Continuous Professional Development Certificate in Educational Mentoring and Coaching for STEM Teachers (CPD-CEMCMT)

APPENDIX

Module 2

5th Edition

TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE AND GENDER IN STEM EDUCATION

March 2022

Module code: PDM1142

UNIVERSITY of RWANDA

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REB RWANDA BASIC EDUCATION BOARD

Continuous Professional Development Certificate in Educational Mentoring and Coaching for STEM Teachers (CPD-CEMCMT)

APPENDIX

MODULE 2

TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE AND GENDER IN STEM EDUCATION (PDM1142)

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Appendix G: General Materials

G.1 Guiding questions for discussions about 5E lessons

1. **Are the 5 E's used correctly?**

- What was done during the **excite/ engage stage**?
    - Was it exciting? Did he/ she capture the attention of the students?
    - Should you use a video when you can do a demonstration?
    - Did the teacher ask the learners to predict the outcome of the demonstration? Did he/she ask why they predicted that outcome?
    - Did the teacher/learners formulate a good key question for the lesson?
- What was done during the **explore stage**?
    - If extra demonstrations are used:
        - Did the teacher ask the learners to predict the outcome of the demonstration?
        - Did he/she ask why they predicted that outcome?
    - Did the teacher give the learners enough time to formulate their ideas?
    - What did the teacher do with wrong answers from learners?
        - Did he/she ignore them or did he/she show interest and ask more explanation?
        - Did he/she use probing questions to explore learners' answers and ideas?
        - Did he/she use questions to challenge learners' answers and ideas?
        - Did he/she encourage interactions among learners asking and answering to each other?
        - Did he/she use the answers in the further reasoning?
- What was done during the **explain stage**?
    - Did the teacher use questioning to help learners to explain themselves?
    - Was the explanation correct? Why (not)?
- What was done during the **elaborate stage**?
    - Was there a new challenge? Did the learners learn something new?
    - Did the teacher apply the lesson concepts to daily life situations?
- What was done during the **evaluate stage**?
    - Was the evaluation related to the goals of the lesson?
    - Will the learners/teacher learn something from it?

2. **Was a demonstration or practical work used?**

- Did it contribute to learning?
- Was the choice to organise the experiment as a demonstration or practical work the right one?
- Are there better alternatives?
- Was the demonstration or practical work didactically well performed?

3. **How was questioning used?**

- How was the quality of the observation and thinking questions?

- How did the teacher help learners when no learner could answer the question?
- Did the teacher use wrong answers to stimulate discussion and learning?
- Were all learners (boys and girls) involved?

4. Self-assessment

- What can you conclude about your lesson (strengths and areas of improvement)

G.2 Voting cards

A	C
B	D

E	F
G	H

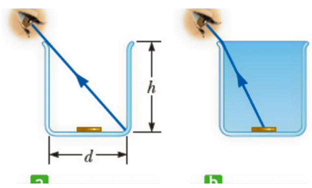
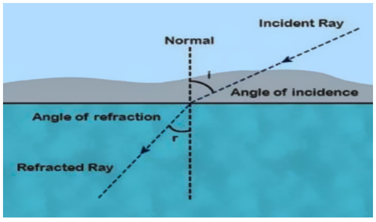
Appendix P: Materials for Physics

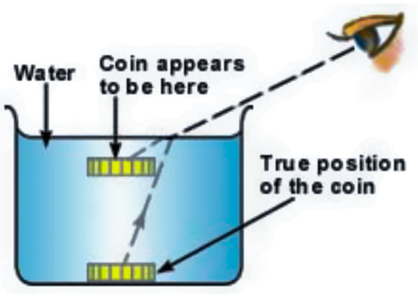
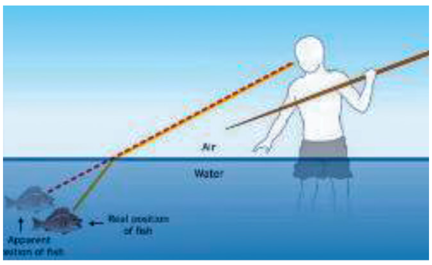
P.1 Example lessons plans with the 5E format

Lesson 1: Propagation of Light

<table>
<tr><td colspan="4">School Name:</td><td colspan="4">Teacher's name:</td></tr>
<tr><th>Term</th><th>Date</th><th>Subject</th><th>Class</th><th>Unit No</th><th>Lesson No</th><th>Duration</th><th>Class size</th></tr>
<tr><td>3</td><td>18/09/2019</td><td>Physics</td><td>S3</td><td>12</td><td>1</td><td>40 minutes</td><td>40</td></tr>
<tr><td colspan="4">Type of Special Educational Needs:</td><td colspan="4">Special attention for slow and fast leaners and leaners with low language skills</td></tr>
<tr><td colspan="2">Topic area:</td><td colspan="6">Light</td></tr>
<tr><td colspan="2">Sub-topic area:</td><td colspan="6">Propagation of light</td></tr>
<tr><td colspan="2">Unit title</td><td colspan="6">Refraction of light</td></tr>
<tr><td colspan="2">Key Unit Competence:</td><td colspan="6">Explain refraction of light phenomena</td></tr>
<tr><td colspan="2">Title of the lesson</td><td colspan="6">Refraction of light through layers of parallel media</td></tr>
<tr><td colspan="2">Learning Objectives</td><td colspan="6"></td></tr>
<tr><td colspan="2">Knowledge &understanding</td><td colspan="6">Explain phenomena of refraction of light</td></tr>
<tr><td colspan="2">Skills</td><td colspan="6">Explain the types of light refraction</td></tr>
<tr><td colspan="2">Attitudes & Values</td><td colspan="6">Listen to each other explanations critically Appreciate the bending of light when it moves from one medium to another</td></tr>
<tr><td colspan="2">Plan for this Class (location: in/ outside)</td><td colspan="6">Inside</td></tr>
<tr><td colspan="2">Learning Materials (for all learners)</td><td colspan="6">Pictures of refraction phenomena. 20 Mini white boards. 11 beakers, some bottles of tap water, laser beam, coin</td></tr>
<tr><td colspan="2">References</td><td colspan="6">Physics for Rwandan schools 3
http://www.walter-fendt.de/html5/phen/refraction_en.htm
https://www.youtube.com/watch?v=uAI6hEVl72o
https://phet.colorado.edu/sims/html/bending-light/latest/bending-light_en.html</td></tr>
</table>

Timing for each step	Description of teaching and learning activities Different activities will be used such us questions and answers, group discussion, learners' explanations, coin experiment and giving examples and applications.		Generic competences, core ideas and crosscutting concepts
	Teacher activities	**Learner activities**	
Introduction **5 min**	**Excite/Engage Phase** • Show pictures or do a demonstration • What is wrong in this picture? • How do we see things? • What do you think you would see if there was no water inside the tank? • What is the key question of this lesson? Write key question on the blackboard: How does light travel through water and air?	  Observe and describe the observations. Formulate a key question related to the observation.	**Communication skills are developed** through questioning and answering orally in respecting learner's ideas. **Critical thinking and problem-solving skills** are addressed through group discussions in reflecting on teacher's questions and performing experiment **Inclusive education** is achieved in encouraging slow and fast learners to participate in lesson process and help these with special education need. **Gender education** is emphasized through encouraging all learners regardless sex to participate in learning and teaching processes. Core ideas: • To see something, light has to reach our eye. Refraction is related to light passing through different media.

Development of the lesson **15 min**	**Explore Phase** *Predict:* Draw what you will see when a laser beam (or a light ray) is passing through: • Air, Water • From Air to Water • From Water to Air *Observe:* Teacher does the experiments as a demonstration *Model.* Teacher presents the elements of a refraction model (Normal, incident ray, refracted ray, i, r) and stimulates learners to write down their conclusions in a compact way. Teacher explains the steps of the coin experiment First in empty beaker, you see the coin, move your head until you do not see the coin anymore. Fill the beaker with water and observe. 	Learners work in groups of 2-4 They discuss their ideas and draw the consensus of their predictions on mini white boards. Learners are confronted with their misconceptions about the visibility of light. They write down the correct observations.  Air->Water: r < i, bending towards the normal Water->Air: r > i, bending away from the normal Learners work in groups of 4 They do the coin experiment. They observe and try to make sense of the phenomenon. Use the mini white board to draw an explanation	Light rays are invisible. Light is traveling rectilinear in both water and air. Light changes direction when it changes from one medium to another. Developing a model for refraction Construct an explanation based on the model

10 min.	**Explain Phase** Evaluate the explanations of the learners. Evoke discussion, help them to formulate the explanation as clearly as possible. Write the correct explanation on the board. *Guiding questions* • Where is the normal on the model? • Compare r and i on the model. • Where does the light start? • What is happening at the interface? • What does our brain expect? We call this the apparent depth of the object. The apparent depth is not so deep as the real depth.	 One group brings its explanation in front of the class. Other groups improve the explanation, if necessary.	Using models to explain a phenomenon Listening skills
5 min.	**Elaborate Phase** When you see a fish in the water. How do you have to aim to catch it? What if your weapon were a laser?	Group work  Students try to make a correct prediction. They draw their answer on the mini white board or sheet of paper.	Using models to explain a phenomenon

