	n	e	e	r		

Definitions:

1. The process in which we perform adjustment between the measurements done by a sensor or a measuring equipment and the physical measurement we want to access - **calibration**
2. A unit for the measurement of volume- **litre**
3. A ruler, a graduation cylinder and a thermometer are examples of **measuring** instruments.
4. A well-known Greek scientist and engineer, that discovered a method for the measurement of solids' volume - **Archimedes**
5. A person who uses his or her creativity and understanding of materials, tools and science to design things that solve problems - **engineer**

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Worksheet 3 Lesson 3 – Imagine

Raising possible solutions and choosing the best solution

Names: ....

Date: ....

Indicate at least 2 possible solutions for constructing an instrument which can measure the maximal exhalation volume.

1. Draw or write what your instrument will look like.
2. Describe how the instrument is used/ how does it work?
3. Write a list of materials you need to build your instrument.

Instrument 1

What does the instrument look like?

How does it work?

....
....
....

Materials needed:

....
....
....

Instrument 2

What does the instrument look like?

How does it work?

....
....
....

Materials needed:

....
....
....

Discuss between you the BEST SOLUTION, taking these criteria into consideration:

1. Accuracy of the measurement
2. How easy is it to build?
3. Is the instrument reusable?

Which one did you choose? ....

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Worksheet 4 Lesson 3 – Plan

Names: ....

Date: ....

Draw a picture of the instrument:

Materials needed:

....
....
....
....
....

- **Show your plan to the teacher**
- **Get permission to take materials**
- **Start building!**

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Assessment sheet 3 Lesson 3 - Final Assignment after Completing the Challenge

Name: ………………………………
Date: ………………………………

In recent lessons you worked as engineers and went through a process of designing a technological device intended to solve a problem. This process is called the Engineering Design Process (EDP).

The EDP begins with a problem or a need that has to be solved. **The Goal** of each group was to assist Yael by means of ………………………………………………………………………………
………

Ask – write at least two things you have learned in order to complete the challenge

1. ……
2. ……

Imagine – write about an idea for measuring exhalation volume – an idea that came up during the group discussion - <u>but you chose not to</u> plan and create.

……
……

Plan – did all the group members participate in the planning? Write the names of the members of the group.

……
………
……

Create – Did you have any difficulties building your instrument? Be specific

……
………
………

Improve – Is the final device you created identical to the one you planned? Why?

……
……
……

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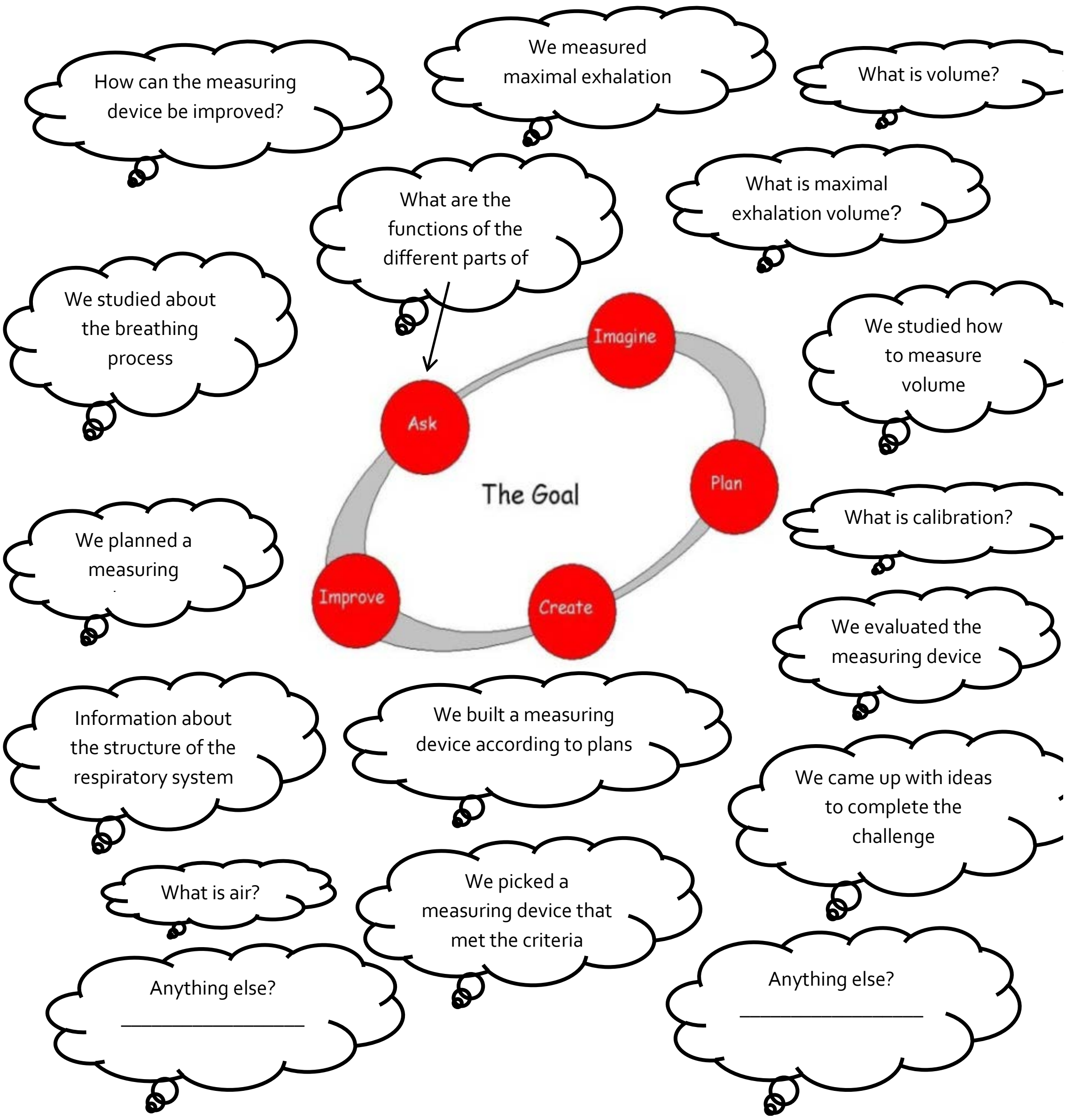
Assessment sheet 4 Lesson 4- Summary of the Bio-Medical Engineering Learning Unit

