Primary Science with €Sense

Teacher Guide

www.cma-science.nl

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The Student Worksheets are available in Word format and can be adapted for own use in the classroom. The latest version of the Student Worksheets and Teacher Guides, and links to download the Coach software can be found at www.cma-science.nl /teaching-resources/teaching-resources-primary.

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A. Pedagogical background

1. Technology enhanced Primary Science Pack

The core of science is about investigating, exploring, asking questions, analysing, and thinking - activities that ICT (Information and Communication Technology) can uniquely facilitate and deepen. The educational research studies showed that ICT tools such as data logging can work positively already at the primary school level (Beichner, 1990, McFarlain et al, 1995, Nicolau et al, 2007, Zucker et al, 2007, van den Berg et al, 2010).

Based on experience with the use of ICT in primary schools (TEEMSS II Project 2007, Pollen Project 2010,) the *Primary Science with €Sense* pack has been developed. This pack provides a series of technology-enhanced inquiry based science activities for students between 9 and 12 years and should help primary teachers, with little or no experience in science education, to introduce use of sensors into their science lessons.

The materials should not be regarded as a complete primary science curriculum but as a supplement of the existing science curricula. They are also not designed as replacement of traditional science hands-on activities but rather as extension of such activities. The materials can be integrated into any science curricula or can be used on their own.

THE PACK CONSISTS OF:

- *€Sense interface package (CMA art. code 009)* - a measuring interface and an external temperature sensor.
- This *Teacher Guide* - which provides background information, advice on teaching approaches, commentaries on the potential learning benefits of the activities and includes outlines of the activities and exemplary data.
- *Get Started* – which describes how to work with the €Sense interface and the Coach 6 Lite software.
- *Students Worksheets* – worksheets, for use by students. These worksheets give space for students' observations, predictions, data, conclusions, etc.
  The worksheets can be freely modified and printed for use in the classroom.
- *Coach Activities* – software activities for use in the Coach 7 and Coach 7 Lite programs.
- *[OPTIONAL] Primary Science Kit (CMA art. code 009kit)* – a set of additional experimental materials, which can be used with the activities.

2. ICT strengths

An important component of ICT is the computer, but its application as a useful educational tool depends crucially on the software used and on the design of learning activities sequences that can scaffold students to develop scientific thinking and conceptual understanding.

2.1. Data logging

The learning strategy of the activities included in this pack is based on student investigations of real phenomena using data logging. The term *data logging* describes the process of gathering and recording measurement data from sensors. One of the most important features of using data logging, compared to a traditional measurement method, is 'real-time' display – the "measurement data" immediately appear on the screen. Students are able to watch the graph being drawn simultaneously on the screen as they perform the measurement. It gives possibilities to make direct associations between the features of the phenomenon and the features of the graph.

Displaying data as it is being collected also reinforces the link between an experiment and its results; students get a better feeling for measured quantities like temperature, light intensity, sound. Sensors often make "visible" what is invisible to our senses.

In the data-logging measurement activities the graph is a starting point for thinking and discussion rather than being the end product as in most traditional measurement activities.

Immediate feedback encourages critical thinking skills; students have more time to spend on observing and interpreting, discussing and analysing data. They can quickly repeat the experiments, change experimental conditions and explore the results of the changes. This facilitates an interactive approach to the experiment. "Lets' see what happens if … ". This is the best spirit of an investigative, inquiry based approach.

These special features provide opportunities for improved learning provided the teacher is aware of them and designs the learning activity appropriately to exploit them.

2.2. Reading and interpreting graphs

Learning with graphical presentations is very important. A great deal of information can be conveyed efficiently with graphs. Students have highly developed visual skills, and it has been found that visual activities have a large influence on cognitive development.

The traditional process of plotting graphs of measured data leaves little time to consider the meaning of the graphs. Computer measurement activities create many opportunities for exploring data and help to focus student attention on the interpretation of graphs. Students quickly learn the 'language' of graphs for representing and describing change and for comparing data. The meaning of graphs becomes more concrete.

There are at least three levels of interpreting graphs. At the first, qualitative level, the shape of the graph may be inspected, identifying trends and interesting features. Students can try to explain what may be going on in an experiment. Very important also is the effect of scale on the shape of the graph.

At the second, semi-quantitative, level, students compare graphs and explain similarities and differences.

Finally, the quantitative level of interpreting graphs involves obtaining information from graphs, reading values and performing simple calculations.

3. Inquiry based approach

The *Primary Science with €Sense* activities have an inquiry-based character and are structured according to the Learning Cycle, a science instruction model, originally proposed in the early 1960s by Atkin and Karplus (1962).

The activities reflect the constructivist view of learning. The essence of this view is the recognition that for children to learn, they have to be actively involved in the learning process; they construct meaning by the process of interaction and inquiry.

3.1. Inquiry-based skills

Through these activities students develop basic abilities to do and understand scientific inquiry:

- Asking and answering questions
- Planning and conducting simple investigations
- Predicting outcomes
- Making observations
- Testing hypothesis
- Employing tools to gather data
- Reading and interpreting graphs
- Analysing data
- Making comparisons
- Using data to construct explanations and conclusions
- Communicating investigations and explanation.

Throughout the materials students are actively involved in performing science investigation and are encouraged to learn basic science concepts around sound, light, heat and temperature. Students are involved in authentic inquiry-based investigations.

3.2. Student's role

In inquiry classrooms the student is the centre of the learning process. The following students behaviours characterize inquiry:

- Students are working as scientists.
- Students are taking responsibility for their own learning.
- Students are working in cooperative groups.
- Students are making decisions.
- Students communicate their findings.
- Students are showing interest in science.

Act as a researcher

Scientists need to measure and communicate, to handle information, to model ideas. In essence, they need to process information. It is important that students realize how today's scientists work. In the 'Primary science with €Sense' activities students use the computer in a similar way as scientists do. In an inquiry-centred class students are acting as researchers. They can make decisions about their own work, how to collect and organize data and how to communicate their findings to the rest of the class.

Design and conduct an own investigation

In activities at the highest level of inquiry students have to design a fair test as a way to try out their ideas, not expecting to be told what to do. They should plan and carry out their investigations by handling materials with care, observing, measuring and recording data. By planning and designing their inquiries, students begin to use higher-level thinking skills, such as analysing and evaluating. Finally they should express their ideas and results in a variety of ways: writing, drawing, graphing, charting etc. They propose and defend their explanations.

3.3. Teacher's role

The teacher's behaviour and competencies are crucial in inquiry classrooms. They set stage for teaching and learning. For teachers, there may be a temptation to adopt the role of observer when computers are used in the classroom, but much research has underlined the important of teacher interventions in securing learning benefits from computer based methods. Teachers are not replaced by technology but become essential as guides to students as they explore, experiment and engage with scientific concepts.

THE ROLE OF THE TEACHER IN THE INQUIRY CLASSROOM IS TO:

- create an atmosphere in the classroom where real things happen and where students are given structured and unstructured opportunities to investigate, observe, test and carry out (their own) experiments;
- limit the use of direct instructions;
- make learning meaningful by exploring students' interest;
- help students to generate ideas and investigations which stem from their own questions;
- listen to student's ideas and become aware of their misconceptions;
- asses prior knowledge before starting a unit and use the students' prior knowledge as a basis for introducing new concepts;
- encourage students to ask their own questions and to seek their own solutions to problems;
- ask questions that require critical thinking skills;
- give students enough time to express themselves rather the interrupt them in the middle of their questions and answers, value their response;
- encourage cooperative group work;
- act as facilitator, mediator, initiator.

Extended teacher commentaries are provided fort each activity to help as well with science and pedagogy as with handling of equipment, computers and software.

Teacher commentaries provide:

- science background - short explanation of core science concepts needed to understand the investigations;
- learning objectives;
- known students' beliefs;
- activities descriptions - explanation of investigations, exemplary data and answers.

Organizing classroom

Inquiry based approach is about students working together, trying things out, coming up with and sharing new ideas. And learning from what does not work. To make this approach effective a classroom culture needs to be created in which all students feel comfortable and have the opportunity to participate in all aspects of the science work – the hands on, experimenting, thinking, talking and writing.

There are many ways in which inquiry science lessons can be organized in primary classroom. It is essential that the teacher selects a method of classroom organization which creates a student-centred, interactive and creative learning environment. Students usually can work with a partner or in a group of three; this is a setting in which they can easily discuss their ideas, perform investigations and share solutions to the problems.

Using students' prior experiences and ideas

Students generally have many ideas about the phenomena they encounter in their every-day lives. Quite often such ideas are incomplete or contradict the scientific explanations of the phenomena. It is very important to be aware of these students' ideas. These ideas, referred as student's beliefs, are listed in the teacher commentaries of activities.

Creating and asking questions

The questions teacher ask play a very important role in the inquiry-based approach. Good questions move the work forward. Each unit has its key question, but many more research questions are asked in activities. Do not offer answers to any questions. Let the students explore, speculate, do not encourage a single correct answer.

Holding group discussion

It is important to give the students the possibilities to share ideas and to understand what they know. They can better realize what they know by expressing their own ideas and hearing the ideas of others. Whether the ideas are accurate or not is not that important, discussing any ideas may open new ways of thinking.

Carefully lead, targeted discussion at critical learning moments like introducing new science concepts can be crucial for better student understanding.

Guiding students as they design an investigation

Learning to design an investigation is an important part of understanding the nature of science. But it is not easy and students need to learn the skills. This means working closely with them, especially in the beginning. The process often begins with a class discussion. Try to clarify the question or problem and determine what elements of the phenomenon are important to study. For an experimental investigation, it is important to discuss how to test the factors, one after another, using the equipment available. Students often have difficulty to realize that in order to be able to interpret the experiment, only one factor can be varied at a time with all others kept constant; they must learn to do a controlled experiment. This is a skill that develops over time.

Having students to work as researchers is challenging for both students and teachers. For students to take new roles, teachers must assume new roles as well. Teachers must trust that students have skills and interest to carry out their own investigations and generate their own ideas. When students act as researchers and are given opportunity to raise questions (of their own choice), they start taking responsibilities for their own learning. Teachers should be facilitators of this process.

Assessment

Formative assessment can take place through observation of students as they work with the equipment and software; discussion with students as they are engaged in activities, group feedback sessions, printed out graphs and tables, filled student worksheets and interpretation of results.

4. Units and Activities

In the *Primary Science with €Sense* activities students investigate phenomena involving light, sound, and temperature. Students get a number of problems that have to be solved by taking measurements with sensors. The threshold of technical skills needed to use the tools is low to allow the primary focus of the activity to be on the science phenomenon itself and on the inquiry approach.

Structure

The pack consists of 3 parts, build around the use of €Sense sensors:

- Exploring Light – use of the light sensor,
- Exploring Heat and Temperature – use of the external temperature sensor,
- Exploring Sound – use of the sound sensor.

Each part consists of a set of units around the selected theme. Each unit offers a set of Activities. Each unit can take 1-3 lesson hours.

Learning Cycle

Units are designed according to the Learning Cycle, which is one of the most effective models of science instruction.

Each unit is started with the Exploration phase. This phase is meant for introducing a problem and getting student's attention by using observations, asking questions, performing simple experiments. This phase should generate students' interest and curiosity, and set the stage for inquiring about a particular phenomenon. This phase also provides an opportunity for the teacher to activate learning, assesses prior knowledge and has students share their prior experience about the topic.

Next unit activities set the Concept Development phase. Students are engaged in investigations using the computer and sensors, starting with more direct instructions and following to more open-inquiry investigations. During this stage students develop hypothesis to test, they record data, collect evidence, draw conclusions and work in cooperative groups. Students use the worksheets to write their ideas, observations, results, and explanations. In addition they learn to present ideas, observations and descriptions in a form that others can understand. This stage enables students to build a common experience and develop science concept knowledge. It also provides opportunities for students with diverse experiences to share their different understanding. During this stage the teacher may choose to assign roles to the individual students working in a group or let students choose a role according to their strengths or interest. It is advised to close the Concept Development phase with whole class discussion lead by the teacher. During such discussion evaluation of the students' findings and summary of the learned science concepts should take place.

The Questions included in each unit offer stage for the Application phase in which students can show their understanding of science concepts introduced in the unit.

Inquiry approach

Through the activities students are guided into inquiry starting at low-level inquiry and developing more advanced inquiry skills. The research questions are already formulated in the activities. Many students prefer to solve their own questions rather than someone else's. This is the highest level of inquiry – open inquiry. In such student-initiated inquiry students raise their own questions, formulate their own procedures, and determine the results. This level of inquiry is not offered in the worksheets but can be done by using the Own Lab Coach Activity. In this activity students can decide what they want to investigate, which €Sense sensors they like to use and how long they want to measure. They can set up their experiments, carry out the measurements, analyse data, draw conclusions and create the final reports. They can share their findings with their classmates by making a presentation, preparing a poster or writing an article in a school newspaper.

Specific skills

Next to procedural student skills (general inquiry skills, science skills) the following operational skills can be reached through 'Primary science with €Sense' activities:

- to set up the equipment, to use €Sense and to be responsible for the equipment.
- to know how to work with the program (start the program, open activities, make measurements, write notes, print information etc.).
- to make a prediction graph.
- to use the information from diagrams:
  - read values from a graph,
  - zoom a part of a graph,
  - determine the scale of a diagram.

5. Get inspired

Better use of ICT is needed not just to give students exposure to the technology or to satisfy parents, but because technology can be used to greatly improve learning and it is an essential part of modern science. It is evident that the use of ICT in teaching can provide many new opportunities: new ways of teaching, new ways of learning and new content. However it is important to realise that the success of ICT crucially depends upon the vision and actions of the teacher.

We hope that via these materials you get inspired in using as well inquiry approach as ICT tools in your classroom.

We wish you to have a lot of learning experiences with our materials!

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B. Teacher commentaries

1. Exploring Light

1.1. Introduction

'Exploring Light' activities encourage student investigations into some of the way in which light behaves. Students use the light sensor built-in the €Sense interface and the computer. The scope of the activities is limited to measuring the light intensity of different light sources, investigating how light is reflected and how it travels.

UNITS:	MATERIALS
■ I. How bright ■ II. Graphing light ■ III. Light and matter ■ IV. Reflected light ■ V. To see and to be seen	■ €Sense **INCLUDED IN PRIMARY SCIENCE KIT (009):** ■ €Sense Horizontal holder (L1) ■ €Sense Horizontal holder (L1) ■ LED lamp with holder (L3) ■ Samples of test materials (L4) ■ Coloured light filters (L6) ■ Coloured plastic squares (L7) ■ 3 white screens with holes in the centre (L8) ■ White screen without whole (L9) ■ A round table with angular degrees (L10) **NOT INCLUDED:** ■ Other light sources like tungsten lamp, torch, candle, desk lamp, fluorescent lamp, energy saving lamp, ■ Different sunglasses

1.2. Unit I. How bright?

In this unit students learn how to work with the €Sense's light sensor and measure light brightness.

Little bit of science

Anything that gives out light is called a light source. There are many sources of light and they use different mechanisms to produce light. One of the most common is heating materials to a certain temperature at which they emit light. Examples of such light sources are sun (glowing gas), incandescent light bulbs (glowing wire), gas flames (glowing solid particles). A light produced by a candle flame is the results of burning chemicals.

In lower temperatures, light can be produced by letting a strong electric current flow through a gas. Examples of such light sources are fluorescent (TL) lamp and neon lamps.

Light can also be produced by living organism (bioluminescence) as the result of a chemical reaction during which chemical energy is converted to light energy. For example a family of insects called fireflies or lightning bugs produce light to attract mates or prey.

Learning objectives

- Get familiar with the light sensor of €Sense.
- Measure light intensities of different light sources.
- Introduce the unit of light intensity lux
- Get a qualitative idea about levels of brightness

Student's beliefs

- Sunlight is different from other sources of light because it is colourless and clear.
- A light source and its effects are not separate.

Materials

- €Sense,
- Light sources like: tungsten lamp, torch, candle, LED lamp, fluorescent lamp, energy saving lamp, etc.

Description of student activities

1. Light sources

Students should be able to name a selection of light sources, including the sun, and identify some of the uses of light in the environment.

Natural light sources: sun, stars, lightning, fire, and fireflies.
Artificial (made by men) light sources: candle, different electric lamps, computer screen, etc.