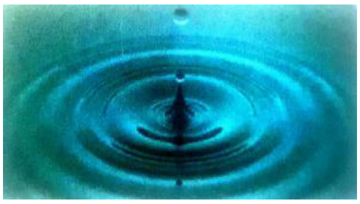
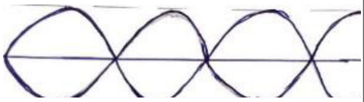
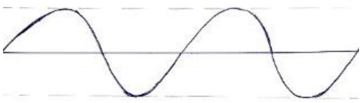
Conclusion 5min	**Evaluate Phase** Explain the initial picture.	 Students formulate their answers on a piece of paper. This paper is collected at the end of the lesson.	Using models to explain a phenomenon
Teacher self-assessment			

Lesson 2: Waves

<table>
<tr><th>Term</th><th>Date</th><th>Subject</th><th>Class</th><th>Unit No</th><th>Lesson No</th><th>Duration</th><th>Class size</th></tr>
<tr><td>2</td><td></td><td>Physics</td><td>S5</td><td>4</td><td>1</td><td>80 minutes</td><td></td></tr>
<tr><td colspan="4">Type of Special Educational needs and number of learners:</td><td colspan="4">Learners with low English language skills. Special attention for slow and fast learners.</td></tr>
<tr><td>Topic area:</td><td colspan="7">Oscillations and waves</td></tr>
<tr><td>Sub-topic area:</td><td colspan="7">Waves</td></tr>
<tr><td>Unit title</td><td colspan="7">Propagation of mechanical waves</td></tr>
<tr><td>Key Unit Competence:</td><td colspan="7">By the end of the unit, learners should be able to evaluate the propagation of mechanical waves</td></tr>
<tr><td>Title of the lesson</td><td colspan="7">Wave concept and characteristics of waves</td></tr>
<tr><td>Learning Objectives</td><td colspan="7">Explain the terms, concepts and characteristics of waves properly
Explain the properties of waves</td></tr>
<tr><td>• Knowledge & understanding</td><td colspan="7">Explain wave concept
Explain the terms amplitude, frequency displacement, wavelength and wave phase.</td></tr>
<tr><td>• Skills</td><td colspan="7">Describe wave properties and their characteristics</td></tr>
<tr><td>• Attitudes & Values</td><td colspan="7">Appreciate applications of wave interference in life</td></tr>
<tr><td>Plan for this Class</td><td colspan="7">Inside</td></tr>
</table>

Learning Materials	Water, container, projector, offline simulation on laptop, blackboard and chalk, rope
References	Physics Learner's Book for Rwanda Secondary Schools Senior 5, page 80-82, Imena Publishers Limited, Kigali, Rwanda (2017) Ocean Beach Surfing Raw | San Francisco, CA https://phet.colorado.edu/en/simulations/category/physics/sound-and-waves

Timing for each step	**Description of teaching and learning activity:** Different activities will be used such us questions and answers, group discussion, learners' explanations, simulation, video and experiment and giving examples and applications.		**Core Ideas, Competences and crosscutting concepts**
	Teacher's activities	Learner's activities	
Introduction **(10 min)**	**Excite/ Engage (10 min)** The teacher uses the following discrepant event: Give a rope to 2 learners and ask them to change the length of the rope and frequency of moving it up and down. Formulate the **key question**, based on learners' answers. Put the key question on the blackboard: How does a rope react to a disturbance?	2 learners use the rope as a demonstration The rest of the class observes and predicts by answering the questions. Learners reflect on the following questions as they are observing: • What do you see? • What do you think will happen when we disturb the rope?	Observation skills: by observing teacher's demonstrations. Language skills: by expressing their reasoning and ideas using scientific language.

Development of the lesson **(65 min)**	**Explore: (25 min)** ***Demonstration: washbasin*** *Predict:* Ask learners to draw what will happen when we disturb water in washbasin. *Observe:* Teacher does the experiment as a demonstration *Model 1.* Draw what will happen when we shake the washbasin. ***Simulation: String*** *Simulation 1:* https://phet.colorado.edu/sims/html/wave-interference/latest/wave-interference_en.html Draw what will happen when we disturb the string (using simulation): *Model 2:* If the string is held at two ends. *Model 3:* If the string is held at one end. Questions for learners • What will happen if the string is disturbed differently (slow and fast) • What factors influence the characteristics of a wave?	 Learners observe the demonstration Learners try to construct an explanation based on the model In groups of 5, learners do experiment and share ideas on what they have seen. Learners discuss and answer the questions. Model 1:  Model 2:  Model 3:  Models 1, 2 and 3 represent waves.	Communication and critical thinking skills: group discussions and reflecting on teacher's questions.

<table>
<tr>
<td></td>
<td>Explain (30 min)

Teacher encourages learners to present their findings

Teacher adds on what students have presented:

Wave: is a disturbance that travels through a medium from one location to another location (So a pulse with a certain amplitude give rise to a wave).

Characteristics of a wave:
Time period is the time it takes for one wavelength of the wave to pass a point in space or the time for one cycle to occur.
Frequency is the number of wavelengths that pass a point in space per second.
Wavelength is the horizontal distance in space between two nearest points that are oscillating in phase.
Amplitude is defined as the maximum distance measured from equilibrium position. It is always taken as positive
Ask learners to predict what would happen:
If we decrease the frequency?
If we decrease the amplitude
If we increase tension on the string?</td>
<td>Learners present their finding about the questions asked and exploration made.

Learners will formulate their own explanation about characteristics of a wave with the help from the teacher and take notes of the explanations given by the teacher.</td>
<td>Critical thinking

Communication skills</td>
</tr>
<tr>
<td></td>
<td>Use the rope to demonstrate each situation (adjust the frequency, amplitude and tension on the string) in order to observe the result and come to the correct answer.
If the frequency decreases, the wavelength will increase. Only the amplitude will decrease.
Tension is directly proportional to the wavelength.</td>
<td>Learners try to make a correct representation and prediction. They discuss their ideas with their neighbour(s)</td>
<td></td>
</tr>
</table>

<table>
<tr><td></td><td>Elaborate: (10 min)

Teacher shows to learners a video showing real life example where waves can be found.

Teacher asks learners to provide other real-life examples of waves.
seismic waves
Radio waves
Microwaves
Light waves</td><td>Learners watch the video attentively.

Learners brainstorm on different real-life examples of waves.</td><td>Thinking skills: applying the new content to related situations.

Curiosity in science: linking content to daily life situations</td></tr>
<tr><td>Conclusion</td><td>Evaluate: (5 min)

Exit ticket
What have you learnt?
Questions you still have?</td><td>Students are given pieces of papers and make their exit ticket and submit it.</td><td>Thinking skills: open questions stimulate thinking more than closed questions</td></tr>
<tr><td>Teacher self-assessment</td><td></td><td></td><td></td></tr>
</table>

P.2 Peer Instruction Examples

Example 1: Why is it dark at night?

Six friends were wondering why the sky is dark at night. This is what they said:

A. The clouds come in at night and cover the Sun.
B. The Earth spins completely around once a day.
C. The Sun moves around the Earth once a day.
D. The Earth moves around the Sun once a day.
E. The Sun moves underneath the Earth at night
F. The Sun stops shining at night.

The reason for the day/night cycle is that the Earth spins completely around its axis approx. every 24 hours (answer B). When our location on Earth is turned away from the Sun, we have night (darkness). When our location on Earth is turned toward the Sun, we have day (daylight).

Example 2: Archimedes' Principle

You can start with a short lecture (7 to 10 minutes) emphasizing the concepts and ideas of Archimedes' Principle. Preferably include a demonstration such as the *Cartesian Diver* (see Appendix P4). Avoid using equations at this point. Then present the following *Concept test*:

Imagine holding two identical bricks under water. Brick A is just beneath the surface of the water, while brick B is at a greater depth. The force needed to hold brick B in place is ________ than the force required to hold brick A in place.

A. larger
B. the same
C. smaller

The correct answer is B. The buoyant force on each brick is equal to the weight of water it displaces and does not depend on the depth.

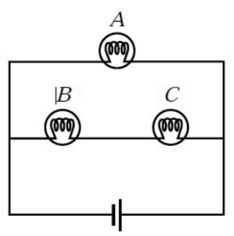
Example 3: Archimedes' Principle (advanced)

A boat carrying a large rock is floating on a lake. The rock is thrown overboard and sinks. The water level in the lake (with respect to the shore) ________

A. rises
B. drops
C. remains the same.

When it is inside the boat, the rock displaces its weight in water. When it is thrown overboard, it only displaces its volume in water so the water level with respect to the shore goes down.

Example 4: Electricity



The three light bulbs in the circuit all have the same resistance. Given that brightness is proportional to power dissipated, the brightness of bulbs B and C together, compared with the brightness of bulb A, is

A. twice as much
B. The same
C. Half as much

Answer C is correct. The potential difference across bulbs B and C in series is equal to the potential difference across bulb A. Since the power dissipated in a resistor of resistance R is V2/R, where V is the potential difference across the resistor, the power dissipated by the series combination is one half the power dissipated by resistor (bulb) A.

Example 5: Mechanics

Two cars, one twice as heavy as the other, are at rest on a horizontal track. A person pushes each car for 5s. Ignoring friction and assuming equal force exerted (acted) on both cars, the momentum of the light car after the push is _______________ the momentum of the heavy car.

A. Smaller than
B. Equal to
C. Larger than

The correct answer is B. The change in momentum caused by a constant force is the product of the force and the time interval ($\Delta p = F. \Delta t$). Because the time interval Δt and the force are the same for both cars, the changes in momentum are also equal.

Example 6: Mechanics

Two cars, one twice as heavy as the other, are at rest on a horizontal track. A person pushes each car for 5 s. Ignoring friction and assuming equal force exerted (acting) on both cars, the kinetic energy of the light car after the push is ___________ the kinetic energy of the heavy car.