Name: ....

Date: ....

Draw a line between each cloud and its correlating Engineering Design Process stage



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Science notes for teachers about the respiratory system

Some key knowledge and science concepts involved in Lesson 2
• the structure of the respiratory system • the function of the breathing process is to supply oxygen to the body for respiration and carry carbon dioxide away from the body as a byproduct of respiration • the stages of the breathing process (inhalation and exhalation) • inhalation is the intake of air into the lungs through expansion of chest volume caused by the contraction muscles attached to the ribcage and contraction of the diaphragm • the expansion of the chest volume during inhalation creates a decreased pressure inside the lungs (compared to the outside air pressure) and this causes a flow of air into the lungs • exhalation is the expulsion of air from the lungs through contraction of chest volume caused by relaxation of the chest muscles and diaphragm • contraction of the chest volume during exhalation creates an increased pressure inside the lungs (compared to the outside air pressure) and this causes the air to flow out of the lungs • volume = the space taken up by a substance or object • air is a substance that takes up space; it can be compressed but still takes up space • various factors such as dust particles and air pollution can cause constriction of the air passages • constriction of the air passages causes a decreased volume of air through the air passages, resulting in the medical condition asthma • maximal exhalation volume = the largest volume of air that can be expelled from the lungs after deep inhalation.

Respiration

The respiratory system is the system in the human body that enables us to breathe. Breathing is a process that involves moving air into the lungs (***inhalation***) and moving air out of the lungs (***exhalation***). Oxygen from the air taken into the lungs passes across thin membranous walls (of the pulmonary alveoli). It is carried by the blood system to all of the body's cells where it is needed for respiration. ***Respiration*** is the process that makes energy available for growth and body maintenance. Carbon dioxide is a by-product of cellular respiration and it is carried away by the blood system from cells to the lungs where it diffuses across the cell membranes of the pulmonary alveoli and is exhaled as we breathe out.

The parts of the respiratory system

The respiratory system is divided into two parts:

1. ***Upper respiratory tract***. This includes the nose, mouth, and the beginning of the trachea (the section that takes air in and lets it out).
2. ***Lower respiratory tract***. This includes the trachea, the bronchi, bronchioles and the pulmonary alveoli of the lungs (the act of breathing takes place in this part of the system).

The organs of the lower respiratory tract are located in the chest cavity. They are delineated and protected by the ribcage, the chest bone (sternum), and the muscles between the ribs and the diaphragm (a muscular partition between the chest and the abdominal cavity).