2. The brightness of different light sources

Students get familiar with the light sensor of €Sense and measure the light intensity (in lux) of different light sources.

Daylight is the brightest and candle light the weakest. Fluorescent strip light is much brighter than tungsten light. Indoor, artificial lighting usually gives the values of 300-500 lux for offices and classrooms. Some typical light intensity values are listed below.

Light source	*Light intensity it produces (lux)*
Direct sunlight	31 000 – 130 000
Full daylight, (not direct sun)	10 000 – 25 000
Overcast day, typical TV studio lighting	1000
Sunrise or sunset on a clear day	400
Office/Classroom lightning	300 – 500
Very dark overcast day	100
Living room	50 – 200
Full moon	0.5

Students should recognize that the most intensive light comes from the sun and actually it is the most important source of light energy on Earth.

3. How much light can the light sensor measure?

The €Sense's light sensor has three ranges: 0 .. 1500 lux, 0 .. 15000 lux and 0 .. 150 000 lux. Since most students' measurements are made indoor the rang selected in the Coach Activities is 0 .. 15 000 lux. This gives problems when the sensor is aimed at the window on a sunny day, or at direct sunlight, or at highly reflective objects such as a piece of aluminium foil in a well-lit room. The light intensity in such cases is higher than the maximum value of 15 000 lux. In this activity students should realize that the light sensor can measure a maximal value of 15 000 lux and is not appropriate for measuring e.g. sunlight.
For sunlight the measuring range of 0 … 150 000 lux should be selected.

4. Which are the brightest and the darkest places in your classroom?

In this activity students investigate the lightning of their classroom. It is important to use the same method of measurement for each measurement place.

1.3. Unit II. Graphing light.

Students learn to make and interpret light intensity graphs.

Learning objectives

- To learn how to use the light sensor.
- To interpret light intensity graphs, to recognize trends like more light and less light.
- To read values (the time and light intensity) from light intensity graphs.
- To explore and match different light intensity graphs.

Materials

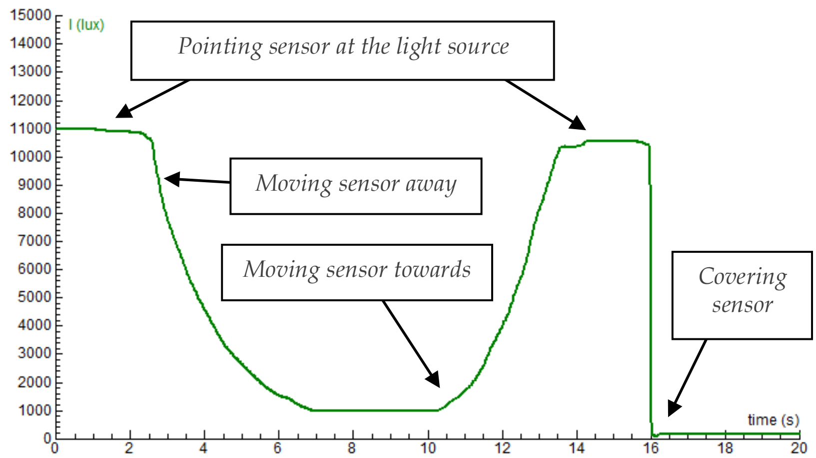
- €Sense,
- A LED lamp or a torch,
- White and black clouds made from paper.

Description of activities

1. Graphing light

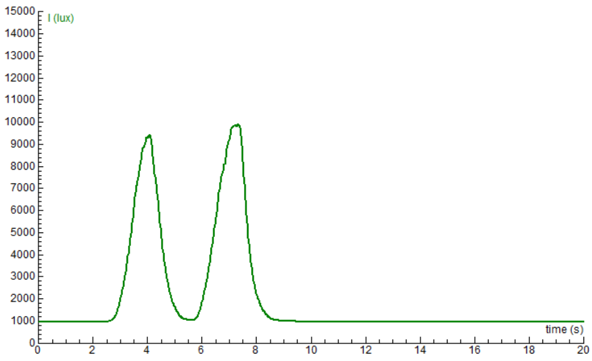
Students use the light sensor to measure light intensity. The measured results are now displayed in the diagram. The red cross displayed along the vertical axis indicates the actual measured value. When the light intensity increases the cross goes up, when the light intensity decreases the cross goes down. Students record the light intensity graph while the light sensor is moved away and towards the lamp.

Example and interpretation of data



2. Match the graph

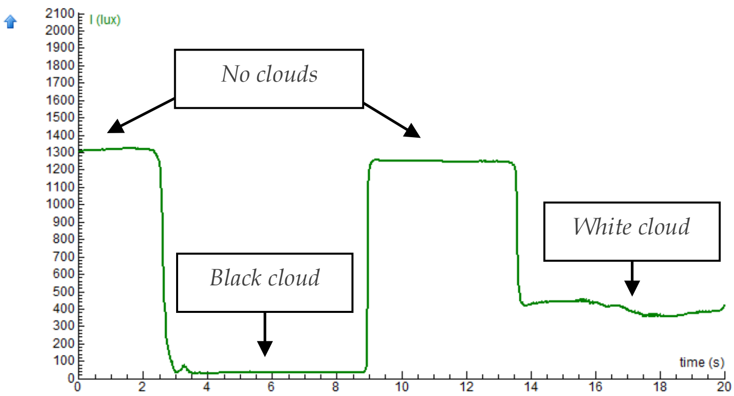
In this activity students try to match a given light intensity graph. They also try to create a light intensity graph that has the shape of M.



Example of data: *A M-letter graph.*

3. "CLOUDS" GAME

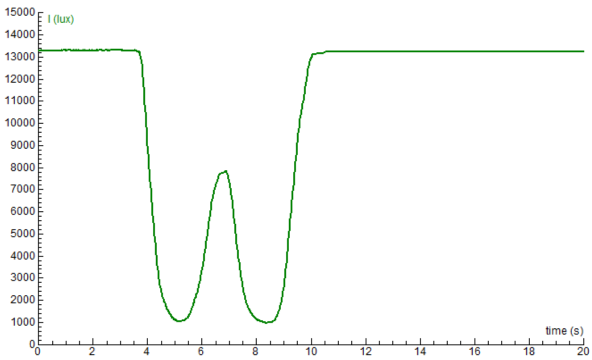
Students play a game. One student places a white or black "cloud" in front of the light source. The other student by knowing the light intensity of each cloud and by looking at the resulting graph tries to figure out which cloud and when was placed in front of the sensor.



Example of data*: Clouds in front of the light sensor. To get reasonable results the light sensor should be well illuminated and clouds should be placed close (1.5 cm) to the light sensor.*

QUESTIONS

Students have to create graphs of 'W' and 'N' and describe the steps they take to make them.



Example of data*: A W-letter graph.*

1.4. Unit III. Light and matter

In this unit students investigate how much light passes through different materials.

Little bit of science

When light strikes an object the light can be reflected, absorbed and transmitted.

A material that is opaque reflects or absorbs all light that strikes it (for example wood or metal). A material that transmits light is transparent. A material that allows only some light to pass through is translucent. Translucent materials scatter light as it passes through.

When you look through coloured transparent objects or translucent objects, you see the colour of light that was transmitted though the materials. All other colours are absorbed.

Learning objectives

- To realize that some materials transmit light and other materials block light.
- To design and perform a fair science investigation.
- To classify opaque, translucent and transparent materials.
- To investigate what light passes through different coloured filters.

Student's beliefs

- Light always passes straight through transparent material (without changing direction).
- When an object is viewed through a transparent material, the object is seen exactly where it is located.
- When light passes through a colour filter, colour is added to the white light.

Materials

- €Sense,
- A light source: LED lamp or a torch,
- Different sunglasses,
- Different materials for testing how much light passes through,
- Coloured transparent filters.

Description of activities

1. Sunglasses contest

Students investigate different sunglasses to test their effectiveness in reducing light. Ask students in advance to bring inexpensive sunglasses.

In this activity focus is given to a fair, scientific investigation. In such investigation one condition (independent variable) affect another (dependent variable) by keeping all other conditions constant. The independent variable is the type of sunglasses (actually the type of material used for reducing the light); the dependent variable is the light intensity of the light passing through. The position of the light source and the light sensor should be fixed and the sunglasses should be placed always in the same position between these two. The amount of light around should not change. If light around varies too much then placing a black shielding around €Sense can help.

If you have a photochromic sunglass students can investigate how fast these glasses darken in the sunlight.

2. Does light travel through every material?

Children explore how much light passes through different materials. A variety of materials, such as glass, cellophane, clear plastic, frosted glass, greaseproof paper, plastic sweet wrappers, paper and water, should be available to the students.

3. What is the difference between translucent and transparent?

Based on the given definition of opaque, transparent and translucent materials students classify the tested materials in the previous activity.

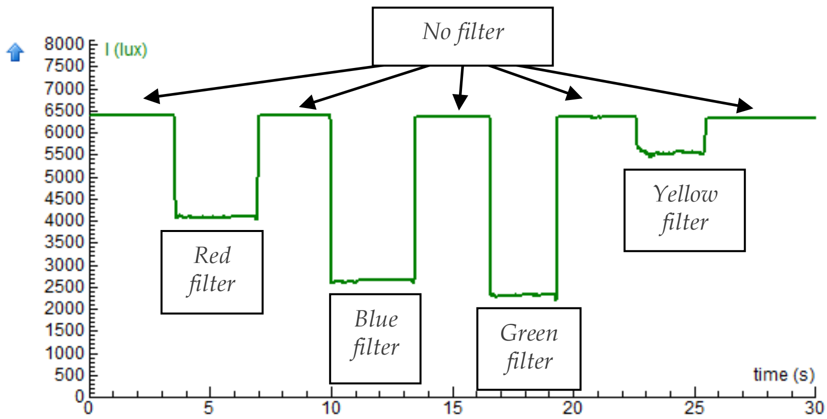
Once the students understand how materials can be classified as transparent, translucent and opaque they should explore the school and their houses for samples of each type.

The last three questions should lead to a discussion about properties of materials which should be used for making common objects such as windows blinds, sunshades, parasols, lampshades, glasshouses, etc. For example they might consider that the material used for glasshouses should be both transparent and waterproof.

4. Coloured filters

In this activity students work with colour filters and investigate which colour filter is the most effective in stopping light.

Example of data:
Coloured transparent filters in front of the light sensor.



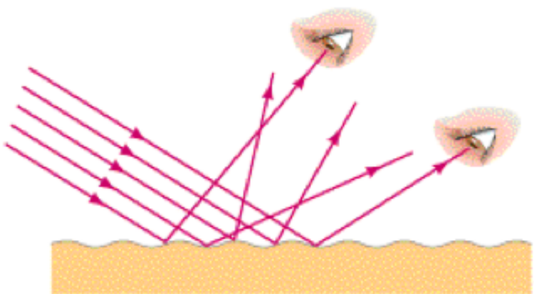
1.5. Unit IV. Reflected light

In this unit students use the light sensor to measure light reflected from different materials and colours. They have to take care that the performed investigations are fair, scientific investigations.

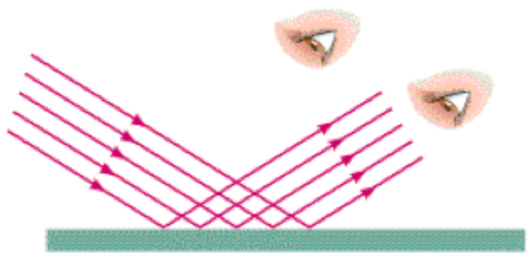
Little bit of science

Light has a very complex nature. To describe many effects of light at the scale of everyday experience it is useful to use the simple ray model. This model assumes that light travels in straight-line paths called light rays. In this model the path of light is taken into account without specific description what it is that is moving along the path.

When light hits a smooth surface, such as a polished mirror, it is always reflected in one direction (*specular reflection*). The new direction of the light rays is related to the old direction. The angle of the light rays reflecting off the surface is the same as the angle of the light rays striking the surface (*the law of reflection*).
When light hits as rough surface such as paper, wood, clothes and skin, it also reflects but it is reflected at all angles. Such reflection of light in random directions is called *diffuse reflection*.



Rough surface



Smooth surface

When you place your eye anywhere above the rough surface you will see some reflected rays (left picture). To see reflected light from a smooth surface your eye has to be in the correct position.

White light is a mixture of many colours mixed together. An object is "coloured," because the light it reflects - all other colours are absorbed into that specific object. For example when a white light shines on a blue fabric, the fabric reflects blue and absorbs every other colour except blue. Similarly a leaf appears green because it reflects the green light and absorbs the rest of the colours. A black fabric absorbs all the colours of white light and reflects little light black. A white fabric absorbs little white light and reflects most colours back.

Learning objectives

- To understand that light reflects from objects.
- To understand what is "source light" and what is "reflected light".
- To measure light reflected from different materials and colours.
- To know how to perform fair, science investigations.
- To understand white light is a mixture of many colours.

Student's beliefs

- While light is reflected by mirrors, it remains on other objects.
- Light is associated only with a source and/or its instantaneous effects. Light is not considered to exist independently in space. Light is not conceived as moving from one point to another with a finite speed.
- Light is reflected away from shiny surfaces, but light is not reflected from other surfaces.
- Colour is a property of an object, and colour is not affected by the illuminating light. The "true" colour of an abject is seen in white light. When coloured light illuminates a coloured object, the colour of the light mixes with the colour of the object.

Materials

- €Sense,
- A desk lamp,
- Samples of different reflecting materials: mirror, shiny and dull materials in the same colour,
- Different coloured paper pieces.

Description of activities

1. What happens when light shines on a mirror

In this activity students investigate the light reflected from a mirror. A mirror has a flat, smooth surface and it reflects light at an equal angle to incoming light. The reflected light in a form of a bright spot can be seen at the wall or ceiling.
A dark piece of material has a dark, bumpy and uneven surface. The light is reflected at different angles and is not visible anymore.

Students also learn to recognize which light comes for a source and which light is reflected.

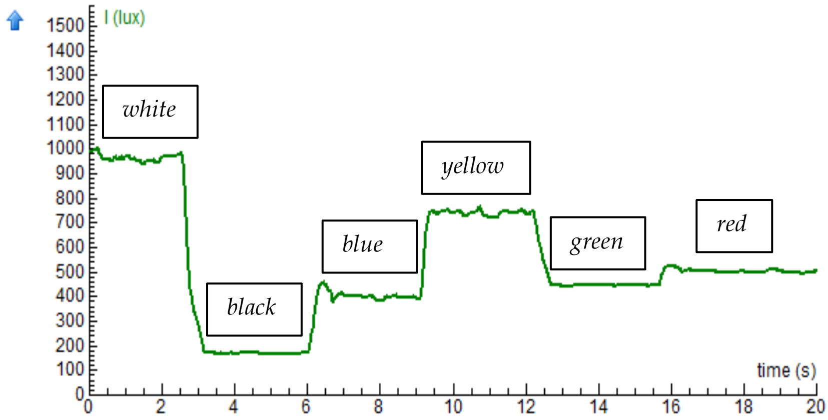
2. Which material reflects the most light?

Here students measure the light intensity of light reflected from different kind of materials. They investigate the materials to find out and describe properties of good reflecting and bad reflecting materials.

3. Which colour reflects the most light?

Now students test how well different colours reflect light. They measure the light intensity of the light reflected from different coloured pieces of papers.

Example of data:
The light intensity of light reflected from white, black, blue, yellow, green and red pieces of paper.



The last question in this activity should lead to a class discussion. Questions like: Which colour of coat should the crossing warden wear?, Which colours are the best for a road sign?, Which colours are the safest for a cyclist? etc. can be discussed.

Questions

Earth has high reflectivity because snow, ice, sand, clouds and water cover a lot of it. The results of the experiment suggest that dark-coloured parts of earth, such as forests and green would have lower reflectivity.

1.6. Unit V. To see and to be seen

We see objects when they reflect light rays into our eyes.

Little bit of science

A great deal of evidence suggests that light travels in straight lines under a wide variety of circumstances. For example, a point source of light like the sun casts distinct shadows, and the beam of a flashlight appears to be a straight line. In fact, we infer the positions of objects in our environment by assuming that light moves from the object to our eyes in straight-line paths. Our whole orientation to the physical world is based on this assumption. This reasonable assumption has led to the ray model of light, which was described in the previous unit.