A. Smaller than
B. Equal to
C. Larger than

The correct answer is C. Because the momentums of the two cars are equal, the car with the larger velocity must have the larger kinetic energy. This will be the lighter of the two; because it has less inertia, its acceleration is larger than that of the heavy car.

P.3 Concept Cartoons[1]

Light

1. The White Cat

Explanation

A common misconception is that a cat's eyes glow in the dark and that we can see white objects in the dark. Of course, without any light we will not see either the eyes or the cat. The cat's eyes and white fur are both reflective surfaces. When light is present, they reflect it and we can see them clearly. In absence of light however, these surfaces won't reflect any light either and remain invisible. The cat's eyes and its fur do not generate light themselves, so neither can be seen in complete darkness.

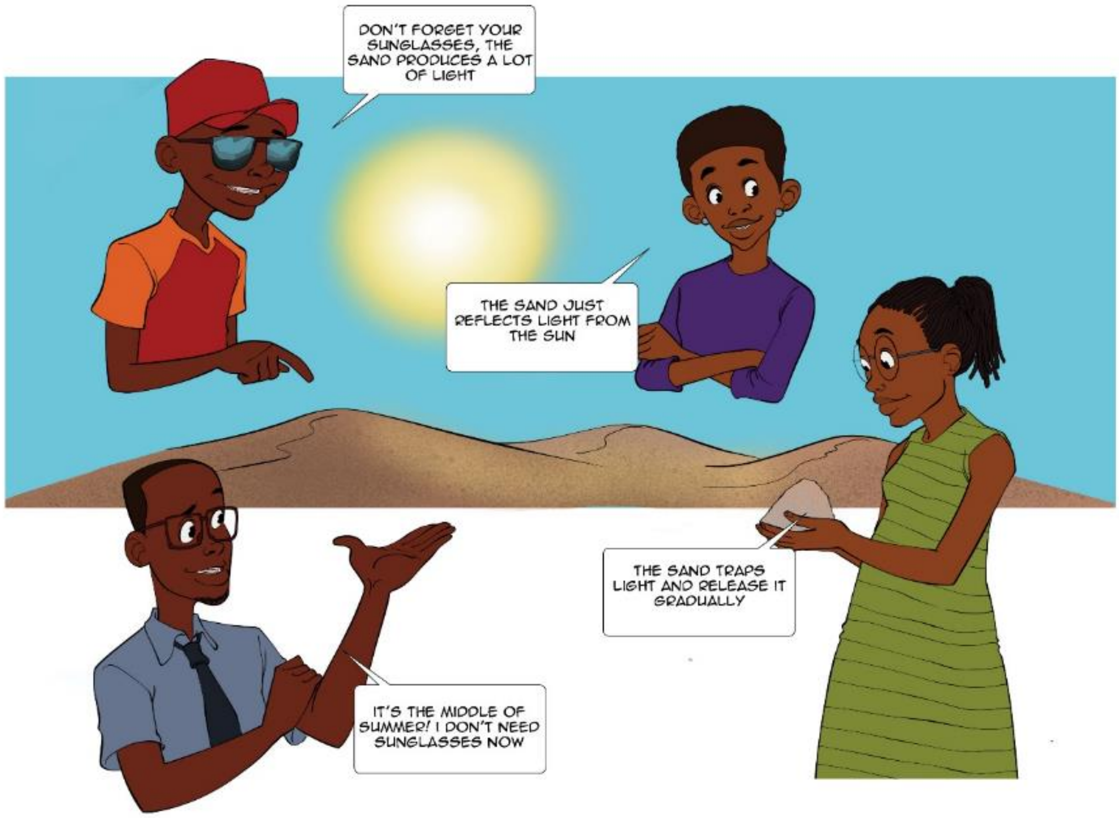
Access to a completely dark room is necessary to test the different possibilities. A windowless room is perfect; alternatively, it may be possible to create a dark "room" with a very large cardboard box. Care needs to be taken to exclude all light. A variety of reflective surfaces could be tested (e.g. coins, mirrors, aluminium foil) to show that there is a consistent and predictable pattern for when objects can be seen.

Position in CBC

S1 Unit 13

1 Source '*Concept Cartoons in Science Education (the ConCISE project)*, Stuart Naylor & Brenda Keogh, Millgate House Publishers.)

2. *Sunglasses*



Explanation

People may be surprised how easily they get sunburnt by sunlight reflecting off sand or lightly coloured soil. The reflection from the sand increases the total amount of sunlight striking the body, so wearing sunglasses is important. However, all light comes from the Sun. The snow itself does not produce or store any light, but simply reflects it. Snow and sand reflect light better than soil and grass.

Position in CBC

S1 Unit 13

3. Shadow screen

Explanation

The closer the person is to the light source; the more light will be blocked. The shadow will be biggest when the person stands close to the lamp. Rays of light from the lamp spread out in all directions, so close to the lamp the light rays are diverging. If the Sun is used as a light source the rays of light are parallel and the distance from the screen makes no difference to the size of the shadow.

The situation can be modelled using a range of objects or shadow puppets cut out from cardboard. Drawing simple diagrams of what is happening to the light and shadow will help to reinforce the idea that light travels in straight lines.

Position in CBC

S1 Unit 13

4. *Shadows at night*

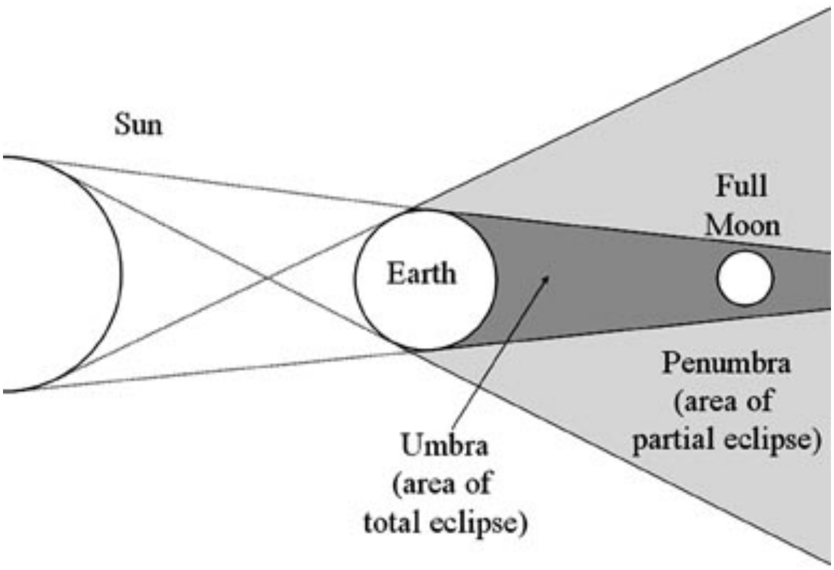
Explanation

Let us assume that we have a dark night (cloudy sky, no other light sources). Every view has its own logic:

- *"There are shadows at night, but you cannot see them"*

Pupils often have this idea because they see shadows as real physical objects. These objects will become visible with additional light, just like any other object.

- *"There are no shadows at night"*



Shadows are associated with the absence of light at a place. If there is no light, there is no shadow.

- *"Everything is shadow at night"*

A picture of the Earth and Sun system sheds a different view on the night. There is no light at the night side of the Earth because that side of the Earth lies in the shadow region of the Earth-Sun system. When you approach the night this way, the night can be considered one big shadow. Most people do not have this feeling because they see shadows as separate entities.

- *"Shadows look darker at night"*

When there is a light source during the night (e.g. Moonlight), there are shadows. Close observation shows that those shadows look darker than during the daytime. During the day there is more indirect light (light reflected on different objects and light scattered by the Earth's atmosphere) reaching the shadow region. So indeed, at night the shadows are darker.

Position in CBC

S1 Unit 13

5. Two trees

Explanation

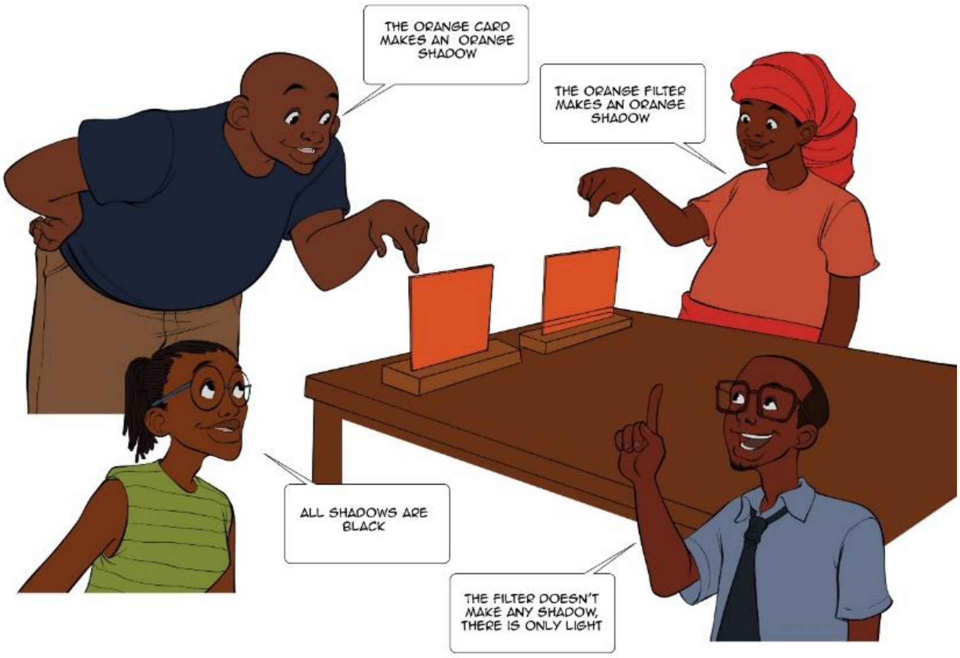
A shadow is caused by the absence of light. If two shadows overlap the darkness of the two shadows would not normally result in a darker shadow. With the trees the situation is complicated by the fact that the trees don't cast a complete shadow because of the number, arrangement and thickness of the leaves. The shadow will therefore be more complete where the two trees overlap, even if it is not darker.