- ***The lungs*** – a pair of organs found in all vertebrates. The structure of the lungs includes the bronchial tree – air tubes branching off from the bronchi into smaller and smaller air tubes, each one ending in a pulmonary alveolus.
- ***The trachea*** – the tube connecting the throat to the bronchi.

– ***The bronchi*** – the trachea divides into two bronchi (tubes). One leads to the left lung, the other to the right lung. Inside the lungs each of the bronchi divides into smaller bronchi, called bronchioles.

– ***Pulmonary alveoli*** – tiny sacs (air sacs) delineated by a single-layer membrane surrounded by blood capillaries. The bulbous structures of the alveoli provide a large surface over which gaseous exchange can occur. The exchange of gases takes place through the membrane of the pulmonary alveolus, which always contains air. Oxygen (O_2) is absorbed from the air into blood capillaries and the action of the heart circulates the blood through all the tissues in the body. At the same time, carbon dioxide (CO_2) diffuses from the blood capillaries into the alveoli and is then expelled through the bronchi and the upper respiratory tract.

For a detailed diagram of the lungs see:
http://www.biologyguide.net/biol1/4_lungs.htm

The breathing process

The breathing process has two stages – inhalation and exhalation.

- Inhalation – is the intake of air into the lungs through expansion of chest volume.
- Exhalation – is the expulsion of air from the lungs through contraction of chest volume.

Inhalation and exhalation involve muscles:

1. Rib muscles = the muscles between the ribs in the chest.
2. Diaphragm muscle.

The diaphragm and rib muscles are constantly contracting and relaxing (approximately 16 times per minute), thus causing the chest cavity to increase and decrease.

During inhalation – the muscles contract:
Contraction of the diaphragm muscle causes the diaphragm to flatten, thus enlarging the chest cavity. Contraction of the rib muscles causes the ribs to rise, thus increasing the chest volume. The chest cavity expands, thus reducing air pressure inside the lungs. This causes air to be passively drawn into the lungs. Air moves into the lungs due to the pressure difference between the external air pressure and the reduced pressure inside the lungs.

During exhalation – the muscles are no longer contracting, they relax.
The diaphragm curves and rises, the ribs descend and chest volume decreases. The chest cavity contracts and creates an increased air pressure inside the lungs (compared with the air pressure outside the lungs). This causes the air in the lungs to be expelled through the upper respiratory tract.

Follow the links below to see animations that illustrates changes in chest volume during inhalation and exhalation – note that they only shows the movement of the diaphragm, not that of the rib muscles.
http://commons.wikimedia.org/wiki/File:Diafragma_ademhaling.gif
http://www.nhlbi.nih.gov/health/health-topics/topics/hlw/whathappens.html

Asthma

Asthma is a medical condition that causes the muscles around the walls of the airways to tighten. As they tighten, they narrow the airways and the lining becomes inflamed and starts to swell. Phlegm production can also further narrow the airways. This irritation makes causes coughing and makes it difficult to breathe. It is known that asthma is more likely to develop if there is a family history of the condition as well as allergies and eczema. It is also known that certain environmental factors such as pollutants (e.g. smoke, dust particles, soot etc.) can also play a role. Asthma may develop in adults as a consequence of a viral infection or a workplace irritant.

The biomedical engineer's task is to develop methods and instruments for diagnosis, treatment, rehabilitation and follow-up. Accuracy, reliability and ease of use are important factors of measuring instruments. The spirometer is a biomedical instrument used to diagnose respiratory problems. It is used to measure ***maximal exhalation volume*** (the largest volume of air that can be expelled from the lungs after deep inhalation). The maximum lung volume of a healthy adult is up to 5-6 litres. In children, the maximum lung volume is up to 2-3 litres, depending on age. In infants, it is up to 600-1000 millilitres. It is known as ***TLC*** (***total lung capacity***).

In the story, Yael is asked to measure her maximal exhalation volume and record the results every day for a week to help the doctor to diagnose her problem. This calls for an instrument that can measure accurately and reliably the amount of air that is expelled.