Human eyes receive light by two means: from sources that emit light and from objects that reflect light. The sources of direct light were discussed in the *Unit I. How* *bright?*. All other objects can be seen because light reflecting off the objects enters our eyes. Most people would disagree if you told them that light was reflected from the book to the eye, because they think of reflection as something that mirrors do, not something that a book does. They associate reflection with the formation of a reflected image, which does not seem to appear in a piece of paper.

We can see colour when receptor cells (called cones) on our eye's retina are stimulated by light. There are three types of cones, each sensitive to a particular colour range.

Learning objectives

- To realize that light travels in all directions.
- To understand that light is needed to see objects.
- To know that we receive light from objects that produce light and from objects, which reflect light.
- To learn how the human eye work and how we see colours.

Student's beliefs

- An object is seen whenever light shines on it, with no recognition that light must move between the object and the observer's eye.
- Lines drawn outward from a light bulb in a sketch represent the "glow" surrounding the bulb. Light from a bulb only extends outward a certain distance and then stops. How far it extends depends on the brightness of the bulb.
- Light is associated only with a source and/or its instantaneous effect. Light is not considered to exist independently in space. Light is not conceived as moving from one point to another with a finite speed.
- Light fills the room as water fills a bathtub.
- The eye is the active agent in gathering light, rather than being just a receiver of reflected light.

Materials

- €Sense,
- 3 carton cards with holes punched in the center of each card,
- A paper circle,
- A candle,
- A piece of white paper with printed large dark 'smiley'.

Description of activities

1. How does light travel?

In this activity students see that light travels in straight paths. In the experiment with cards unless the cards are positioned with the holes in a straight line, the light does not pass through the holes in the cards. At the end of this activity children can be introduced to the ray model. It is important to tell them that this is not the only scientific model, which describes the behaviour of light.

In the experiment with cards a torch with a well-defined beam of light is more effective.

2. Light intensity around

In this activity students realize that light travels in all directions. When measurements of light intensity are done in a circle around a light source (a candle or a light bulb) the light intensity values are close to each other.

3. Seeing things

Here students should realize that we can see not only because objects are emitting light but also because light is reflected from objects. Based on the idea of the ray model the lines can be drawn to show how light travels and reflects from the object to enter our eyes.

4. Finding shapes with the light sensor

Now instead of eyes student use the light sensor to find a dark shape ('smiley') on a white paper.

2. Exploring Heat and Temperature

2.1. Introduction

'Exploring Heat and Temperature' activities use €Sense and its external temperature sensor to investigate a variety of experiments in which the temperature is changing.

UNITS:	MATERIALS
▪ I. Hot! Cold! Warm! ▪ II. Graphing Temperature ▪ III. Keeping warm ▪ IV. Getting the right temperature ▪ V. Cooling down ▪ VI. How to cool faster ▪ VII. Melting ▪ VIII. Heat absorption ▪ IX. A chemical reaction	▪ €Sense with external temperature sensor, **INCLUDED IN PRIMARY SCIENCE KIT (009KIT):** ▪ Large plastic tray (T1) ▪ Styrofoam beakers (T3) ▪ A 100 mL measuring cylinder (T3) ▪ A 250 ML beaker (T4) ▪ A 100 mL (plastic) (T5) ▪ 3 test tubes with rubber stops (T6, T7) ▪ Test Tube rack (T8) ▪ Piece of wool for rubbing (T10) **NOT INCLUDED:** ▪ Wool mitten or gloves, ▪ A lamp (100 W) for heating "things" up, ▪ Isolation materials like cotton balls, Styrofoam, paper, fleece, plastic foil with air bubbles or foil, ▪ Additional "kitchen" materials such as: large pans, water, ice, salt, baking soda, vinegar, spoons, paper towels to clean, and sand.

SAFETY

Some of the activities require students to use water near the computer. If a spill occurs computers could be damaged and electrical shock could occur. To avoid this problem, we recommend placing beakers with water in a large plastic container.
To avoid burns we advice to avoid water above 50° Celsius.
Warm water should be prepared before the lesson and stored in thermoses.

2.2. Unit I. Hot! Cold! Warm!

Students learn how to measure temperature in an objective way.

Little bit of science

The sense of touch is unreliable for measuring temperature. If you touch a wooden door on a cold day with one hand, and an iron door knob with the other hand, the iron feels colder. Both objects have the same temperature, but our senses are fooled. The reason is that the sense of touch can detect the direction of heat flow. When heat flows away from the hand, the object it touches feels cold. The iron feels colder than the wood, because iron can conduct heat much better than wood.

To measure temperatures objective by a measure device like thermometer or a temperature sensor should be used.

Temperature indicates how hot or cold things are. Materials are made of atoms, which are often grouped in molecules. Atoms and molecules are constantly on the move. The hotter something is, the faster atoms move, the higher the temperature is. The colder something is, the slower atoms move, the lower the temperature is.

Learning objectives

- To realize that using human senses is not an objective way of measuring temperature.
- To familiarize with the temperature sensor.
- To predict and measure temperatures of different objects.
- To read temperature values from the digital meter on the screen.
- To understand that the sensor reacts slowly and needs some time to get the temperature of its surrounding – air, water, skin, etc.
- To understand that temperature is a measure of how hot or cold things are.

Student's beliefs

- Temperature is a property of a particular material or object (metal is naturally colder than plastic).
- The temperature of an object depends on its size.
- Metal is colder because it absorbs more cold than plastic.

Materials needed

- €Sense with external temperature sensor,
- Three large pans: one with cold water, one with lukewarm water, and one with hot water - as hot as a hand can bear.

Description of activities

1. Feeling temperature

After one hand is placed in hot water and the other hand in cold water then the hands feel different in the lukewarm water. The hand from the hot water feels cold; the hand from the cold water feels warm. To measure temperatures accurate a thermometer or a temperature sensor has to be used.

2. Measuring water temperature

Students learn how to use the €Sense external temperature sensor to measure water temperatures. They read the temperature values from the digital display on the screen. The temperature sensor always needs some time to get the temperature of its surroundings e.g. air, skin, water, etc. so make sure students wait a while until the temperature measurement stops changing.

3. Measuring temperature of different objects

Students measure temperatures of different objects, like air temperature (room temperature), skin temperature, temperature of objects in the classroom. Interesting is to pick up objects which have the room temperature but "feel" different temperature e.g. a metal object feels colder and a Styrofoam object feels warmer but both have the same room temperature.

2.3. Unit II. Graphing temperature

Students learn to make and interpret temperature graphs.

Learning objectives

- To learn how to use the temperature sensor.
- To interpret temperature graphs, to recognize trends like warming up and cooling down.
- To read values (the time and respective temperature) from temperature graphs.
- To explore different temperature graphs produced by placing a temperature sensor in cold, warm and hot water.

Materials needed

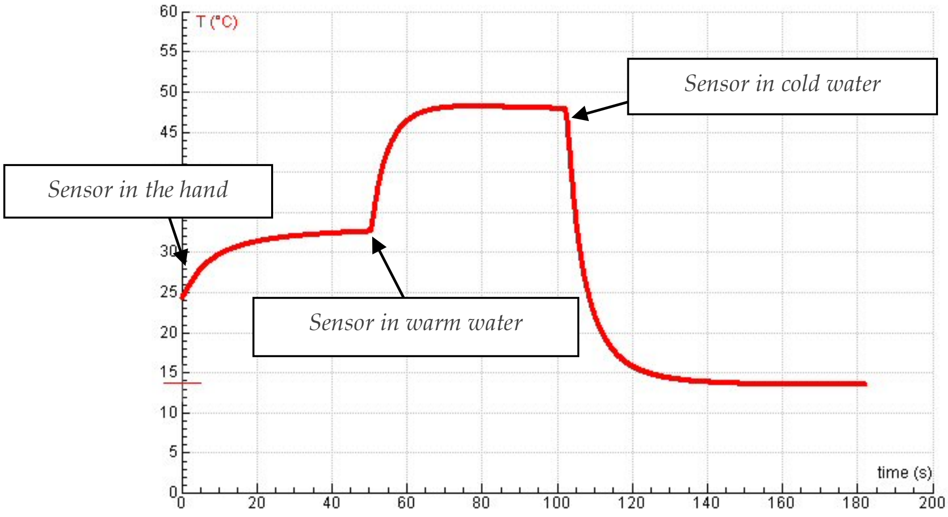
- €Sense with external temperature sensor,
- Styrofoam beakers, one with cold, one with warm and one with (not too) hot water.

Description of activities

1. Graphing temperature

Students use the temperature sensor and produce their own temperature graph by placing the sensor into beakers with cold and warm water. They notice that when the temperature goes up the cross on the vertical axis also goes up, when the temperature goes down the cross on the vertical axis goes down.

Example of data



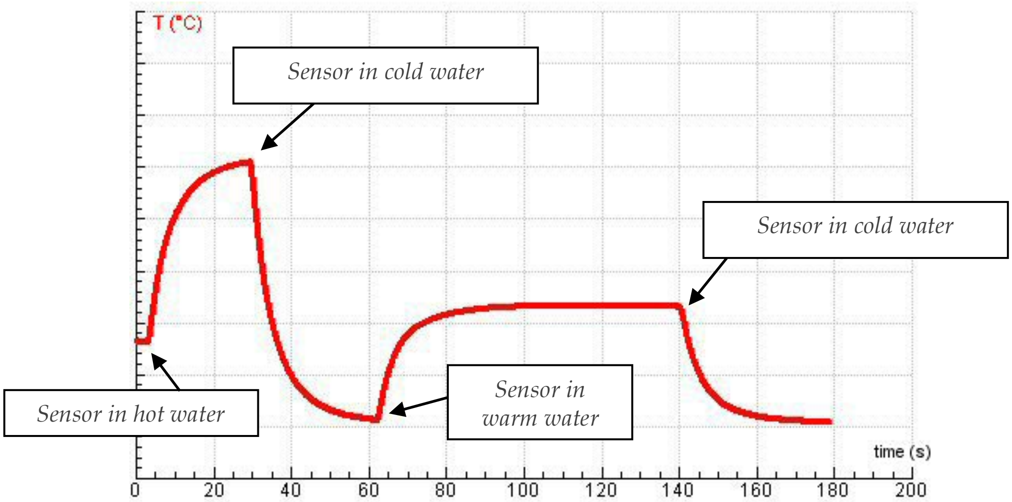
2. Temperature game

Students play a game. One student puts the temperature sensor slowly in and out of beakers with cold and warm water. The other student by looking only at the resulting graph has to tell when the sensor was dipped and in which beaker. To estimate the moments when the temperature sensor was dipped in the cold or warm water he has to read out on the time axis where the temperature respectively goes up or goes down.

3. How good can you control temperature?

Students try to match a given temperature graph. First they have to interpret the graph and write down how the graph was made.

Example of data

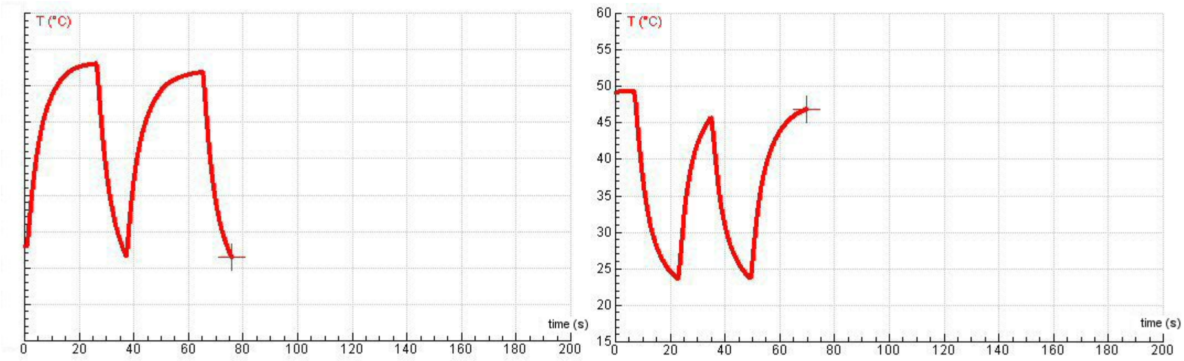


4. Reading temperature

Students interpret the given temperature graph which shows daily temperature changes during a summer day. They write a story about the temperature change.

Questions

Students have to create graphs of letters like 'M' and 'W' and describe the steps they take to make them.



***Example of data:** Graphs of letters M and W.*

2.4. Unit III. Keeping warm

Students learn how to warm up the temperature sensor, by using heat sources and by using friction. They discover the difference between heat sources and heat insulators. In this activity attention is given to the concept of a fair, scientific investigation.

Little bit of science

A substance does not contain heat – it contains internal energy, which is the total of all energies inside the substance. In addition to the energy of moving atoms and molecules there is also energy due to the forces between molecules. To make an object warmer heat should be transferred into it, to make atoms and molecules move faster.

Heat can be transferred from warmer objects to colder objects. You can also make heat by burning things (chemical reactions), or by rubbing things together (friction). Materials, which stop heat escaping or entering, are called insulators. Such materials can be used to keep things as well hot as cold.

Learning objectives

- To learn how to warm up the temperature sensor.
- To help student to understand that heat is a form of energy.
- To understand the concept of isolation.
- To understand that mittens act as an insulator not as a heat source.
- To understand the concept of heat sources.

- To design and perform a fair science investigation.

Student's beliefs

- Heat acts as a fluid. It accumulates in one spot until that spot is full. Then that spot "bursts" and heat overflows to other parts of a substance.
- Heat is not energy.
- Heat only travels upward.
- Heat makes things rise.
- Heat moves around and rises.

Materials needed

- €Sense with external temperature sensor,
- Wool mitten or gloves,
- Pieces of materials for rubbing,
- Isolation materials: cotton balls, Styrofoam, paper, fleece, plastic foil with air bubbles or foil, etc.

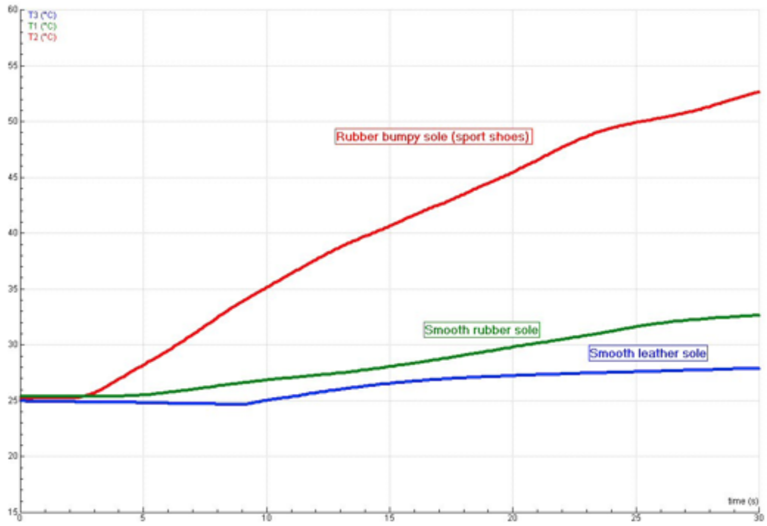
Description of activities

1. How to make things warm

Students think and discuss about different ways of making objects warm.

2. Making things warm

First students use different heat sources like warm water, heater, or lightning bulb to warm the temperature sensor up. Then they make the sensor warm by rubbing the sensor by hands, or by a piece of material (the temperature can go up to 60 °C). Interesting is to rub the temperature sensor on the soles of different types of shoes as they give different results. By using a bumpy rubber sole of sport shoes the temperature can go up to 60 °C, while by using a smooth leather sole the temperature goes only to 30 °C. In general more friction between the temperature sensor and the sole material causes the temperature to go higher.



Example of data:

Change in temperature over time of 30 seconds for 3 different types of soles.

3. Do mittens make heat?

Students make temperature measurements to answer the question "Do mittens make heat?". They discover that mittens do not produce heat, in other words mittens are not heat sources. They are warm because they help holding in heat from the hand and minimize the heat loss into the surrounding air. Mittens act as insulators.