Observation of actual shadows cast by trees is not difficult and the situation can be modelled using card or paper models to cast a shadow. Comparing shadows made by overlapping opaque, translucent and transparent objects is an interesting extension to the activity. With transparent objects some light will be absorbed to produce a faint incomplete shadow, so overlapping transparent objects will produce a darker shadow.

Position in CBC

S1 Unit 13

6. The colour of shadows



Explanation

In most circumstances a shadow is simply the absence of light, so shadows usually are black. A coloured filter absorbs some of the light, but light of a particular colour passes through. The shadow will then be an area of reduced and coloured light. An orange filter will let orange light pass through and produce an orange shadow. Since the orange card blocks all light, its shadow will be darker than that from the filter.

You can set up simple experiments to determine the colour of the shadow cast by different objects. Placing the objects on a white surface will help to make shadows better visible. If a glossy card is used then the situation may be complicated by reflection from the surface of the card, so that there may be a faint orange tinge to the shadow. Interesting comparisons could be made between the shadows cast by dull or reflective surfaces, by opaque or transparent materials and by a white or coloured light source.

Position in CBC

S1 Unit 13

7. Moon eclipse

Explanation

A solar eclipse happens when the Moon passes between the Earth and the Sun, so that the Moon blocks out the Sun's light and the Earth is in the Moon's shadow. This happens rarely because the three bodies need to line up precisely. It can only happen with the Moon's shadow since no other planetary body is close enough to the Earth to block out the Sun's light. This is quite different from a lunar eclipse, which happens when the shadow of the Earth falls on the Moon so that the Moon can no longer reflect light from the Sun.

It is not easy to prove this experimentally. Understanding can be developed with a model (with balls of different sizes) or a (computer-based) simulation. The situation can be modelled using a globe and strong light source, with a small ball to represent the Moon.

Position in CBC

S1 Unit 13

8. Curved mirror

Explanation

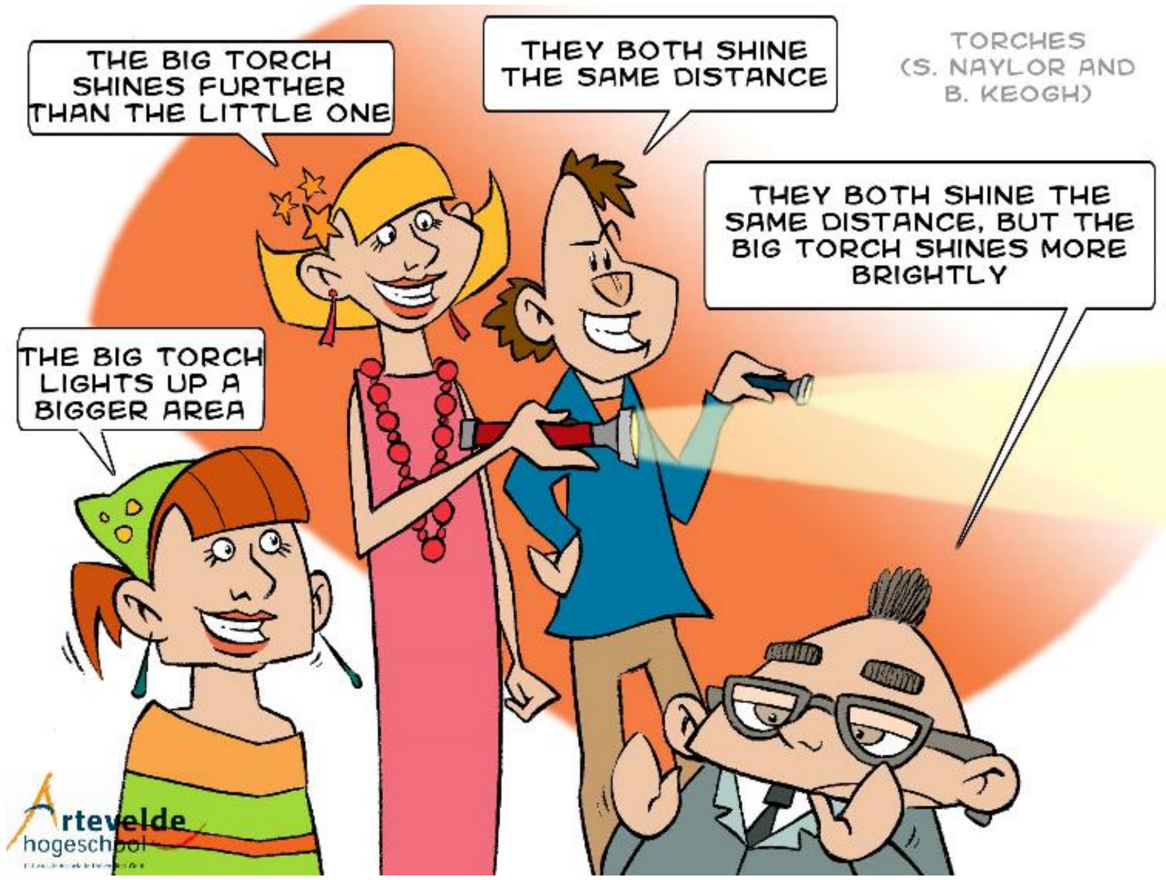
Although with a convex mirror the image is always the right way up, this is not the case with a concave mirror. The image in a concave mirror can be the right way up or upside down, depending on the curvature of the mirror and how far away the object is. The critical factor is the position of the object in relation to the focal point (that is the point at which rays of light reflected from the mirror cross). If the object is closer to the mirror than the focal point, then the image will be upright and magnified. If the object is further away from the mirror, the image will be upside down and reduced in size.

Systematic observation of the type of image produced by concave mirrors in different circumstances will produce consistent patterns in the size and orientation of the images. The concept can be applied to a range of everyday situations such as car wing mirrors and make-up mirrors.

Position in CBC

S2 Unit 14

9. Torches



Explanation

It is a common misconception that the distance that light travels, depends on the brightness of the light source. In fact, in the same medium light always travels at the same speed so it will travel the same distance. What does vary is the brightness of the light and/or the area illuminated. A brighter torch can illuminate a bigger area, illuminate an area more brightly or both.

Measuring the speed that light travels is extremely difficult. A more useful line of enquiry is to observe the area illuminated and the brightness of the illumination with different light sources. Enquiry can also include thought experiments ("What would happen if . . .?").

Position in CBC

S1 Unit 13

10. Mirror box

Explanation

If light were a material substance, like air, then light would still be in the box after the lid is shut and be released when the lid was opened. However, light is not a material substance. In fact, the light is absorbed by the inner surface of the box. As the light is absorbed the energy has to end up somewhere, so the temperature of the mirrors will increase a little bit. Given the speed at which light travels, opening the box lid carefully to see if any light comes out is impossible. However, in theory it would be possible to shine a light into the box, shut the lid and then open it in a completely dark area to show that no light emerges.

Position in CBC

S1 Unit 13 & S2 Unit 14

Mechanics

11. Falling

Explanation

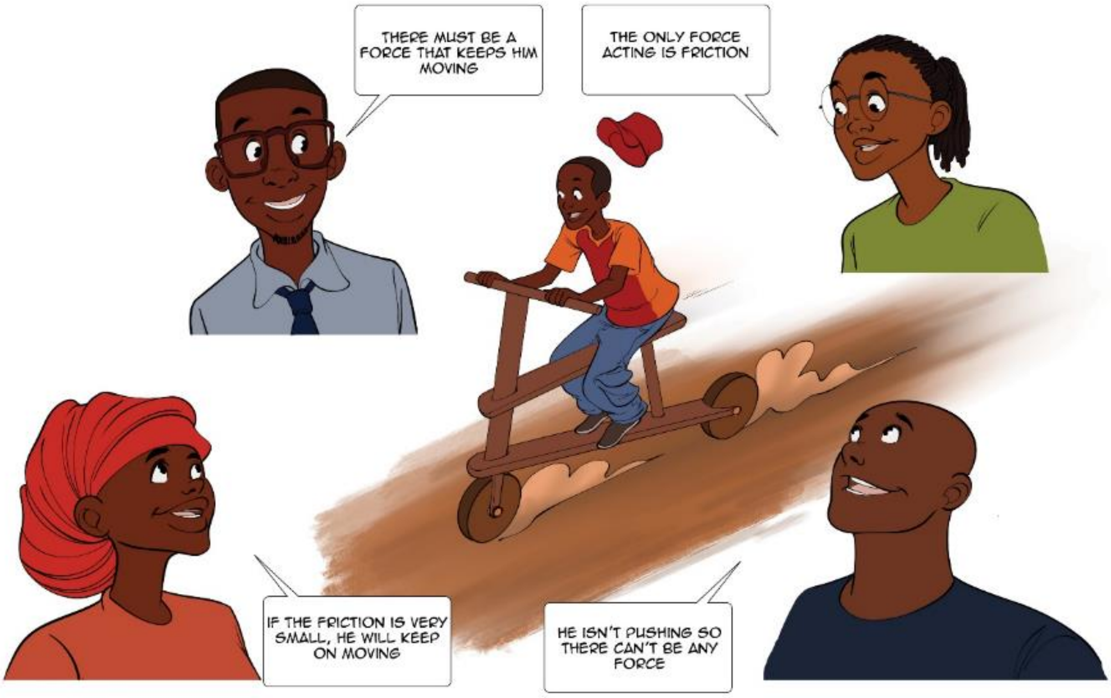
A common misconception is that heavy things fall faster than light things. Although the force of gravity is greater on a heavier object, a heavier object also needs a bigger force to make it move. Air resistance can make a difference to how objects fall, particularly if they have a large surface area. The weight and the size do not have any direct impact on the rate of falling. The feather and paper fall slowly because of their relatively large surface areas which create a lot of air resistance as they fall.