Tip – you can find more information about measurements of lung function here:
http://www.mada.org.il/en/about/engineer/challenge/respiratory-system#functions

Measurement

Some things cannot be measured in a quantitative way (e.g. emotions, preferences); they are measured in a qualitative way by comparison (e.g. preferring the taste of one type of apple to that of another type). Measuring devices, however, measure precisely in comparison with standard measures (e.g. a centimeter, a kilogram, a degree Centigrade, a second). The most important aspect of measuring devices is their ability to repeat and reproduce results. In other words, each time we measure the same thing, we must obtain the same result. To learn more about measurement follow the link:

Tip – you can find more information about measurement here:
http://www.mada.org.il/en/about/engineer/challenge/measurement?from=ref-inpage

Some pupils' ideas about the respiratory system and volume

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 air

The perception amongst many pupils is that air does not have matter (it has no mass and no volume), and is therefore not taking up space. Driver et al. (1) report a study of French students by Séré that found that by the age of 11 the idea that air exists in open containers was well established, and pupils thought that air could get into and out of containers. However, some pupils were less sure that air occupied a sealed container and they identified the presence of air only when they could sense it moving.

The notion of air volume is critical in understanding lung function and so, Lessons 2.3, 2.4 and 2.5 are designed to help pupils to build the concept of air taking up space. In Lesson 2, students experiment themselves and watch demonstrations that illustrate the fact that air is matter.

Children's ideas about volume

Some pupils will predict that the same volume of liquid reaches the same level in different containers. They find it difficult to realise that the same volume of liquid reaches a lower level in a wide container, and a higher level in a narrower container (that is, they do not understand that ***volume is conserved***). According to psychologist Jean Piaget, conservation of volume is indicative of *logical* thinking and develops around the ages of 7-12 years during what he described as *the concrete operational stage of development*. Read more about Piaget's fascinating ideas, including critical examination of his position at:
http://www.simplypsychology.org/concrete-operational.html

In Lesson 2.12, volume conservation is addressed explicitly as pupils pour the same volume of water into two containers, one wide and one narrow. It illustrates the fact that fluid volume can look different in different shaped containers. It is important to allow the pupils to make predictions, to look closely at the outcomes and to discuss the significance of their observations in order to begin to address this intuitive idea.

Children's (and adults') ideas about the lungs and lung volume

Children's knowledge of body parts and their function usually begins with what they can see, feel or hear (2), so they are much more likely to be aware of the heart than the lungs. It is important, therefore, that pupils have the opportunity to focus on their own experience of inhalation and exhalation. The pupil needs to experience the movement of air in and out of his/her own body and feel their chest cavity expand and their diaphragm move up and down. In this way they are more likely to make useful connections to experiments designed to simulate parts of the breathing process.

Care also needs to be taken with the language we use in talking about this subject. Teachers will need to help pupils become more precise in their use of terms, for instance, we commonly use the word 'chest' when we mean 'lungs'. Research in the UK has shown that pupils aged 7-11 years often have difficulty in locating the position of the lungs on a drawing of the human body (2). While most are fully aware that they 'will die if they

do not have air'; they appear to think that the air which we breathe in simply 'comes out'. Others have an idea that expelled air is changed (e.g. into 'bad' air) and that air goes into the body (2).It is likely, therefore, that children's knowledge of the role of respiratory gases (oxygen and carbon dioxide) may be limited and still evolving. Teachers must be careful not to overload pupils with too much terminology prior to developing understanding of the process. While the quotation below indicates some understanding of lung function, this may be a relatively rare instance (2).
'It goes into your lungs - it comes out of these kind of tubes - it goes into your heart and then into your blood'.

Contrary to what is commonly believed, there is no difference in lung volume and functioning between healthy humans who are physically fit and those who are not. Improved physical fitness affects the functioning of the heart, not the volume and functioning of the lungs. The reason for this is assumed to be that our lungs contain a very large reserve of air. Thus, lacking a 'challenge' for the respiratory system, there is 'no reason' to improve, or enlarge, lung volume. Nevertheless, swimmers and divers have greater lung volume, because of water resistance to the expansion of the chest through respiration.

Children's (and adults') ideas about the reason for increasing the volume of the chest

The reason for the entry of air into the lungs is the increased volume of the chest, causing a decrease in the air pressure in the lungs in comparison to the air pressure outside. The outside air, which has a higher pressure in comparison to the air pressure in the lungs, enters the breathing passages and the lungs. There is a mistaken tendency to think that the chest expands due to the air entry into the lungs. This is a very complex idea for learners of this age. Driver at al (1) refer to Séré's work with 11-13 year old pupils on air pressure that found that pupils often think that wind (not still air) exerts pressure. This needs to be considered in Lesson 2.7 where inhalation and exhalation are demonstrated and explained. It is advised that the concept of pressure should be adapted to the level of the pupils, in accordance with curriculum requirements.