Way of measurement	*Measured temperature (°C)*
Open hand	31.5 °C
Empty mitten	22.5 °C
Open hand in mitten	33.5 °C

Example of data: *The room temperature is 22°C.*

The temperature of the surface of a hand is typically below normal body temperature because heat is lost to the cooler surrounding air. Empty mitten should have the same temperature as the room (air) temperature. The temperature in the mitten with a hand inside is higher because the hand is providing heat to warm the temperature sensor. This temperature is also higher than the temperature of the open hand (without the mitten). The mitten prevents the outside cold air from making contact with the hand. The mitten insulates the hand from the cold surrounding, thus hands are warmer in mittens.

4. How to keep things warm as long as possible?

Students investigate different materials to find the best insulator for the temperature sensor. You can ask your students to bring different materials from home.

In this activity focus is given to a fair, scientific investigation. In such investigation one condition (independent variable) affects another (dependent variable) while keeping all other conditions constant. The independent variable is the insulation material; the dependent variable is the temperature. For each material the begin temperature and the measurement time should be the same. The best insulator is the material which keeps the temperature sensor warm the longest, in other words the temperature difference in the given measurement time is the smallest.

For each measurement, the sensor can be warmed up by rubbing it by hands, or by a piece of material.

2.5. Unit IV. Getting the right temperature

Students mix cold and hot water and they make predictions and measurements of the resulting temperature of the mixtures.

Little bit of science

Transfer of heat occurs when two liquids at different temperature are mixed together. When a cup of hot water is added to cold water then heat from hot water is transferred to cold water; the warmer water loses heat and the cold water gains heat. The energy of the faster moving molecules of hot water is transferred to slower moving molecules of cold water. The hot water molecules move then slower (the hot water cools down); the cold water molecules move then faster (the cold water warms up).

How much heat flows between the warm and cold water depends not only on the temperature difference but also on the masses (volumes) of hot and cold water.

Learning objectives

To predict and measure what happens to the temperature when the same amounts of cold and hot water are mixed together.

To predict and measure what happens to the temperature when different amounts of cold and hot water are mixed together.

To understand that during adding cold water into warm water heat is transferred from the hot into the cold water.

To understand that the final temperature of the water mixture depends as well on the initial temperatures as on the volumes of cold and warm water.

Student's beliefs

The temperature of a body is related to its size and mass.

Temperature is used to measure heat, and heat is "hot".

There is no difference between heat and temperature. Temperature is the amount of heat: it tells the hotness of something. More heat raises temperature. (You can add more hot water to a bathtub of hot water, adding more heat without changing the temperature).

Materials needed

- €Sense with connected external temperature sensor,
- A large plastic container (tray),
- 2 Styrofoam beakers,
- Measuring cylinder (100 mL).

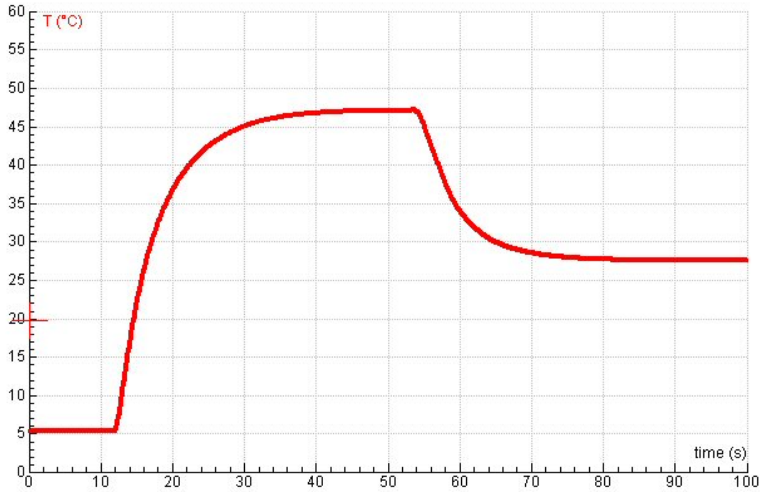
Description of activities

1. A TOO HOT BATH

Students think how to adjust the water temperature of a bath.

2. TEMPERATURE OF MIXING WATER

Students mix the same volume of cold and warm water. They measure initial temperature of the cold and warm water and the final temperature of the mixture. Best results can be achieved using cold ice water and warm water.



Example of data

Water volume (mL)		*Water temperature (°C)*			*Increase of water temperature (°C)*	*Decrease of water temperature (°C)*
cold	*warm*	*cold*	*warm*	*mixture*	*cold*	*warm*
50	50	5.6	47.0	27.6	22.0	19.4

Students should be able to discover that when volumes of cold and warm water are equal then the increase in the temperature of the cold water is close to the decrease of the temperature of the warm water. The heat gained by the cold water is near equal to the heat lost from the warm water. It is not exactly equal because some heat is used to warm up a beaker.

3. ACCURATE MEASUREMENT OF MIXING WATER

Students mix specific volumes of cold and warm water.

Again the same rule applies: the heat lost from the warm water is near equal to the heat gained by the cold water. When two times more warm water (100 mL) is mixed with cold water (50 mL) the increase in the temperature of the cold water is near twice as much as the decrease of the temperature of the warm water. And also opposite, when two times more cold water (100 mL) is mixed with warm water (50 mL) the increase if the temperature of the cold water is half of the decrease in the temperature of the warm water.

Water volume (mL)		*Water temperature (°C)*			*Increase of water temperature (°C)*	*Decrease of water temperature (°C)*
cold	*warm*	*cold*	*warm*	*mixture*	*cold*	*warm*
50	50	3.4	42	22.5	19.1	19.5
50	100	3.4	43.6	30.3	26.9	13.3
100	50	3.8	42.3	18.0	14.2	24.3

2.6. Unit V. Cooling down

Students record the temperature during a process of cooling.

Little bit of science

The direction of spontaneous heat flow is always from warmer things to a cooler neighbourhood. How fast heat is transferred depends on the difference between the temperature of the warm object and the temperature of the cooler surroundings.

The larger the temperature difference is, the faster the cooling process is. The process of cooling stops when the temperature of the warm object reaches the temperature of its surroundings. The objects come into thermal equilibrium. The heat lost by the warm object is gained by its surroundings.

Learning objectives

To record a temperature graph of a cooling process.

To learn to use the Sketch option for making prediction graphs.

To understand that the speed of cooling (rate of temperature change) depends on the temperature difference between the object and its surroundings.

To understand that heat is transferred always from a warmer object into cooler surroundings.

To understand that a larger object cools slower than a small object.

Student's beliefs

- Objects of different temperatures, which are in constant contact with each other, or in contact with air at a different temperature, do not necessarily move toward the same temperature.

Materials needed

- €Sense with connected external temperature sensor,
- A large plastic container (tray),
- A large beaker (250 mL),

- A small beaker (100 mL).

Description of activities

1. A CUP OF TEA

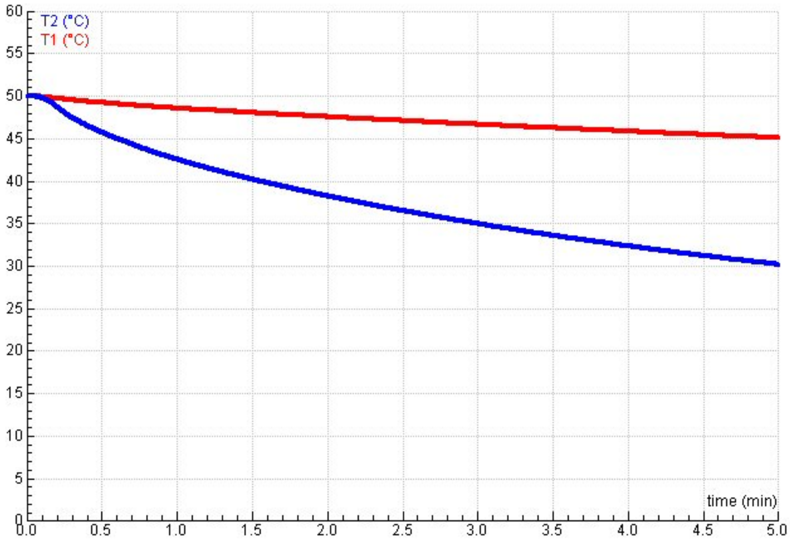
Students record and interpret the temperature graph of the cooling of warm water in a small beaker. The water does not cool equally in each minute of the measurement: in the first minute it cools the most, a minute later a little bit less, in the last minute it cools the least. The speed of cooling (the rate of temperature change) depends on the temperature difference between the beaker with warm water and the temperature of the surrounding air.

Example of data: The graph shows a 5 minutes temperature measurement of the cooling of warm water in the 60-ml plastic beaker. In the first minute the temperature change is 1.5 °C, in the second 1.1 °C, in the third 0.9 °C, in the forth 0.8 °C and in the fifth minute 0.7 °C. The Scan option can be used to read the temperature in each minute of the measurement and then the temperature difference can be calculated.

2. A COLD BATH

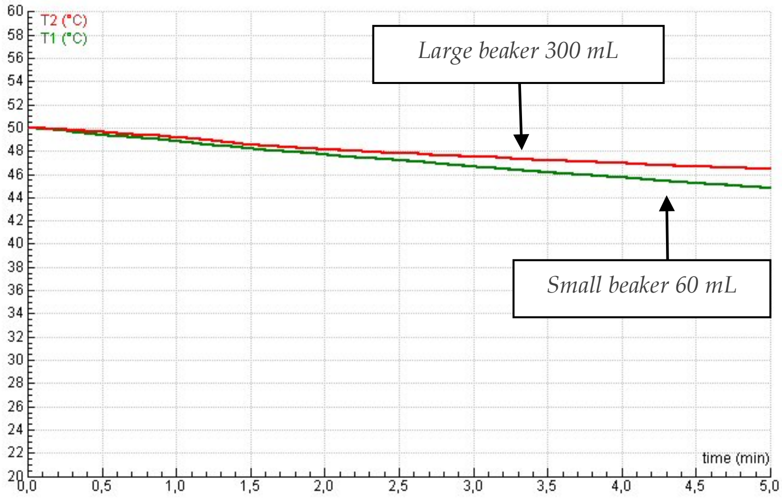
By placing a beaker with warm water in a cold bath the temperature of surroundings change, now it is not the temperature of the surrounded air but the temperature of the cold bath, which is much lower. The temperature difference is larger and the process of cooling goes faster. Students should explain how they can see that the process is faster - the temperature graph goes steeper down, the temperature change per minute is larger, etc.

Example of data: *The blue graph shows the temperature change of the warm water in the beaker when the beaker is placed in a cold bath. The cooling process is much faster (for comparison the red graph of the previous measurement is also drawn). The cold water bath has temperature 17.5 °C.*



3. What cools faster, a baby animal or an adult animal?

This activity has the form of an own investigation; students have to design a fair experiment to test which animal, a baby animal or an adult animal, cools faster. A small beaker with warm water can represent a baby animal; a large beaker with warm water can represent an adult animal.



Example of data: *The cooling process is slower for the large beaker. To make this fair test the begin temperature and the measurement time should be the same for each "animal".*

2.7. Unit VI. How to cool faster?

Student investigate in which ways the heat can be transferred and how to cool things faster.

Little bit of science

Heat can be transferred in different ways:

1. Convection is the transfer of heat by movement of a gas or liquid – for example air circulation in a room with a heater or with an open window.
2. Conduction is heat flow due to direct contact – for example touching a hot object or heating a metal spoon by leaving it in a cup of hot liquid.
   Good conductors are for example metals. Poor conductors (also called insulators) are for example air, cork, rubber and plastic.
3. Radiation is the transfer of heat through space (carried by electromagnetic waves) – such as heat energy from the sun or from the heater.

In the process of evaporation a lot of heat is used to change a liquid into a gas. This cools an object. Our body uses evaporation to keep cool. When we feel too warm we start to sweat. As the sweat evaporates, it draws heat from the body. Cooling by evaporation can be a problem. If someone's clothes get wet on a cold, windy day, his body can cool very quickly.

Learning objectives

- To understand how heat can be transferred.

- To find the fastest way of cooling a hot drink.
- To discover that evaporation causes cooling.

Student's beliefs

- Heat is a substance.
- Heat is not energy.
- Heat only travels upward.
- Heat rises.

Materials needed

- €Sense with connected external temperature sensor,
- A small beaker (100 mL),
- A (large) metal spoon,
- Different liquids for evaporation: alcohol (perfume or after-shave), oil, acid etc.

Description of activities

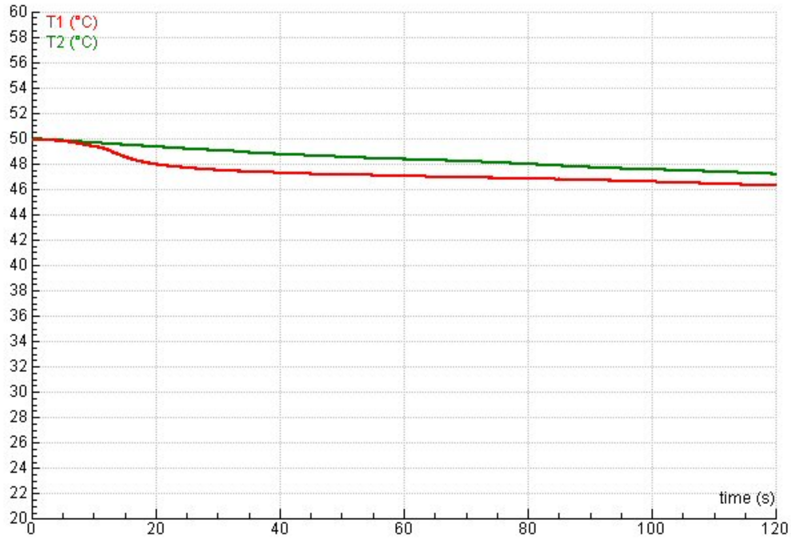
1. HOW DOES HEAT FLOW?

Students analyse how heat is transferred in different situations.

1. When the window is open the cold outside air mixes with the warm air in the room. Close to the window the air is cold; a little bit further from the window it is less cold and further away it is still warm. When the window is open for a longer time then the air temperature in the room gets closer to the outside air temperature. In this example heat is transferred by convection.
2. When a wooden spoon and a metal spoon are placed in hot water, the metal spoon feels warmer. In this case heat is transferred from the hot water to the spoons by conduction. Since metal is a better conductor than wood the metal spoon feels warmer.
3. Possible ways of cooling hot chocolate are: blowing, using ice blocks, stirring, placing near an open window, placing in a cold bath, dividing into two smaller cups, etc.

2. THE BEST WAY OF COOLING

Students investigate different ways of cooling hot water and try to find the most efficient method of cooling. Some of the student's examples should be discussed to analyse the way heat is transferred.
To make this investigation a fair test the begin temperature and the measurement time should be the same for each way of cooling.



Example of data:
Cooling of 60 mL of water in a glass beaker, with and without a metal spoon.

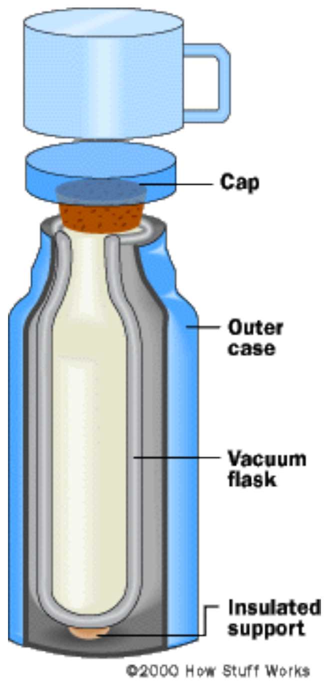
3. Can water cool you down?

Students observe and measure the cooling effect of water being evaporated from the temperature sensor. The best method is a wet sensor, which is waved in the air.

Sensor	*Temperature °C without waving*	*Temperature °C with waving*
Dry	24 °C	23,3 °C
Wet	22.4 °C	20.9°C

Exemplary data

4. Do all liquids cool in the same way as water?



Students investigate which liquid cools the fastest by evaporation. The best cools alcohol or perfume with alcohol.

Questions

A nice way of investigating the problem 'How de elephants keep cool?' is by measuring the temperature inside a metal can of water. The can should be wrapped in aluminium foil and have two large "ears" made also from aluminium foil.

Additional activity

A good way to review the methods of heat transfer is analysing how the thermos works.

A thermos consists of a double-walled glass container with vacuum between the walls. The glass surfaces that face each other are silvered. A stopper made of cork or plastic seals the bottle. Any liquid in the thermos – hot or cold – remains close to its original temperature for many hours.