Investigations could include finding out how to make the paper fall faster, such as screwing it up or folding it. Similarly, the effect of modifying the vane or dropping the feather in different ways can be explored. Showing video footage of the first lunar astronauts dropping a hammer and a feather on the Moon (where there is no atmosphere) will be useful. Factors such as weight, surface area and shape can each be investigated.

Position in CBC

S2 Unit 2

12. Wooden bicycle



Explanation

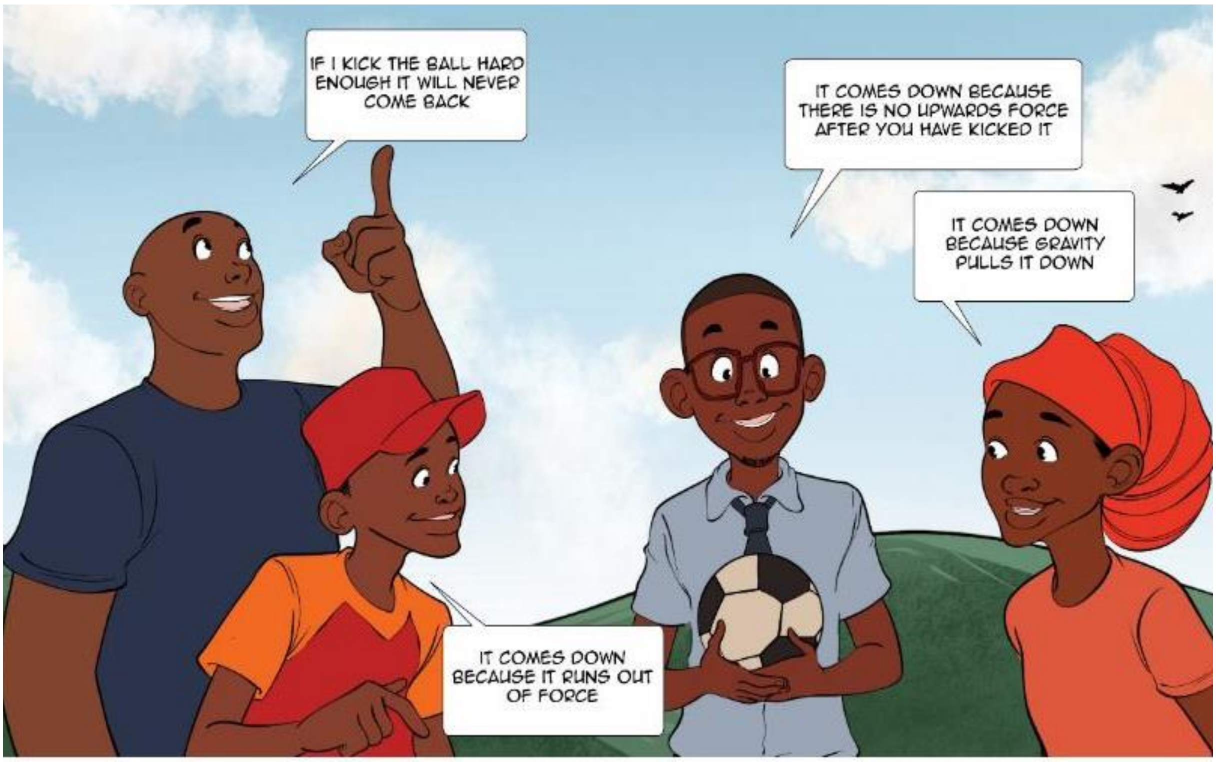
Although it seems counterintuitive, objects do not need a force to keep them moving. Moving objects slow down because of friction. If there is no friction, then the object will keep on moving in the same direction. We take friction for granted and don't really notice its acting. In this situation the bicycle slows down because of friction. There is no force to keep the bicycle moving, except when he pushes herself along with her foot.

The situation can be modelled by using objects which roll or slide and pushing them to see how far they go. The effect of pushing with different amounts of force can be investigated. Pushing them on a range of surfaces (e.g. a wooden table, a polished floor or a carpet) will allow the effect of different amounts of friction to be explored. Sliding a piece of ice on a polished surface makes a useful comparison.

Position in CBC

S3 Unit 2

13. Soccer



Explanation

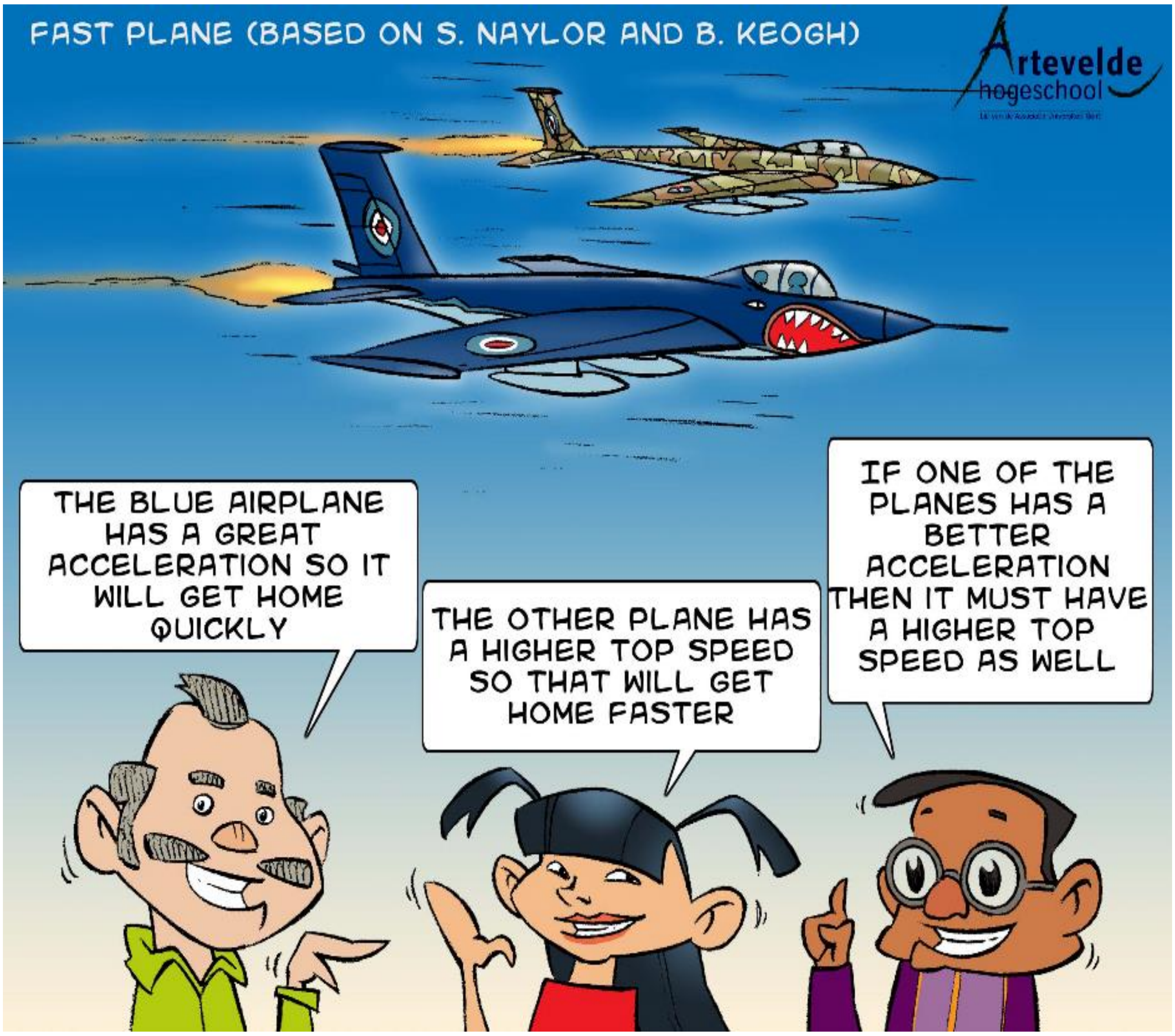
A common misconception is that moving objects have a force acting on them in the direction of movement. With the football the only forces acting when it is in the air are gravity and a small force caused by air resistance. In theory it would never come down if you could kick it hard enough (like satellites can stay permanently above the Earth), but in practice this is not possible.

It is not easy to directly measure the forces on the ball while it is in flight. There are no obvious practical investigations that directly address the situation shown. Enquiry is likely to focus on modelling some aspects of the situation (e.g. looking at the forces involved in horizontal motion).

Position in CBC

S1 Unit 3

14. Fast plane



Explanation

The issue here is the relationship between acceleration, speed and journey time. Journey time depends on average speed, not acceleration. Although good acceleration is useful for the plane to get up to cruising speed quickly, it will not make much difference to the journey time except over very short distances. Having good acceleration does not necessarily mean that the top speed is greater or that the journey time will be noticeably less.