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Glossary of terms relating to this unit

The respiratory system

1. **Upper respiratory tract** – the upper respiratory tract includes the nose, mouth, and the beginning of the trachea (the section that takes air in and lets it out).
2. **Trachea** - the tube connecting the throat to the bronchi.
3. **Bronchi** - the trachea divides into two bronchi (tubes). One leads to the left lung and the other to the right lung. Inside the lungs each one of the bronchi divides into smaller bronchi
4. **Bronchioles** - the bronchi branches off into smaller tubes called bronchioles that end in the pulmonary alveolus.
5. **Lungs** – a pair of organs found in all vertebrates. The structure of the lungs includes the bronchial tree – air tubes branching off from the bronchi into smaller and smaller air tubes, each one ending in a pulmonary alveolus.
6. **Alveoli** - tiny sacs (air sacs) delineated by a single-layer membrane with blood capillaries at the other end. The exchange of gases takes place through the membrane of the pulmonary alveolus, which always contains air: oxygen (O_2) is absorbed from the air into the blood capillaries and the activity of the heart circulates it through all the tissues in the body. At the same time, carbon dioxide (CO_2) is transmitted from the blood capillaries into the alveoli and then expelled through the bronchi and the upper respiratory tract.
7. **Diaphragm** – a thin and flat muscle which separates the chest from the abdominal space. This muscle plays an important role in the respiratory process (inhalation and exhalation).
8. **Inhalation** - the intake of air into the lungs through expansion of chest volume.
9. **Exhalation** - the expulsion of air from the lungs through contraction of chest volume.

Volume

1. **Volume** - the space taken up by a substance (in litres)
2. **Air volume** - the space taken up by air (in litres)
3. **Maximum lung volume** - The volume that can be obtained by maximum strenuous inhalation.
   The maximum lung volume of a healthy adult is up to 5-6 litres. In children, the maximum lung volume is up to 2-3 litres, depending on age. In infants, it is up to 600-1000 millilitres. It is known as TLC (total lung capacity).
4. **Maximal Exhalation volume** - the volume of air that is expelled from the lungs after maximal exhalation.

Engineering

1. **Engineer/Engineering** – A person who uses his or her creativity and understanding of materials, tools and science to design things that solve problems.
2. **Biomedical engineer** – a person who combines his or her knowledge of science, math and living creatures to design technologies that solve problems that deal with the human body.
3. **Technology** – anything, system or process that people create and use to solve a problem.
4. **Biomedical instrument** - devices designed through a combination of mechanical, electronic, electro-optic, and computer systems, as well as biological methods; they are used for diagnosis, treatment, rehabilitation, and follow-up.
5. **Engineering Design Process** – the five stages that engineers use to design something to solve a problem: ASK, IMAGINE, PLAN, CREATE and IMPROVE.

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Measuring instruments

1. **Measuring devices –** instruments used for measuring. All measuring devices have in common the fact that the results obtained are in numbers: 10 centimetres, 35 degrees, or 100 grammes. They are used for many purposes: rulers measure length, thermometers measure temperature, and scales measure weight/mass.
2. **Calibration**: Process in which we perform adjustment between the measurements made by a sensor or measuring equipment and the physical measurement we want to access. For example: on a spring which changes its size according to the mass hanging on it, the calibration will be the adjustment between the degree of elongation and the weight (if 1kg causes 5cm of elongation, 2kg causes 10 cm of elongation).
3. **Reliability**- the ability to repeat and reproduce results. In other words, if a measuring device is reliable, then each time we measure the same thing, we obtain the same result.
4. **Accuracy**: Degree of maximal error (discrepancies) which may be between the measured/calculated size and the actual size. In a ruler divided in scale intervals of millimetres, the accuracy is no more than half a millimetre; in a digital thermometer in which the last digit is one degree- the accuracy is no more than half a degree.
5. **Spirometer** – A biomedical instrument that helps to diagnose obstructive diseases of the respiratory system.

References

(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

Partners

Bloomfield science Museum Jerusalem
The National Museum of Science and Technology "Leonardo da Vinci"
Science Centre NEMO
Teknikens hus
Techmania Science Center
Experimentarium
The Eugenides foundation
Condervatoire National des Art et Métiers- muse des arts et métiers
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