1. Heat transfer by conduction - not possible through vacuum, some heat escapes through the glass and stopper, but very slow because these are poor conductors.
2. Heat transfer by convection – not possible in vacuum.
3. Heat transfer by radiation – reduced by silvered surfaces.

2.8. Unit VII. Melting

In this unit students are introduced to the concept of melting. They find the melting temperature of ice and observe the change of this temperature after adding salt.

Little bit of science

Materials can exist in three different states: solid, liquid and gas. Depending how warm water is it can be in one of the states:

Below 0 °C water is solid, ice or snowflakes.
At 0 °C water can be solid and liquid. This temperature is called the melting temperature of ice (a freezing temperature of water). The temperature remains 0 °C as long as the ice melts.
Above 0 °C and up to 100 °C, water is liquid.
At 100 °C water can be liquid and gas (steam). This temperature is called the boiling temperature of water. The temperature remains 100 °C as long as not all the is vaporized.
Above 100 °C water is a steam.

When you add salt to the water, it dissolves and forms a salt solution. This causes the melting temperature to be lowered by a few degrees, depending on the amount of salt added. It means that salt water must be lowered to below 0 °C in order to freeze. This effect is called *freezing point depression*. For a solution of table salt in water, this temperature can reach -21 °C under controlled lab conditions. In the real world, salt can melt ice only down to about -9 °C. This is the reason why freezing salt water in oceans is more difficult (sea water consists of circa 35 gram salt per litre) than freezing fresh water in lakes. It is also why rock salt is used to de-ice roads in winter.

Learning objectives

- To measure the melting temperature of ice (0 °C).
- To see the effect of adding salt on ice's melting temperature.

Student's beliefs

- Soft things melt more easily than hard things.
- Large ice cubes have colder temperature.
- Cold is opposite to heat.

Materials

- €Sense with connected external temperature sensor,
- A large beaker (250 mL),
- Ice cubes,
- Salt.

Description of activities

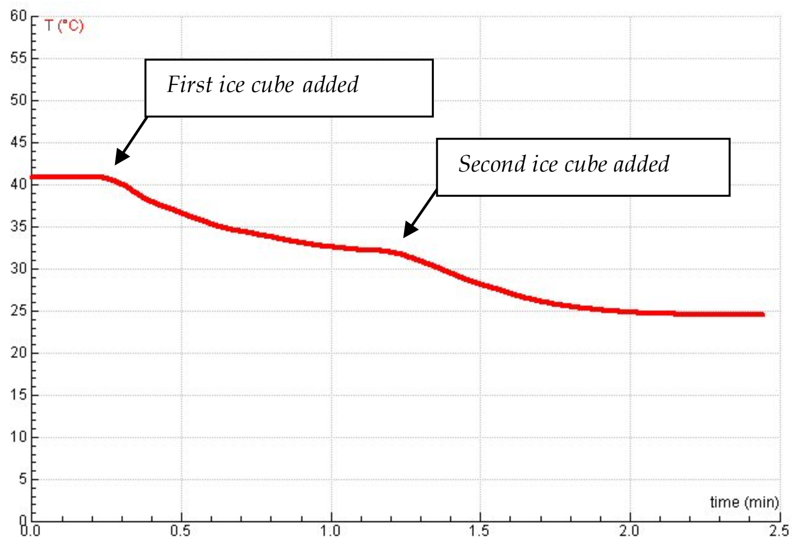
1. MELTING SUBSTANCES

Students describe what would happen to different substances when they are put into hot water. For example butter and ice cubes will melt. Clay will not melt.

Possible teacher demonstration: heating the baker with ice to observe what will happen to the ice as it is warmed up.

Students make observations about melting of ice cubes in lukewarm water and measure the effect of melting ice on the temperature of the water. Remind students to stir the water for the entire data collection.

Example of data:
Two ice cubes added
to the lukewarm water.

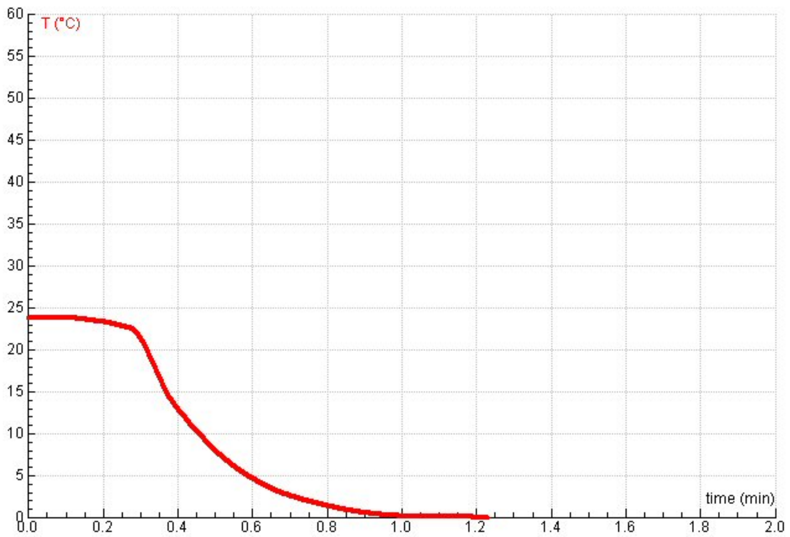


Ice cube number	*Begin temperature °C*	*End temperature °C*	*Temperature difference °C*
1	40.8	32.1	8.7
2	32.1	24.6	7.5

There is a smaller temperature change when the second ice cube is added than when the first ice cube is added. The second cube melts slower than the first cube. The temperature changes are affected by the size of the ice cubes.

2. ICE WATER

Students watch the effect of adding more ice cubes into lukewarm water.

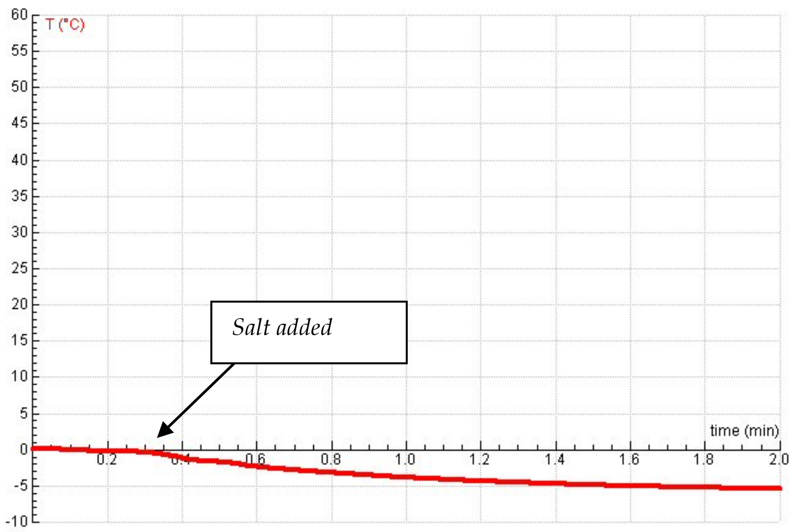


Example of data:
Many ice cubes added to the lukewarm water.

When ice is added to the water then the temperature decreases fast to 0 °C, this is the melting temperature of ice. As long as ice is melting the temperature remains 0 °C.

3. CAN YOU MAKE ICE WATER EVEN COLDER?

Students watch the effect of adding salt into ice cold water.



Example of data:
By adding 2-3 teaspoons of salt to the ice water its temperature decreases. Salty ice water in this experiment reached the temperature of – 5.4 °C.

2.9. Unit VIII. Getting warmer

Students learn the concept of heat absorption.

Little bit of science

Common heat sources are the sun, a lamp filament, burning embers in a fireplace. These objects emit infrared radiation in addition to visible light. When radiant energy encounters an object, it is partly reflected and partly absorbed. The part that is absorbed increases the thermal energy of the object and its temperature rises. For example if you stay in a sunny place or near a fireplace, you feel the radiation as warmth.

Dark objects are better absorbers than light objects.

Good emitters of radiant energy are also good absorbers and the other way around. A dark car may remain hotter than their surroundings on a hot day, but at night it cools faster.

Different materials absorb energy in different ways. For example, for the same change in temperature water needs more heat than some other materials like iron or sand. This is because water has a so-called high specific heat capacity[1].

Learning objectives

- To understand that a black (dark) colour object warms faster then a white (light) colour object.
- To understand that sand warms faster than water.
- To measure the temperature in a model of a greenhouse.

Materials

- €Sense with connected external temperature sensor,
- A lamp – when using a strong lamp (for example 100 W) the change of temperature is faster and larger,
- Black and white piece of paper,
- A test tube filled with sand,
- A test tube filled with water,
- Beaker with black paper on the bottom,
- Plastic transparent foil.

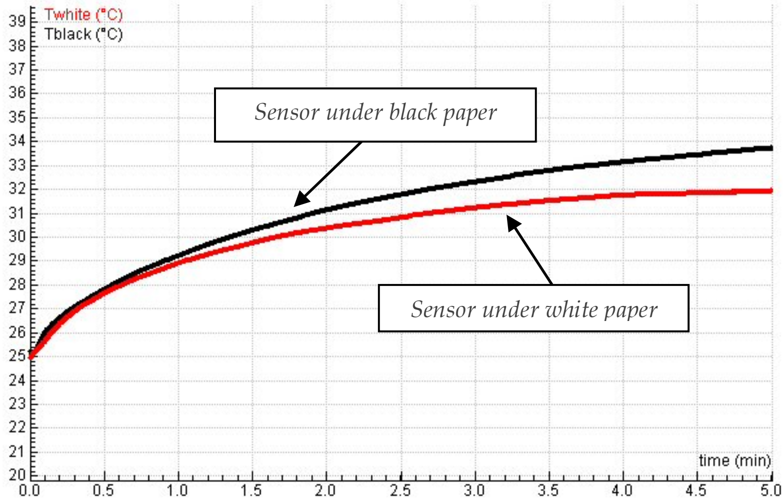
[1] The specific heat capacity of any substance is defined as the quantity of heat required to change the temperature of a unit mass of the substance by 1°C.

Description of activities

1. WHICH COLOUR GETS HOTTER?

Students explore under which fabric, white or black, their hand will get warmer in the sun.

Students investigate which colour, black or white, better absorbs heat and warms up faster.

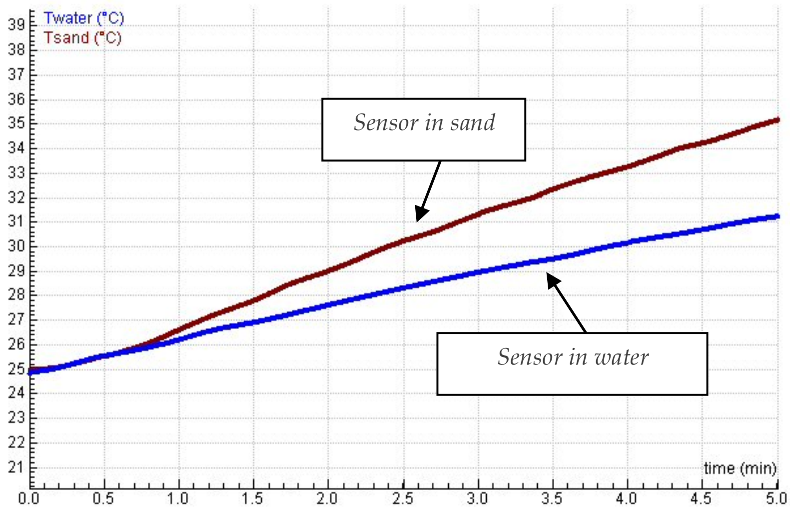


Example of data:
The sensor under the black paper warms up faster than the sensor under the white paper.

Colour	*Begin temperature (°C)*	*End temperature (°C)*	*Temperature difference in 5 minutes (°C)*
White	24.9	31.9	7
Black	25.2	33.7	8.5

2. WHAT DOES GET HOTTER, SAND OR WATER?

Students investigate which substance, sand or water, better absorbs heat and warms up faster. The test tubes with water and sand should be left for a while in a classroom to get the same initial temperature.



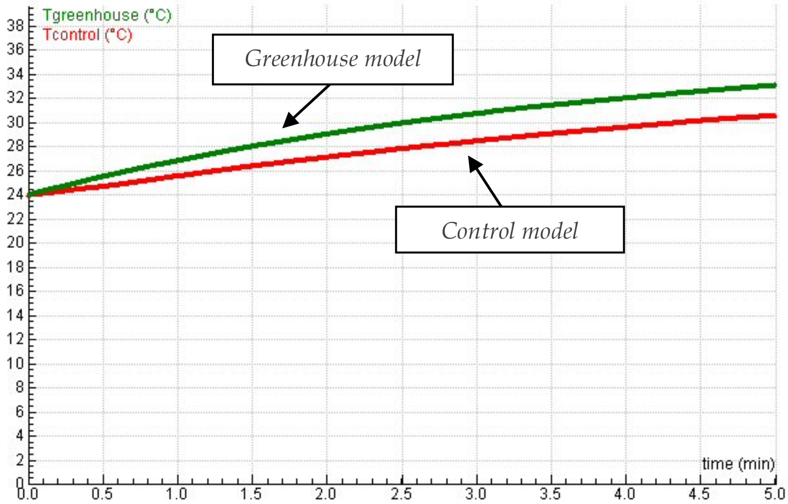
Example of data

Substance	*Begin temperature (°C)*	*End temperature (°C)*	*Temperature difference in 5 minutes (°C)*
Sand	24.8	35.1	10.3
Water	25.0	31.2	6.2

Water has a much higher capacity for storing heat than sand. The temperature of water increases less than the temperature of sand, when the same amount of radiation energy is transferred from the lamp.

3. Greenhouse effect

Students first measure the temperature in a beaker with 1 cm black soil or black paper placed on the bottom of the beaker. This is a control model used for comparison. To create the greenhouse effect the beaker is closed tightly with the plastic wrap.



Example of data

Model	*Begin temperature (°C)*	*End temperature (°C)*	*Temperature difference in 5 minutes (°C)*
Control model	24.0	30.6	6.6
Greenhouse model	24.0	33.1	9.1

The "greenhouse beaker" warms faster than the control beaker. The glass walls of the beaker allow visible light to enter and be absorbed by the soil (black paper). In turn the glass walls of both the model greenhouse and the control trapped the heat radiated from the soil inside. The roof of the model greenhouse keeps warm air inside from escaping.
This simple experiment can be a great introduction to the greenhouse effect.
A similar trapping of heat happens in the earth's atmosphere. Sunlight passes through the atmosphere and warms the earth. Greenhouse gases trap the heat radiating from the surface. This is called "greenhouse effect". If the greenhouse effect becomes stronger, it could make the Earth warmer than usual and cause all sorts of problems.

2.10. Unit IX. A chemical reaction

Students measure the temperature change during a chemical reaction of vinegar and baking soda.

Little bit of science

Heat can also be made by chemical reactions. During such processes chemical bonds are made and broken, and the heat is released (temperature increases) or heat is absorbed (temperature decreases).

During the chemical reaction between vinegar (acetic acid) and baking soda (sodium bicarbonate) a student can observe a temperature decrease. This reaction is described by the following chemical equation:

Vinegar + baking soda → carbon dioxide gas + sodium acetate + water

The actual reaction takes place in several steps. Evaporation and expanding of CO_2 gas need so much heat that the total solution is cooling down..

Learning objectives

- Produce a chemical reaction between vinegar and baking soda
- Measure the temperature change during this chemical reaction.