Enquiry can include calculating journey times in a range of situations, drawing distance-time graphs and the use of computer simulations.

15. Moon rock

Explanation

Since the rock weighs less on the Moon than on Earth we would expect it not to sink. However, its mass and its volume are the same, so its density has not changed. The same is true for the water - it weighs less but its density has not changed. Therefore, the relationship between the density of the rock and the density of the water has not changed. So, the rock will sink on the Moon like it does on Earth. Since the force of gravity on the Moon is smaller than on Earth, the rock will sink more slowly.

We cannot practically investigate the situation since we cannot escape the Earth's gravity. A range of activities and experiments to develop a thorough understanding of floating and sinking should enable intelligent predictions to be made about what would happen on the Moon.

Heat

16. Boiling water

Explanation

A common misconception is that small amounts of liquid will boil at a lower temperature than larger amounts. It takes less energy to boil a smaller amount of liquid so small amounts will boil more quickly, but the boiling temperature will be the same.

The situation can be investigated using a container for boiling water. It is possible to compare the time taken to boil and the boiling temperature using different amounts of water. The effect of heating the water more strongly can also be measured. The best way to heat the liquid is to use a small heater since it can be difficult to control how much energy is supplied. A useful extension is to compare the boiling time and temperature using other liquids, such as a salt solution or milk.

17. Block of ice

Explanation

A common misconception is that some materials have the property of making things warm. Wearing a coat keeps us warm and causes a belief that it will also make the block of ice warm and melt quickly. In fact, the coat acts as an insulator, reducing the movement of energy in either direction. On a person it can prevent energy loss, while it prevents the block of ice from getting warmer. The block of ice will melt more slowly with the blanket.

The situation can be investigated using ice. Water can be frozen inside plastic drinks bottles or plastic containers. A piece of cloth can simulate a coat and allow the effect of the coat to be investigated. A useful extension is to investigate the effect of other factors such as the nature, colour and thickness of the coat.

18. Teapot

Explanation

The issue here is how quickly thermal energy travels through or is lost from different materials. Energy loss from the teapot will depend on the thickness (it takes more energy to warm a thicker teapot), the nature of the material (metals are good conductors of energy), the colour (dark colours lose energy more quickly) and how shiny it is (dull surfaces lose energy more quickly). The interaction of the different factors is difficult to predict accurately.

The situation can be investigated using real teapots full of hot water and measuring the rate of cooling with a thermometer. It can be modelled using containers of different materials filled with hot water, which can allow the effect of each factor to be analysed separately. An interesting experiment is to let students work together to make the best insulating bottle.

19. Windy day

Explanation

The wind feels cool because it encourages faster evaporation from the surface of the skin. By blowing away the layer of moist air which usually surrounds our bodies it allows more water to evaporate, cooling the skin as it does so (evaporation requires energy, taking it from the surroundings and thereby making it a cooling process). The wind also blows away the layer of warm air surrounding our bodies. As this warm air is replaced by colder air, we lose energy by warming this new layer of air.

If a container or can is filled with hot water, it will cool as it loses energy to the environment. The cooling effect of the wind can be seen if a fan blows a stream of air around the container, preferably with the can wrapped in moist tissue paper to show the importance of evaporation. The effect of trapping a layer of air around the container can be investigated by wrapping an insulator (such as a woollen cloth or bubble wrap) around the container and comparing the rate of cooling.
This concept can also be explored with the situation of a fan providing cooling during hot days.

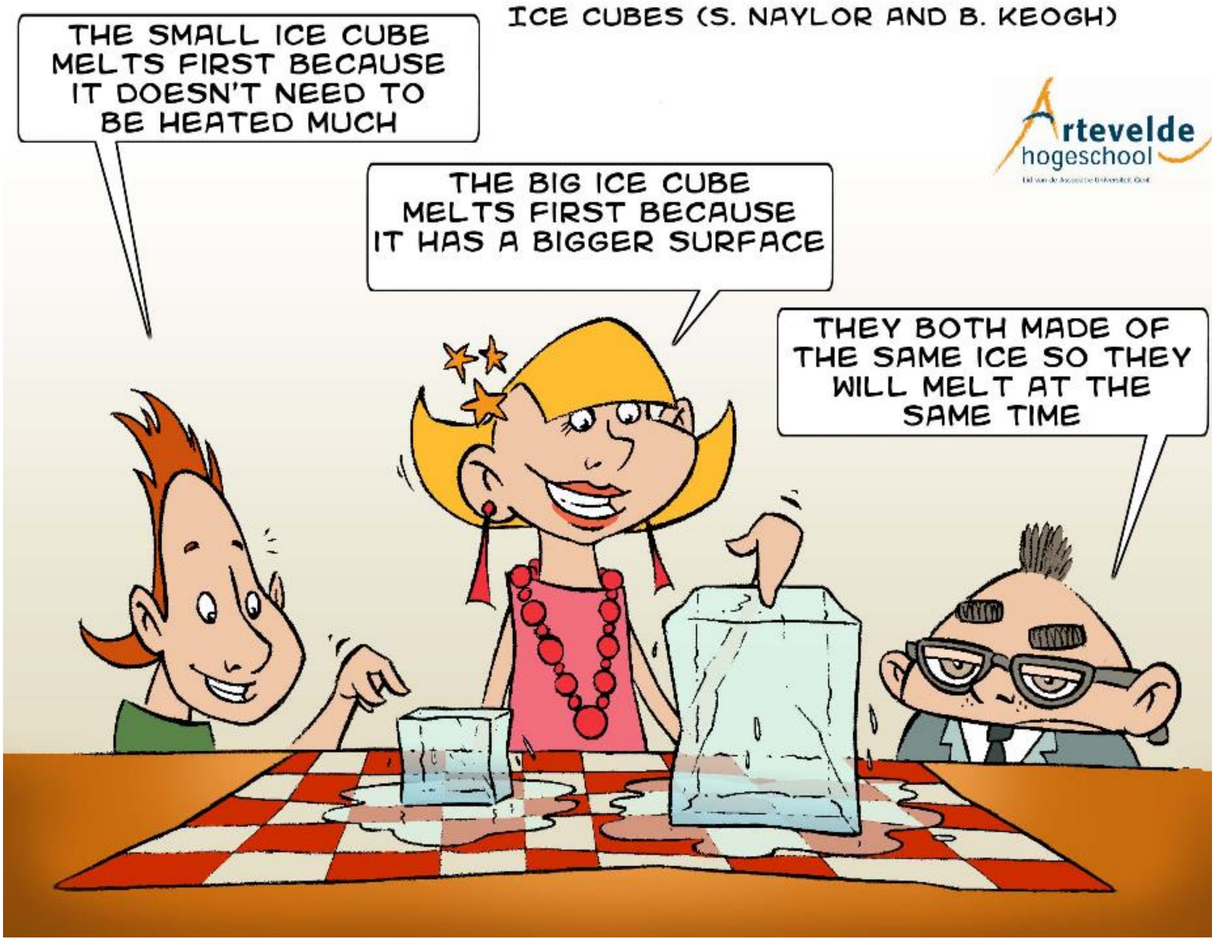
20. *Melting ice*

Explanation

This concept cartoon illustrates the frequent confusion between weight and density. Ice is less dense than water, which is why it floats on water. When the ice melts its weight does not change. Ten grams of ice will melt to give ten grams of water. However, the volume does change when the ice melts. Ten grams of water take up less space than the ten grams of ice, so the density of the ice is less than the density of the water. There is plenty of scope for confusion here! The water and ice are exceptional in that almost all other substances get denser as they solidify.

The weight of a given amount of ice can be measured before and after melting to see whether the weight changes. Exploring how density alters with changes of temperature is more interesting and can lead to discussions on why icebergs float, where ice forms as water is freezing (at the bottom or at the surface) and how fish manage to survive over the winter when ponds freeze.