Materials

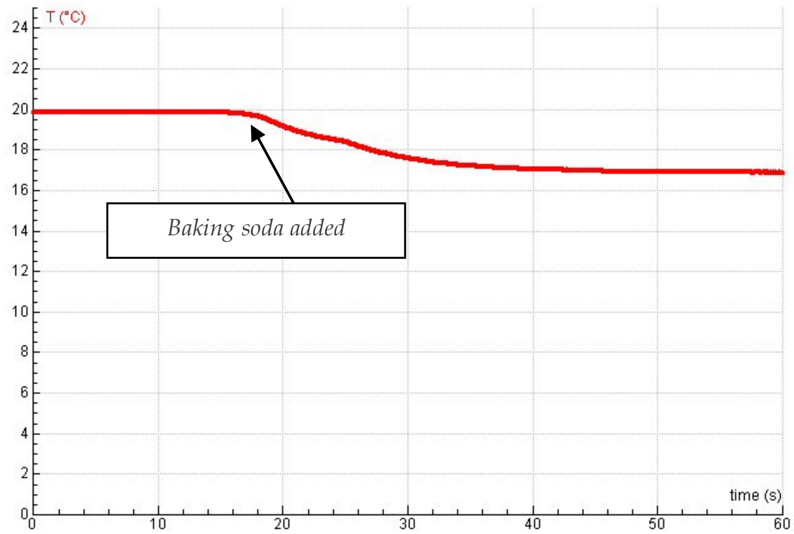
- €Sense with connected external temperature sensor,
- A plastic container (tray),
- Goggles,
- A beaker,
- A plastic spoon,
- Baking soda,
- Vinegar,
- Paper towels to clean up.

Description of activities

1. Chemical reaction between vinegar and baking soda

Students record the temperature during the chemical reaction between vinegar and baking soda. Such reaction produce white bubbles and the temperature of the mixture drops down. The volume of vinegar and the amount of baking soda can vary but such amounts should be chosen which would not cause flowing over the beaker. To protect a student desk and the computer students should place the beaker in a plastic container or on a plastic tray.

Example of data:
Temperature drops
as baking soda reacts with vinegar.



Begin temperature (°C) (vinegar only)	*End temperature (°C) (vinegar mixed with soda)*	*Difference in temperature (°C)*
19.9	16.9	3.0

By adding more baking soda further reaction can take place and the temperature of the mixture goes even down more, but at the moment when all vinegar is used up adding more baking soda will not make a difference.

3. Exploring Sound

2.1. Introduction

Sound is a very important part of our lives. In 'Exploring Sound' activities students are introduced to sound and its properties. Students use the €Sense sound sensor. They record sound waveforms produced by different sound sources and measure sound intensity of sounds.

UNITS:	MATERIALS
■ I. What is sound? ■ II. Making voice sounds ■ III. Making musical sounds ■ IV. How does sound travel and how do we hear it? ■ V. How loud ■ VI. Stop that noise	■ €Sense **INCLUDED IN PRIMARY SCIENCE KIT (009KIT)** ■ Tuning forks with different frequencies (S1)(S2) and rubber hammer (S3) ■ A drinking straw or a plastic tube for a model of vocal cords (S4) ■ Monochord (S5) ■ Materials for the eardrum model: Large plastic tube (S6), Balloon (S7), Rubber band (S8) and bag with rise (S9) ■ Sound-sources which make a constant sound like a buzzer (S10) ■ Test tubes (T6) and Test tube rack (T8) **NOT INCLUDED:** ■ Different sound makers and musical instruments, ■ Sound absorbing materials like cotton, wool, fabric, polystyrene chips, pebbles, and shredded paper.

3.2. Unit I. What is sound?

In this unit students explore how sound is produced, they use the sound sensor to record the sound of a tuning fork and to display its sound waveform.

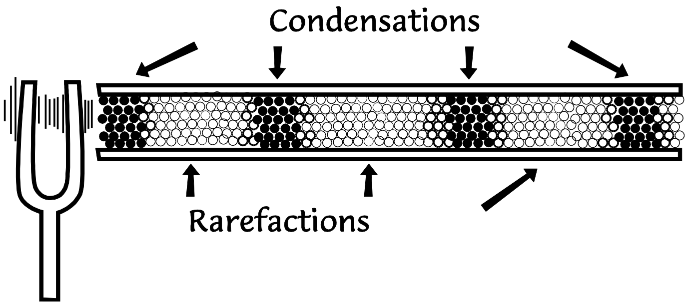
Little bit of science

Almost anything that vibrates can produce sound. When something vibrates in air it pushes the air particles around it, forth and back, and those particles in turn push the further air particles around them, carrying the pulse of the vibration in all directions from the vibration source. The vibrations cause the air pressure changes that are detected by a human ear or a sound sensor. The sound sensor coverts them into an electrical signal registered by the computer.

Sound waves are called ***longitudinal*** waves because particles of the medium (e.g. air) through which the sound is transported vibrate parallel to the direction that the sound wave moves.

The way we experience sound depends on three: loudness, pitch, and timbre.

The ***loudness*** of a sound results from the difference in pressure between the higher-pressure areas (high density of particles - condensations) and the lower-pressure areas (low density of particles - rarefactions).
A greater difference in pressure results in louder sound.



The ***Pitch*** results from the frequency of the vibrations. Frequency, by definition, is the number of vibrations per time unit. A higher frequency gives a higher tone. The frequency of vibrations is not the same as the speed of sound. Different frequencies all travel at the same speed in the same medium.

The ***timbre*** is what makes a sound distinct and recognizable as a particular instrument, voice, vowel sound, or just noise.

Learning objectives

- To investigate how objects produce sound.
- To learn that sounds are made by vibrations.
- To record a tuning fork's sound waveform.
- To understand that the term "loudness" describes how loud sound is and is connected to the amplitude of sound vibrations.

- To understand that the term "pitch" describes how high or low sound is and is connected to the frequency of vibrations.

Student's beliefs

- Sounds can be produced without using any material objects.
- Hitting an object harder changes the pitch of the sound produced.
- Loudness and pitch of sounds are the same things.

Materials

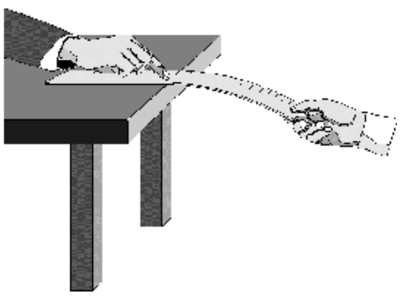
- €Sense,
- Two (or more) tuning forks with different frequency.

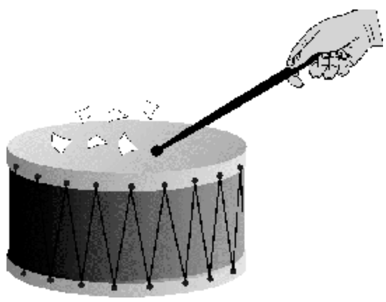
Description of student activities

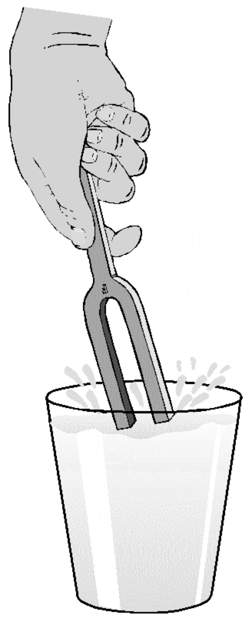
1. How are sounds made?

Students investigate how sounds are produced by different objects. The following objects are used: an elastic ruler, a tuning fork, a drum, a rubber band stretched around a box, a bottle with water.

Let students make their own investigations and allow each group to describe one of the sound makers to the rest of the class.





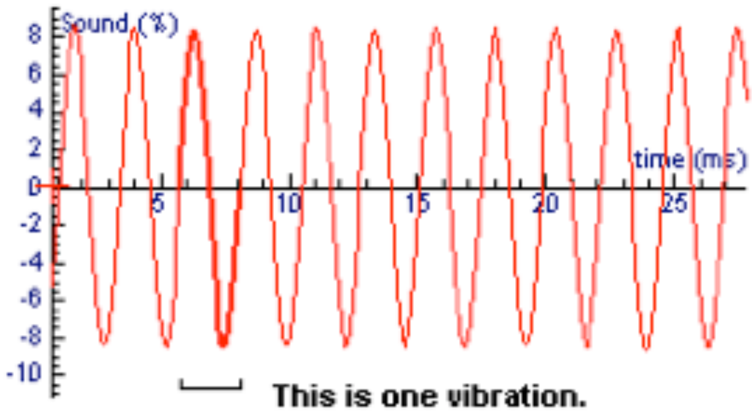


The conclusion of the student investigations should be that sound is produced by vibrations of objects. If sound is heard, something is vibrating.

2. Make sound visible

Students use the sound sensor and record a sound pattern (waveform) produced by a tuning fork. The tuning fork gives a pure tone of one frequency e.g. 440 Hz[2].

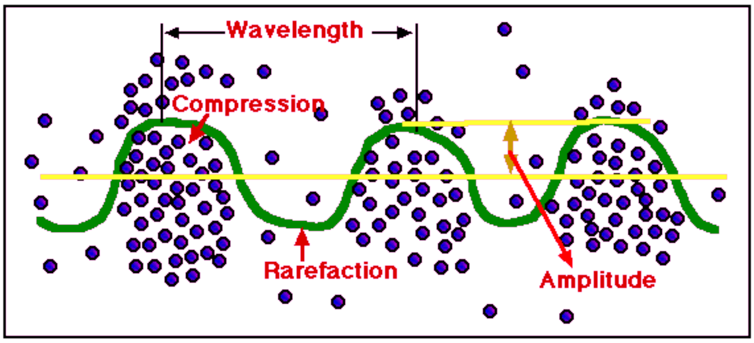
[2] Hz (Hertz) is a unit of frequency and means one vibrations per second. 440 Hz mean 440 vibrations per second.



Example of data: The recorded sound of a tuning fork.
The picture shows the periodical changing sound pattern called also sound waveform.
In this sound waveform it is possible to determine a sound pattern of one vibration.

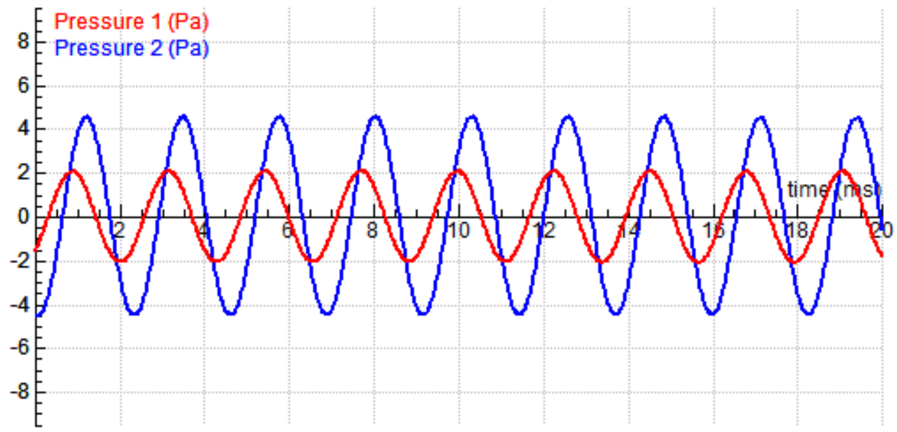
At the end of this activity the student should read the Explanation about the way sound is produced and travels.

After the explanation what the sound vibrations are students try to draw a sound waveform on the given picture, in the way shown below. This picture also indicates the wavelength and amplitude of the sound wave. Wavelength is the distance between two consecutive wave compressions (or wave rarefactions). Amplitude is related to the loudness of sound.



3. Changing sound – hard and soft

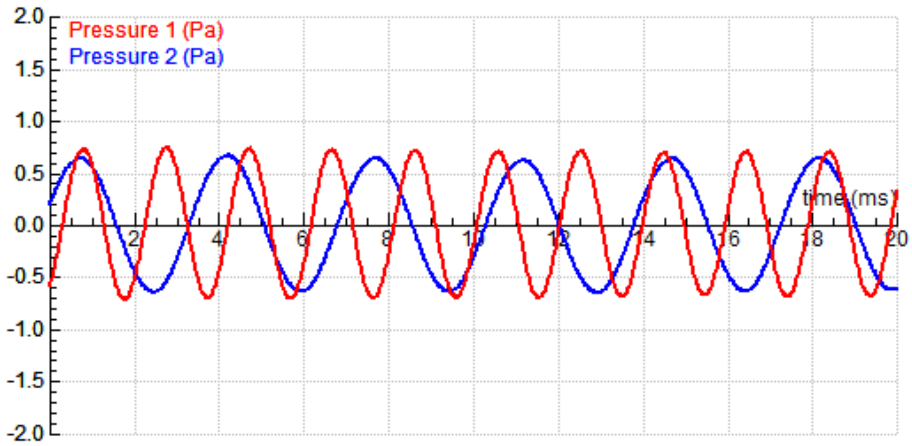
Students investigate the loudness of sound. They discover that the sound loudness is related to the height of the sound vibrations or in other words to the amplitude of sound vibrations.



Example of data: *Vibrations of a hard struck tuning fork (blue waveform) have higher vibrations (higher amplitude) than vibrations of a soft struck tuning fork (red waveform). The number of vibrations in 20 ms [3] time remain the same.*

4. CHANGING SOUND – HIGH AND LOW

Students investigate the pitch (how high or low the sound is). They discover that the pitch is determined by the number of vibrations in a time period (sound frequency). Discuss this with students and conclude that sound with a high frequency (many vibrations per second) will make a high-pitched sound, and one with a low frequency (less vibrations per second) will make a low-pitched sound.



Example of data: *The tuning fork of a high frequency (high-pitched sound) has more vibrations in the recorded time period (10 vibrations in 20 ms) than the tuning fork of a low frequency (6 vibrations in 20 ms). When the tuning forks are struck with the same force (loudness) the amplitude of the waveforms remain near the same.*

[3] 1 ms = 0.001 second

3.3. Unit II. Making voice sounds

In this unit students explore how sound is made by human voices. Students use the sound sensor to record waveforms of voice sounds. Finally they create a model of vocal cords.

Little bit of science

The source of sound in human speaking and singing are the vibrations of the vocal cords, which are located inside the larynx. The vocal cords are set into vibrations by air from the lungs that moves through the windpipe passing over them. You can feel vocal cords vibrations when you place your fingers on your neck near your larynx and then sing or speak loudly.

Adult men and women have different sizes of vocal cords, this causes different voice sounds. Adult male voices are usually lower-pitched and have larger cords than adult women voices.

The sound waveforms of vowels are more complicated than sound waveforms of tuning forks or humming. The sound of a vowel consists of several vibrations of various frequencies and intensities in addition to the main or "fundamental" frequency. This results in a more complicated but still as periodical sound pattern.

Learning objectives

- To learn how human voice sounds are produced.
- To record sound waveforms of humming.
- To investigate waveforms of vowels.
- To make a model of vocal cords.

Student's beliefs

- Human voice sounds are produced by a large number of vocal cords that all produce different sounds.
- Loudness and pitch of sounds are the same things.

Materials

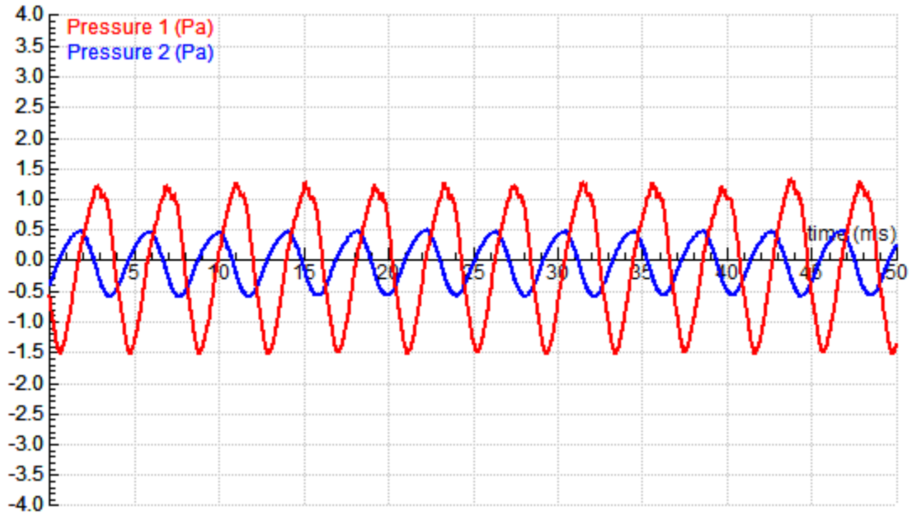
- €Sense,
- A drinking straw or a plastic tube to make a model of vocal cords.