21. *Ice cubes*



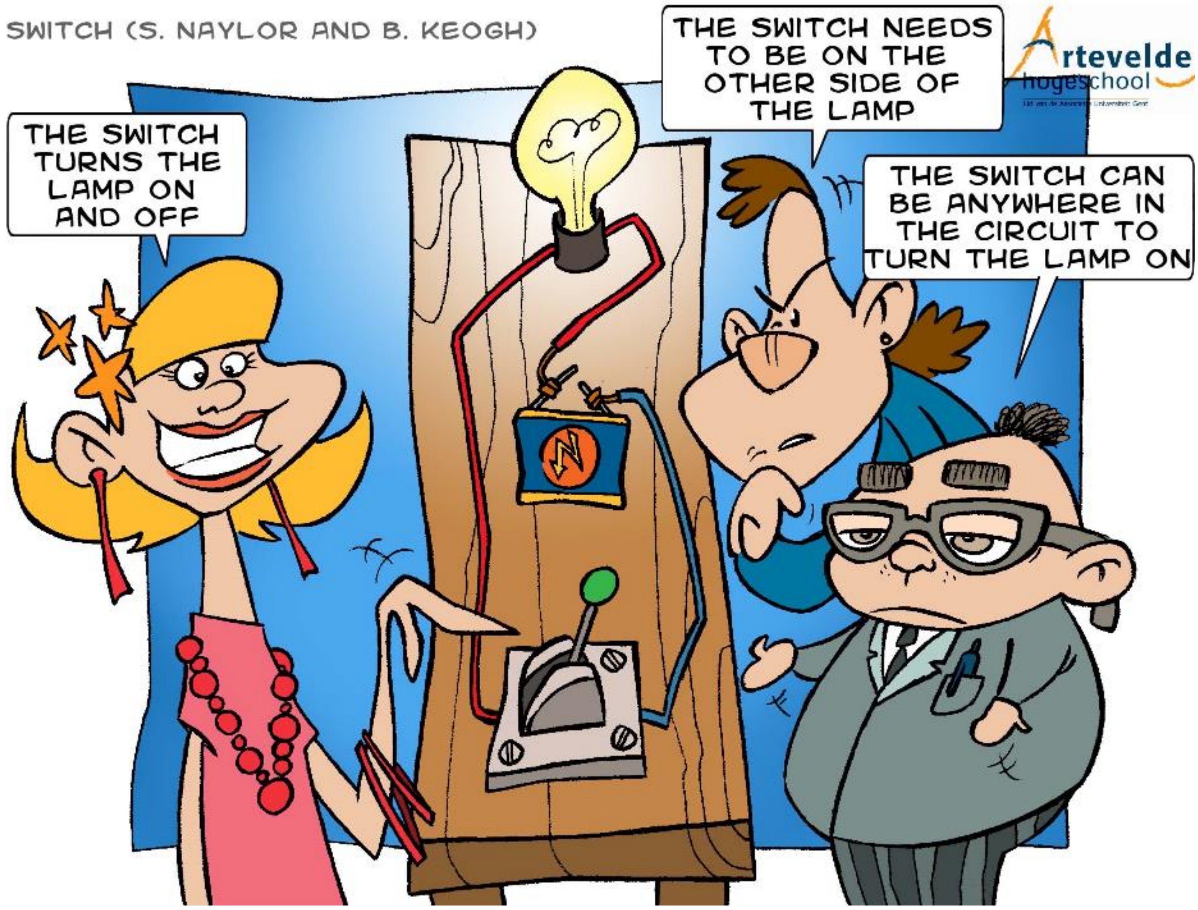
Explanation

The smaller ice cube will melt first. Assuming that the two ice cubes have the same temperature, the bigger ice cube needs more heat energy to melt it because there is more ice to be melted. The ice cubes gain energy from the environment. The bigger cube has a larger area and will gain energy more quickly. However, the smaller cube has a larger area: volume ratio, so it will melt before the bigger cube.

The situation can be investigated quite easily using a range of different sized ice cubes and timing how long they take to melt. A useful extension would be to investigate the rate of melting at different temperatures to show that the bigger ice cube takes longer to melt whatever the outside temperature (as long as it is the same for each cube). Students can analyse this quantitatively using various ice volumes and/ or temperatures and plot their results in a graph.

Electricity

22. Switch

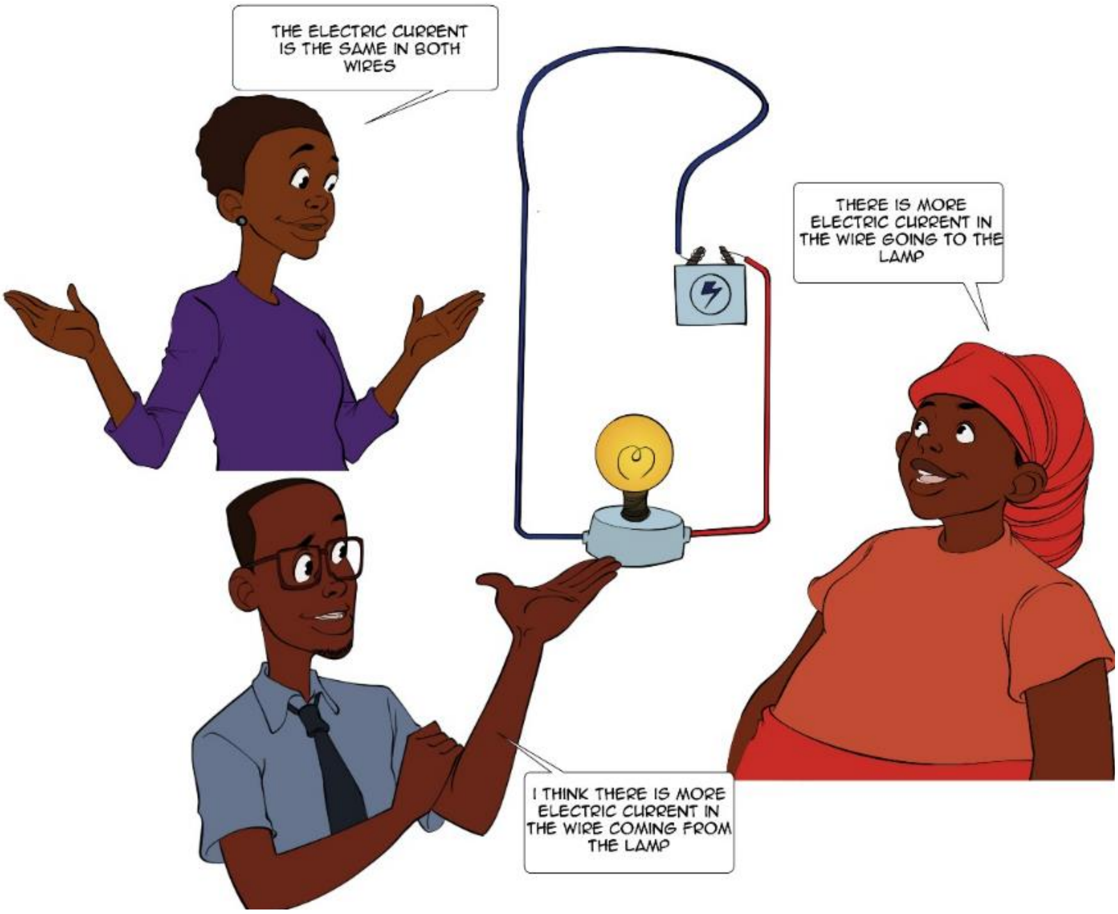


Explanation

A common misconception is that electricity starts at the battery and goes through each component of the circuit in turn, so that a switch needs to be on the “positive” side of the lamp to turn it on and off. The electricity flows in all parts of the circuit at the same time, so the switch can be anywhere in the circuit and it would still have an effect on the lamp.

The problem shown in this circuit can be investigated with simple practical equipment. Arranging a switch in different places in a simple circuit is sufficient to clarify the effect of changing the location of the switch.

23. Current flow

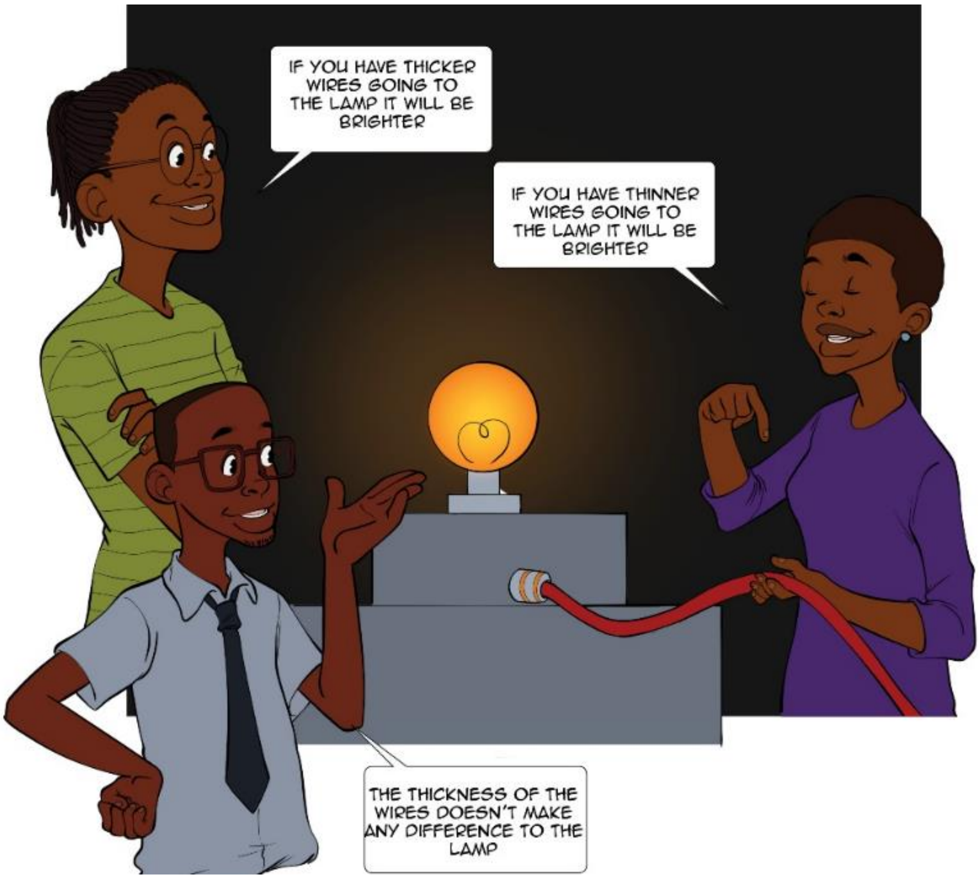


Explanation

Since batteries go flat something must be being "used up" in electrical circuits. It therefore seems reasonable to suppose that there will be more electric current going to the lamp than going away from it. The fact that the current is the same in both wires seems counterintuitive. Learners' understanding can be further complicated when they learn about electric current without clearly separating it from electrical energy. The electrical current enables electrical energy to be transferred, and although electric current is constant around the circuit the electrical energy is not.