Description of student activities

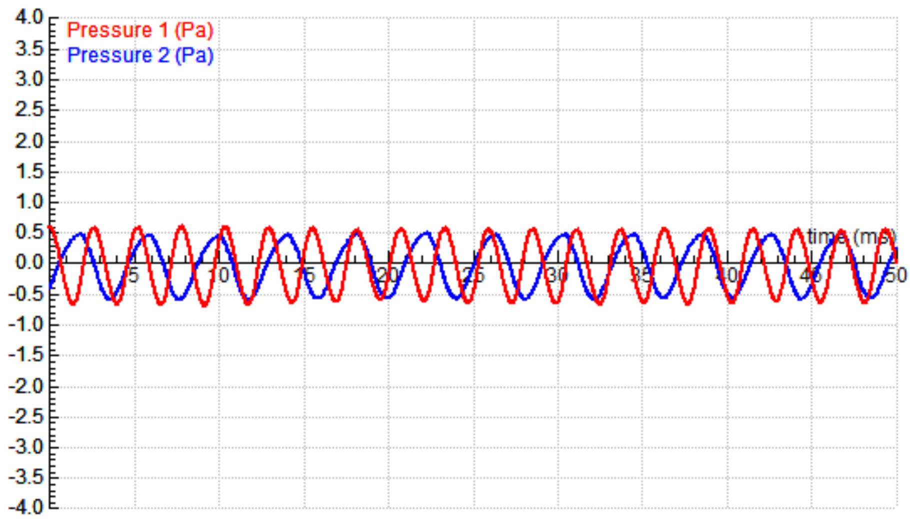
1. FEELING SOUND
Students "feel" throat vibrations when they speak, hum or sing.

2. RECORD YOUR OWN VOICE
Students record sound produced by their own voice. They hum into a sound sensor

and discover that the sound waveform of humming is similar to the sound waveform of a tuning fork; in both cases periodical repeated vibrations are recorded. The amplitude of sound vibrations indicates the loudness of humming. The frequency of sound vibrations indicates the pitch of humming.



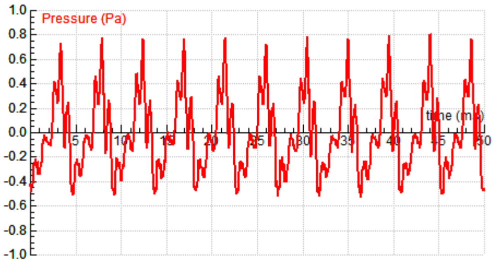
Example of data: *The sound waveform of humming. The blue graph shows vibrations of soft humming; the red graph shows vibrations of loud humming. The difference between the graphs is the loudness thus the amplitude of vibrations. The number of vibrations in the given measurement time remains the same for both sounds (12 vibrations in 50 ms).*

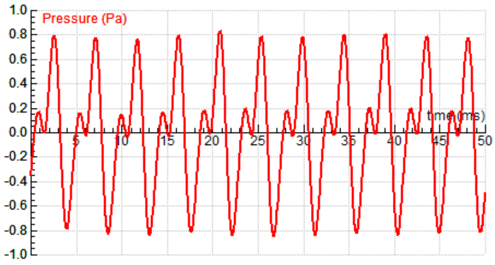


Example of data: *The sound waveform of humming. The blue graph shows vibrations of low-pitched humming; the red graph shows vibrations of high-pitched humming. The difference between the graphs is the sound pitch thus the frequency of the vibrations. The number of vibrations in 50 ms for low humming is 12 and for high humming is 20. The humming loudness (the sound amplitude) remains the same.*

3. Investigate vowels

Students investigate sound waveforms of different vowels. They discover that the vowels have different patterns, which periodically repeat.





Example of data: *The sound waveforms of vowels, left 'aaaa' and right 'oooo'.*

4. How sounds are made in your throat

Students read the explanation 'How sounds are made in your throat' and by blowing through a drinking straw or a plastic tube against the space between two fingers of their hands they mimic the vocal cords.

3.4. Unit III. Making musical sounds

In this unit students use the sound sensor to record sound waveforms of the sounds created by strings and air columns.

Little bit of science

To make musical sounds regular changes in the pressure of air should be produced. A common way of producing a musical sound is to use something that vibrates regularly. Twanging a ruler on the edge of a table, twanging a stretched rubber band or string, blowing across the neck of a bottle, hitting a bell – all of these objects produce vibrations which cause regular changes of pressure in the air.

To make different notes, the frequency of vibration must be changed. For example by stretching more a rubber band or a string or shortening the vibrating air column of a bottle filled with water. The higher the frequency of the vibrations the higher the musical pitch of the note.

The timbre is what makes a sound distinct and recognizable as a particular instrument.

Similar to human voices almost all instruments create several vibrations of various frequency and intensities in addition to the main or "fundamental" frequency. This results in more complicated but also periodical sound pattern.

Interesting addition to this activity can be online activity: http://www.bbc.co.uk/schools/scienceclips/ages/9_10/changing_sounds.shtml

Learning objectives

- To investigate how sounds are made by musical instruments.

- To record sound waveforms of a string and an air column vibrations.
- To understand that tightening or shortening a string changes the frequency of its vibration.
- To understand that shorter air columns produces vibrations with higher frequency.

Student's beliefs

- Human voice sounds are produced by a large number of vocal cords that all produce different sounds.
- Loudness and pitch of sounds are the same things.
- Music is strictly an art form; it has nothing to do with science.

Materials

- €Sense,
- A guitar or a monochord,
- Test tubes,
- Water.

Description of student activities

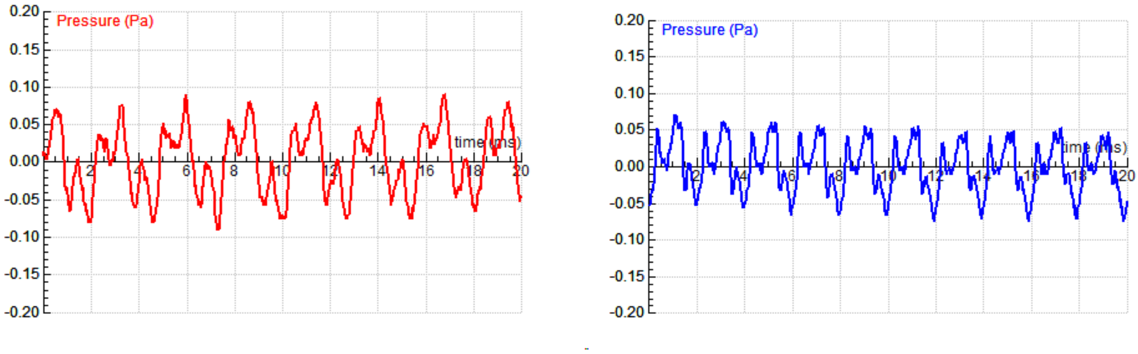
1. Sounds of musical instruments

Students identify the sources of sound vibrations of different instruments. For a guitar, violin and piano these are vibrating strings, for a flute – a vibrating air column, for a cymbal and a drum – vibrating surfaces.
Encourage students to bring their own musical instruments and discuss how these instruments produce sound.

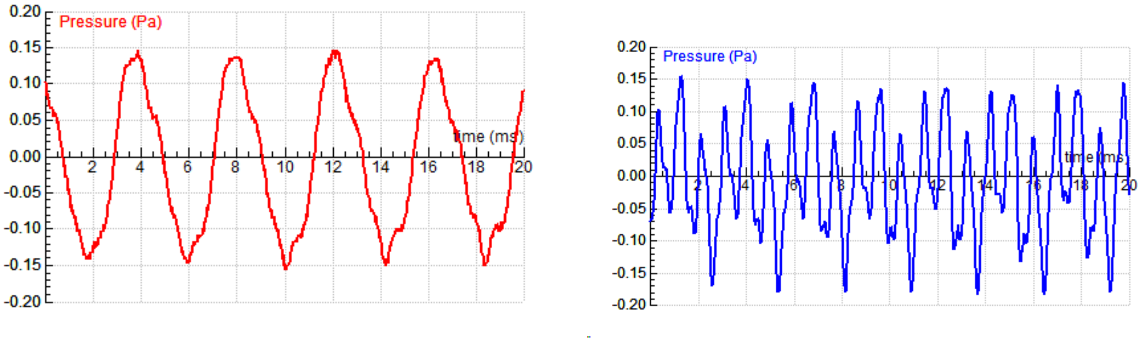
2. Sounds of a string

Students record sound produced by a string. They investigate how tightening and shortening the string influence the frequency of string vibrations.

The string sounds are rather soft sounds; the amplitude of string vibrations is low. This is because a string is very thin and it cannot make very large pressure changes in the air. This is the reason that a monochord and string instruments have extra wooden bodies, sounding boards, to make their sounds louder.



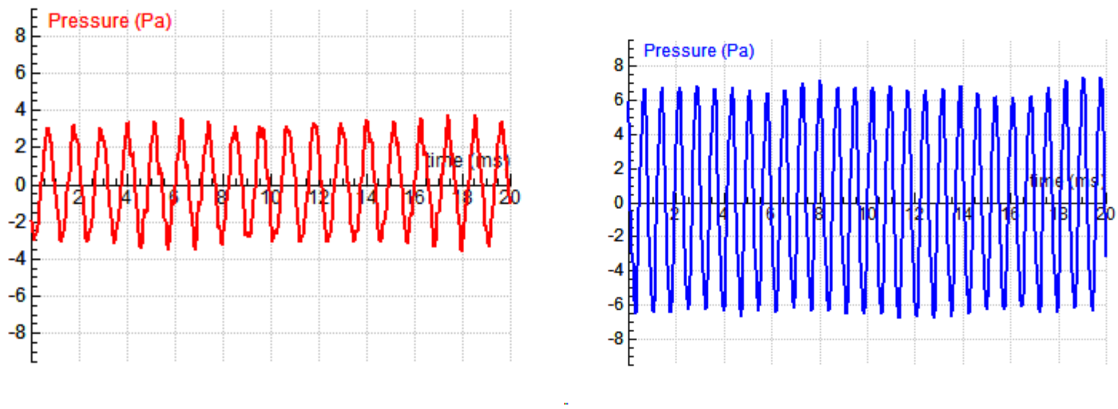
__Example of data:__ Left: vibrations of a long string. Right: vibrations of a short string.
The shorter the string, the higher the frequency of vibrations
(the higher the number of vibration patterns recorded in the given measurement time).



__Example of data:__ Left: vibrations of a string. Right: vibrations of the same but more stretched string.
The higher the string tension, the higher the frequency of vibrations
(the higher the number of vibration patterns recorded in a given measurement time).

3. Sounds of air

Blowing across a bottle causes air to vibrate and produces sound. Students record the waveforms of sound produced by air columns in an empty and a half filled with water test tube. They compare the frequency of vibrations.



__Example of data:__ Left: vibrations of an air column in an empty test tube.
Right: vibrations of an air column in a half-filled with water test tube.
The shorter the air column, the higher the frequency of vibrations
(the higher the number of vibrations recorded in a given measurement time).

4. BUILD A MUSICAL INSTRUMENT

Students have to design and build their own musical instruments and test them with a sound sensor. Check students' designs before they start to build their instruments. Ask how the instruments can play soft and loud sounds and how the musical pitch can be changed. At the end of the lesson let the students make a performance with their instruments.

3.5. Unit IV. How does sound travel and how do we hear it?

In this unit students learn that sound needs a medium to travel and can travel not only via air but also via other materials. They also learn how we can hear sound.

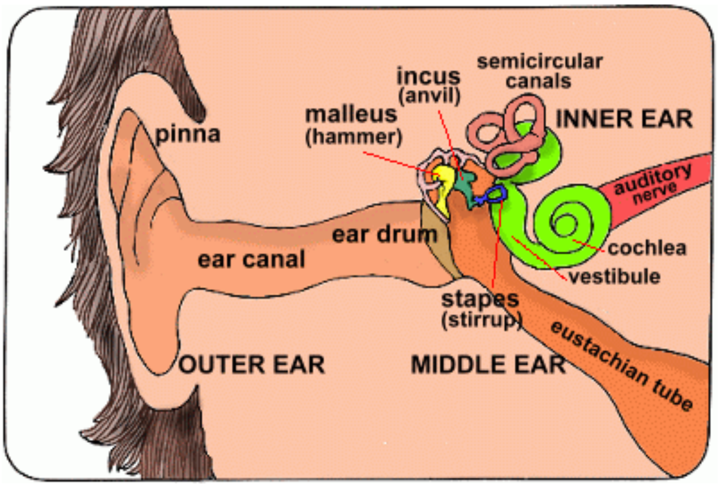
Little bit of science

Sound is produced by vibrations but sound can also cause things to vibrate. When sound travels through the air, the vibrations of the air molecules cause other things to vibrate (e.g. a surface of a drum in activity 1). We can say that sound carries energy called also sound energy. Such energy can be transferred to other objects; it can make things move (like rice grains moving on a drum in activity 1). The sound energy is quite low (rice grains are tiny and light), that is because producing of sound requires only a small amount of energy.

Most sounds that we hear are transmitted through the air. Without air or another medium the vibrations will not be able to travel. Then there would be nothing to carry the sound to our ears. This is the case, when a sound source is placed in a container without air (vacuum); we cannot hear the produced variations.

Sound needs a medium to travel. It travels through gases, liquids and solids. It travels better through liquids then through gases, and even better through solids (wood, stone, metal) than through liquids. Sound travels about 5 times faster in water and about 14 times faster in steel than in air. Sound travels better through solid because the molecules are closer together and the motion can be transferred more rapidly and effectively.

How do we hear?



Hearing is possible because of our remarkable sensitive ears. Sound waves usually move in all direction. The outer ear, the part of the ear that can be seen, catches sound waves and directs them into the ear canal. Some animals have larger ears that function like ear funnels. Some animals can also turn their ears, to listen more effectively to

sounds from particular directions.
The outer ear directs the sound via the ear canal to the eardrum (*tympanic membrane*) of the *middle ear***.** The middle ear consists of the eardrum and the three middle ear bones, the *ossicles*, consisting of the *malleus*, *incus*, and the *stapes*. These are the smallest bones in our whole body.
The middle ear transforms sound waves into movements of the middle ear bones, conducting sound to the inner ear.
The inner ear (*cochlea*) contains microscopic cells (*hair cells*) that are specialized to convert the movement into neural signals. These hair cells are very tiny and possess tiny finger-like projections, called *stereocillia*, on their tops. The stereocilia are bundled together as *hair bundles*. The hair bundles move back and forth when sound waves reach the inner ear. The hair cells activate nerves in the inner ear, which transmit the sound-induced signals to the brain. The brain interprets it as sound.

Learning objectives

- To understand that sound carries energy.
- To understand that sound needs a medium to travel, it does not travel through a vacuum.
- To know that sound can travel not only through air but also through liquids and solids.
- To learn how do we hear sound.
- To understand the role of ear trumpets.

Student's beliefs

- Sound can travel through empty space (a vacuum).
- Sound cannot travel through liquids and solids.
- We can hear because we concentrate on the source of the sound.

Materials

- €Sense,
- A constant sound source e.g. a whistle or a buzzer
- Materials for a drum model: a balloon, a cardboard tube or a can with both ends open, a rubber band, rice grains,
- Materials for an ear trumpet: sheet of paper, sticky tape.

Description of student activities

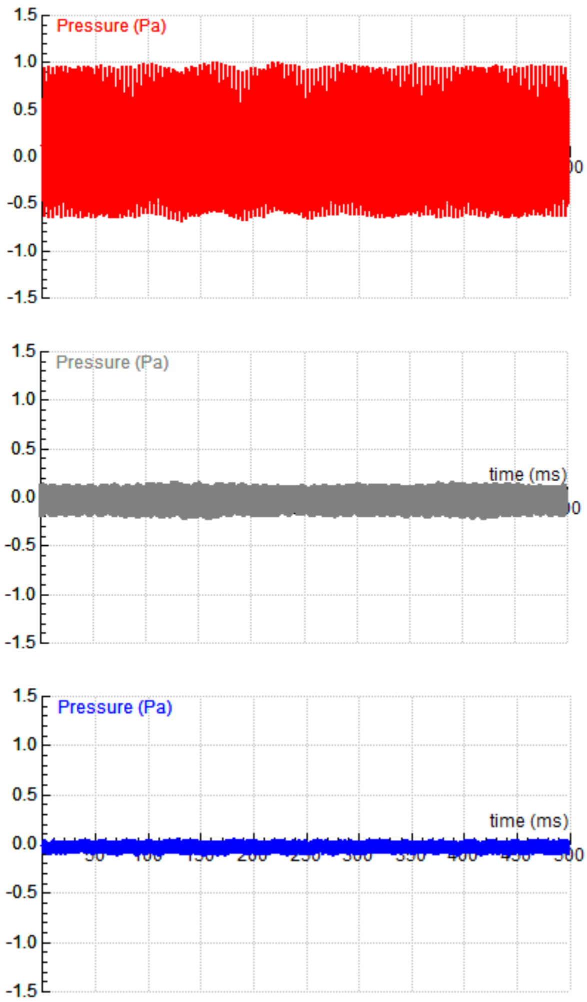
1. CAN SOUND MOVE THINGS?

Students make a drum and observe what happens to rice grains placed on the drum when they talk and sing into the open bottom of the tube.

When a sound is made on one end of the tube, the sound waves hit the rubber balloon and make it vibrate. The vibrations of the balloon surface cause the rice grains to move. The sound energy is transformed into rice grains and makes them move (sound energy transforms into kinetic energy of rice grains). Demonstration with dominoes can help students to imagine how energy is transferred from one object to another. Students also realize that air is needed for sound to travel. They watch a video in which air is pumped out of a container in which a ringing alarm is placed. When more air pumped out of the container less sound can be heard. The conclusion is that sound needs air (medium) to travel.

2. Does sound travel through things?

Students can test different materials to see if sound can travel through them. They can press a sound sensor into an object and make a sound at the other end of it. They might test a metal pipe or table leg, a wooden door, a fish tank, a balloon filled with water (this can be little bit dangerous if the balloon is filled with too much water), or a balloon full of air. They will need a sound source that makes a constant sound. Students should realize that sound travels through all kinds of materials and conclude that sound travels in gases, liquids and solids.



Example of data:
Red graph: sound vibrations of a buzzer in air.
Grey graph: sound vibrations recorded at other side of a metal pipe.
Blue graph: sound vibrations recorded at the other site of a balloon filled with water.

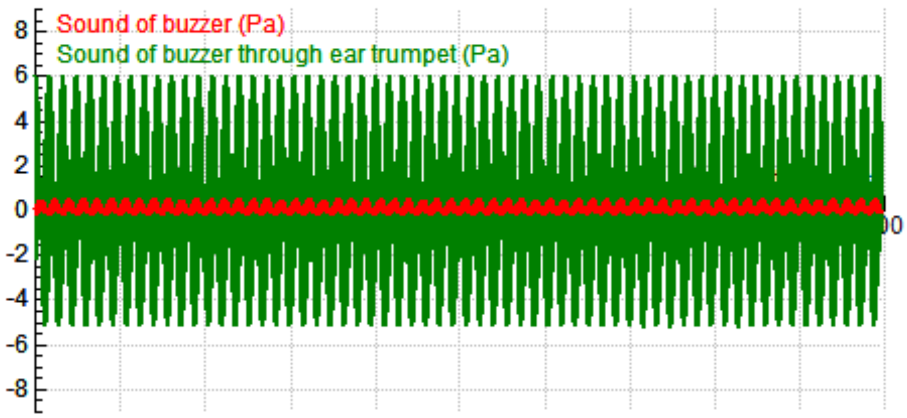
3. How do you hear sound?

Students read the explanation 'How does your ear work?' and discuss about the necessity and ways of taking care of their own ears.

4. How can you hear better?

Ear trumpets help people to hear better. These are tubular or funnel-shaped devices, which collect sound waves and lead them into the ear. The ear trumpet gathers and focuses the sound waves from the air into the ear. The bigger the guide-end the more sound energy it gathers, the smaller the ear-end the more the sound waves are focused. This results in a strengthening of the sound energy impact to the eardrum and thus a better hearing for reduced or decreased hearing individuals.

In this activity students make an ear trumpet and investigate the sound level with and without using their ear trumpet.



Example of data: Vibrations of a buzzer recorded without (red) and with (green) an ear trumpet. The distance between the buzzer and the sound sensor should remain the same for both measurements.

3.6. Unit V. How loud?

In this unit students use the sound sensor and measure sound intensity (sound level) of different sounds. The sound sensor is calibrated as a sound level meter and measure loudness in decibels (dB).

Little bit of science

The intensity of sound depends on the amplitude of pressure changes within the sound wave. Sound intensity is measured in decibels (dB), which is a logarithmic measure of the loudness of a sound. The quietest sound that we can actually hear is about 0 decibels. An increase of 10 dB multiplies the intensity of sound by 10 times, a sound of 10 decibels is 10 times as intense as 0 decibels, an increase of 20 decibels is 100 times more, and an increase of 30 decibels is 1000 times more, etc. The loudest sounds we hear without causing us pain are about 120 dB. Such sounds have about ***one million times more energy*** than the quietest sounds we can hear.

Most sounds we hear are in the range of 30 to 100 dB. Here are a few examples:

Sound	*Sound level (dB)*
Human whisper (at 1 m)	20 dB
Human conversation (at 1 m)	60-70 dB
Power saw (at 1 m)	110 dB
Yelling in someone's ear	114 dB
Threshold of pain to the human ear	120-130 dB
Sirens (at 1 m)	134 dB
Jet engine (at 20 m)	140 dB
Peak of rock music (at 5 m)	150 dB
Blue whale	188 dB

Thunder is one of nature's loudest sounds. A nearby thunderclap may reach 120 decibels, equivalent to being within 60 meters of a jet aircraft during take off. Volcano eruptions may be the loudest commonly occurring sounds on Earth, at over 272 dB.

Learning objectives

- To understand that sound intensity is measured in dB.
- To understand that a small increase in dB value (e.g. increase of 3 dB) means a large increase in the sound intensity (increase of 3 dB means twice as loud).

Materials

- €Sense,
- Two buzzers.

Description of student activities

1. Loudness of sound

Students describe sounds and estimate how loud these sounds are. Divide the students into groups and let them discuss how objective their estimations are.

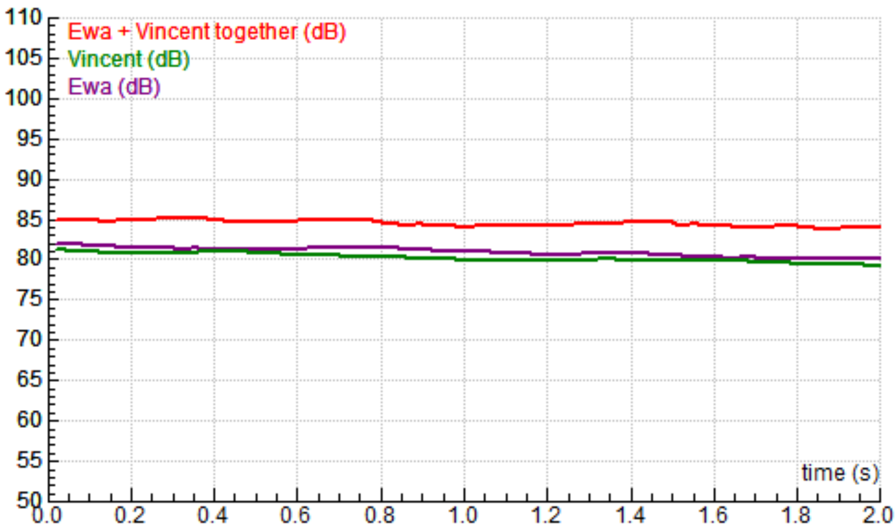
2. How loud?

Students measure the sound intensities of different sound makers. The sound sensor works here as a sound level meter and measures the sound intensity in dB.

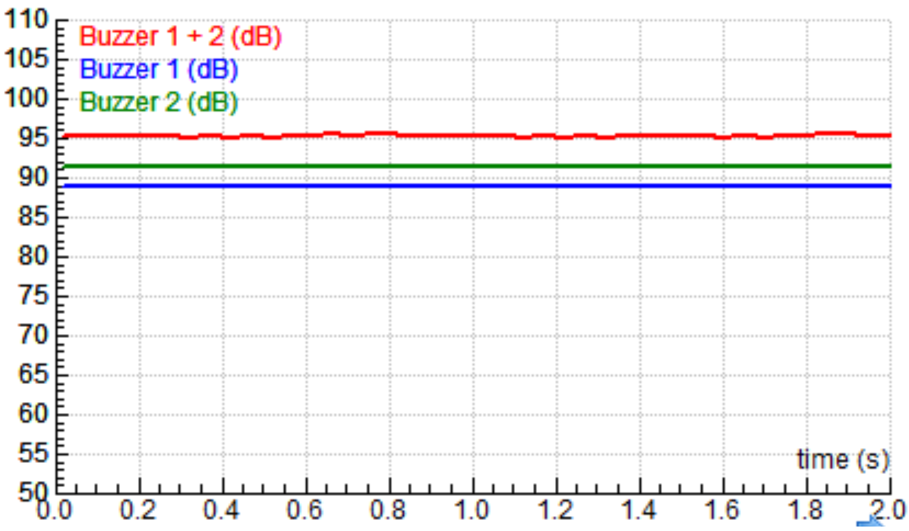
The sensor data are displayed on a digital value, a meter, and a graph (measurement time interval is 2 s). Notice that for some sound sources the readings of the sound sensor can change rapidly. The average values should be taken.

3. WHO WHISTLES THE LOUDEST?

Students play a game and measure who of two students can whistle or hum the loudest. Then they record the sound intensity when they whistle together at the same time.



Example of data*: Measured sound intensities in dB.*
The graph above - two students whistling separate and together. The graph below - two buzzers, separate and together.



The sound intensity measured for two students or two buzzers is not the sum of the sound intensities measured for each student or buzzer.
When the sound intensity increases with 3 dB then the sound is twice as loud. The sound intensity of 63 dB is 3 dB more than the sound intensity of a sound of 60 dB. This means that a sound of 63 dB is twice as loud as a sound of 60 dB. And 66 dB is again twice as loud, so 4 times louder than a sound of 60 dB.
A sound of 80 dB is not twice as loud as a sound of 40 dB, it is 10 000 times louder.

Notice that the sound sensor does not differentiate between the classroom noise and the whistling of children. Take care that there is not too much background noise.

4. Noise in the classroom

Students record the sound intensity during a lesson. Then they analyse the resulting graph.

3.7. Unit VI. Stop that noise

In this unit students realize that loud sounds can cause hearing damage and investigate ways of decreasing sound intensity.

Little bit of science

The amount of time you listen to sound affects how much damage it will cause. The quieter the sound, the longer we can listen to it safely. Sounds that are less than 80 dB are unlikely to cause hearing loss. Noise levels greater than 80 dB can be hazardous and can cause hearing damage. Many experts agree that 8 hours of continual exposure to more than 85 dB is dangerous to your hearing.

Many common sounds may be louder than we think.
A typical conversation occurs at about 65 dB, not loud enough to cause damage. When listening to music on earphones at maximum volume level, the sound reaches a level of over 100 dB, loud enough to begin permanent damage after just 15 minutes per day!

Continuous dB	*Permissible Exposure Time*
85 dB	8 hours
88 dB	4 hours
91 dB	2 hours
97 dB	30 minutes
100 dB	15 minutes
103 dB	7.5 minutes
106 dB	Less than 4 minutes
109 dB	Less than 2 minutes
112 dB	Less than 1 minutes
115 dB	Less than 30 seconds

Noise induced hearing loss can be caused by a one-time exposure to loud sound as well as by repeated exposure to sounds at various loudness levels over an extended period of time. Damage happens to the microscopic hair cells found inside the inner ear, in the cochlea. Different groups of hair cells are responsible for different sound frequencies. The healthy human ear can hear frequencies ranging from 20 to 20, 000 Hz. With loud sound exposure over time, the hair cells may get damaged or broken. If enough of them are damaged, hearing loss results. Sound is one of the most common occupational hazards facing people today. Even outside of work, many people participate in recreational activities that can produce harmful sound levels (musical concerts, use of power tools, etc.). Also children often listen to music on earphones at maximum volume level.

Interesting, additional materials and activities, are available via 'Dangerous decibels' website at http://www.dangerousdecibels.org/virtualexhibit/index.html.

Learning objectives

- To understand that loud sounds can damage your hearing.
- To be aware that some materials better absorb sound than others.
- To design and perform a fair test to decide which material absorbs sound the best.

Student's beliefs

- Noise pollution is annoying, but it is essentially harmless.

Materials

- €Sense,
- Sound absorbing materials like: cotton, wool, fabric, polystyrene chips, pebbles, shredded paper.

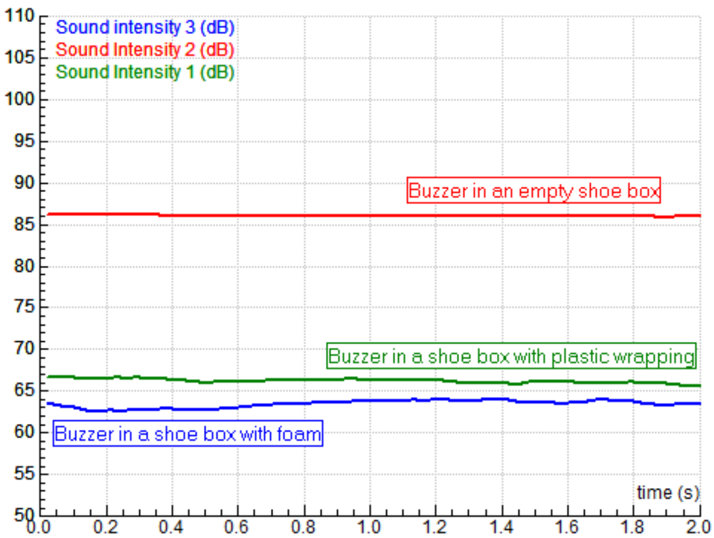
Description of activities

1. Dangerous decibels

Discuss with children how dangerous sound can be. Students should understand reasons for attempts to control the noise level.

2. How to muff sound

In this activity students investigate how different materials absorb (isolate) sound. They design their experiment and collect sound absorbing materials. Students should be able to predict and deduce from their results that soft, bumpy materials absorb sound better than hard, flat materials.

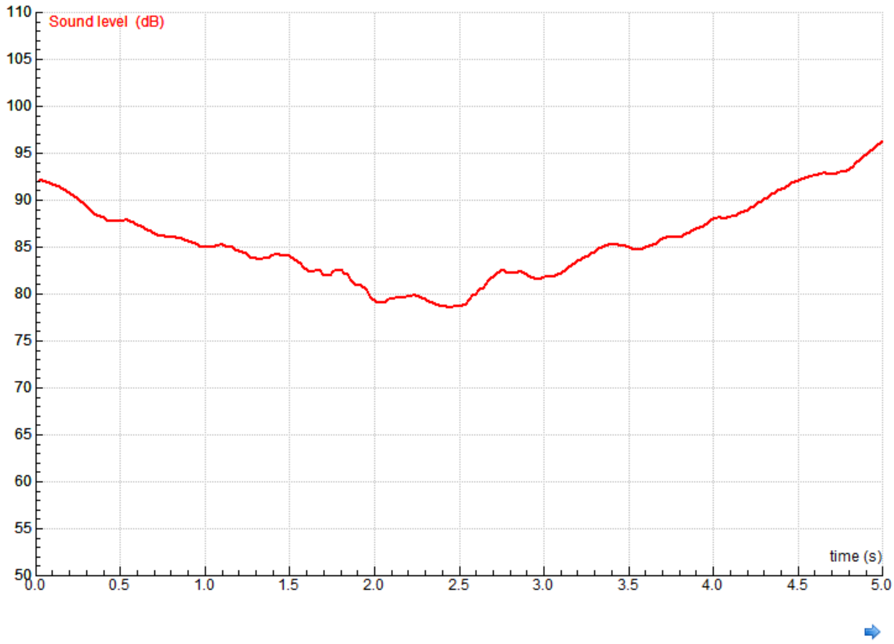


***Example of data**: A buzzer placed in a shoebox and wrapped with different materials.*

Background noise in the class might affect the results of the measurement. A quiet testing area is needed.

3. Does sound get more quiet further away?

In this activity students use the sound sensor and measure to see how sound intensity changes with distance.



***Example of data**: €Sense is moved away and towards the sound source. The sound intensity first decreases and then increases.*