If an ammeter is available, the electric current can be measured at various points on the circuit to show that it is constant. Finding out more about the chemical reactions going on inside the battery is also helpful.

24. Thicker wires

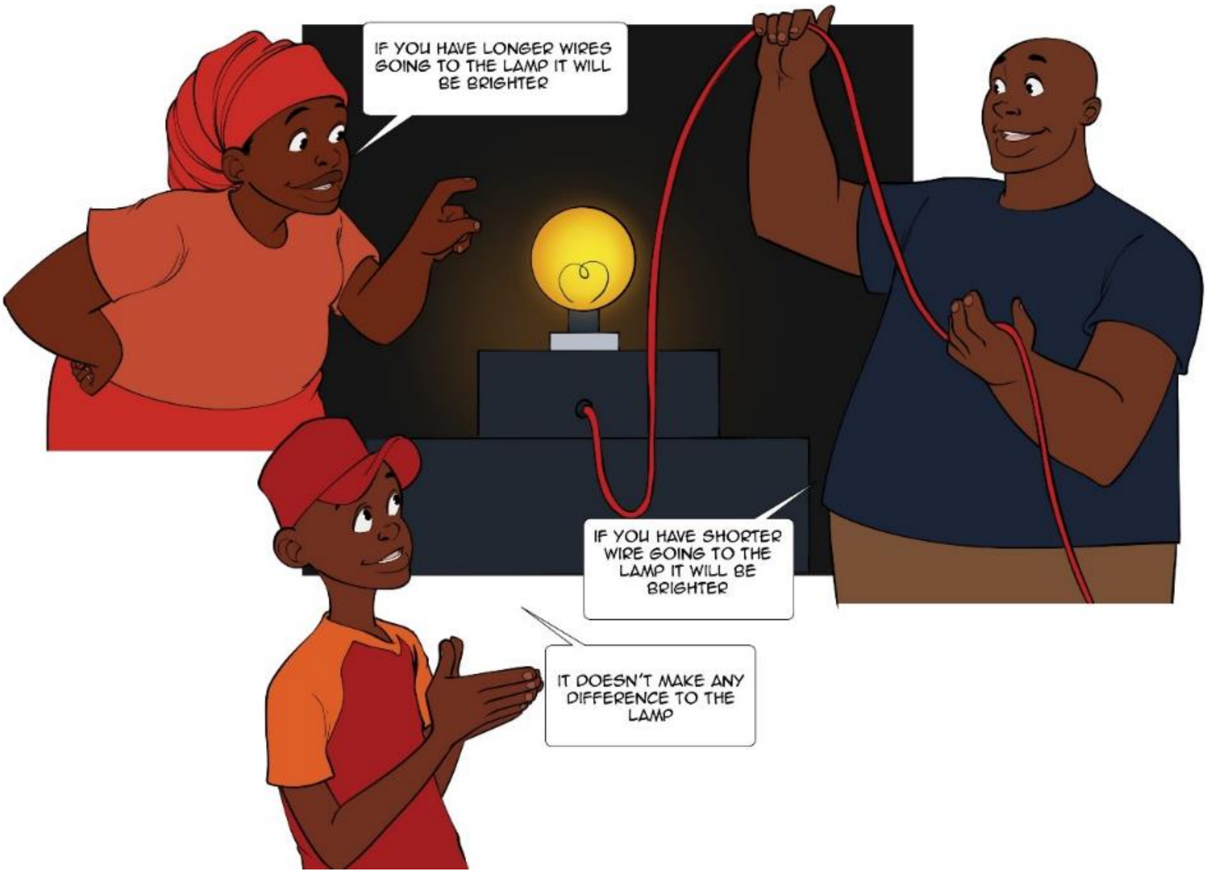


Explanation

Many students think that thicker wires will allow more electricity to flow through the wire and the lamp will shine brighter. In reality, thicker wires in a circuit do not make the lamp shine more brightly. The brightness of the lamp depends on the resistance to the flow of electric current round the circuit. The limiting factor in determining the flow of electric current is therefore the thickness of the filament in the lamp.

The situation can be investigated by setting up a simple circuit in which thinner or thicker wires connect the battery to the lamp. With very thin wires it should be possible to notice that the current flow is reduced, and the lamp is dimmer, though thicker wires do not normally make any difference. This cartoon is a useful introduction to the concept of resistance and to how current flow in a circuit is controlled.
More info on: https://www.bbc.com/bitesize/guides/z8b2pv4/revision/1

25. Longer wires



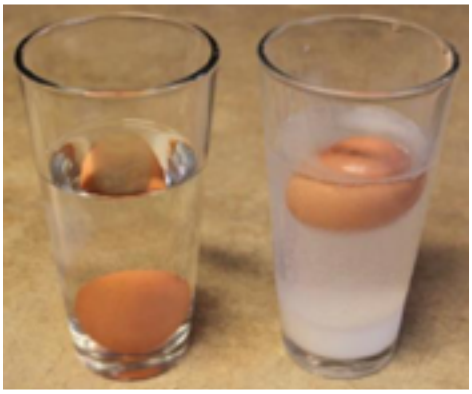
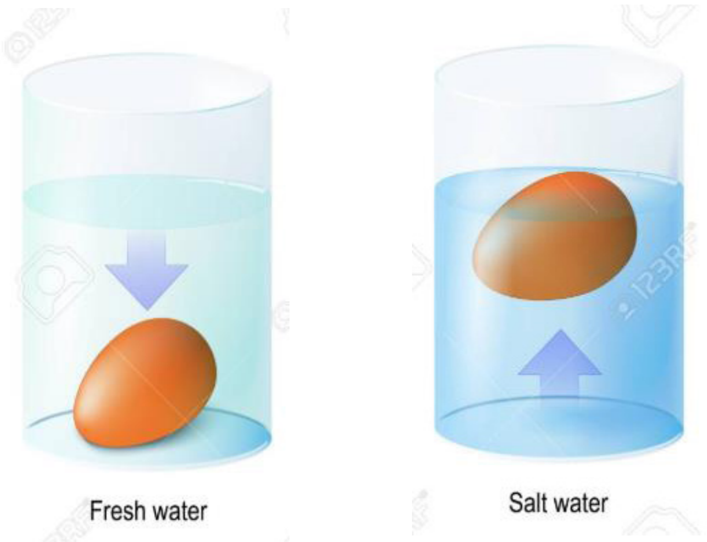
Explanation

Many students think that with longer wires the electricity will take longer to move around the circuit and the light will be dimmer. However, using longer wires in a circuit does not make the lamp shine noticeably more brightly or dimly. The electricity flows in all parts of the circuit at the same time, so having longer wires does not make any difference to the flow of electric current. The limiting factor in determining the flow of electric current is the thickness of the filament in the lamp.

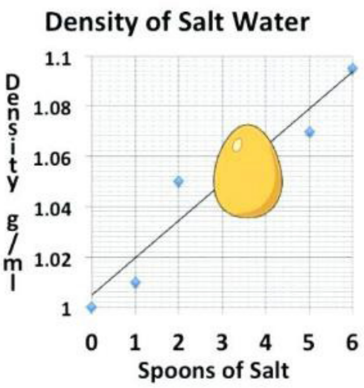
The situation can be investigated by setting up a simple circuit in which longer or shorter wires connect the battery to the lamp. Normally the length of wire does not make any noticeable difference. However, there may be some reduction in brightness with very long wires or when very thin wires are used. This can be a useful introduction to the concept of resistance and to understanding how current flow round a circuit is controlled.

P.4 Low-Cost Experiments

1. Density: eggs

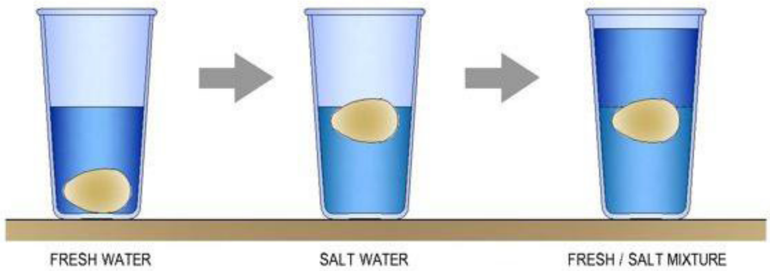
Competence-based Curriculum	S1 Physics - Mechanics - unit 1 Laboratory safety rules and measurements of physical quantities. Curriculum physics page 19.
Main ideas	A massive body can float, sink or suspend in a liquid. The behaviour of the body depends on the density of that body and the liquid.
Key question	Why is the same egg sinking in the first glass and floating in the second one?
Necessary materials	2 glasses, water, salt, an egg (or 2 eggs)
How to make it	1. Fill 2 glasses with water. • In the first glass you add nothing to the water. • In the second glass you add salt until the egg starts floating. 2. Put an egg in both glasses.  (frugalfun4boys, 2019)
schematic reference	 (123RF, 2019)

Experiment	Ask the student
1. Put the eggs in the 2 glasses filled with (only) water.	3. What do you see? What happens with the eggs? Is there any difference between the 2 glasses? Where are the eggs located? What could be the cause of it?
2. Add salt in the second glass. Keep adding salt until the egg rises.	4. What happens when you add the salt? What happens with the location of the eggs? What is changing?

<table>
<tr><td>Possible student misconceptions</td><td>The egg is different and the water is the same in both glasses.</td></tr>
<tr><td>Explanation</td><td>


The density of the water increases when you add salt. The more salt you add, the higher the density.

$\rho = m/V$



(realfreshcookin, 2018)

Three states:

- Sink (denser than liquid) (ρ egg > ρ water)
- Suspend (same density as liquid) (ρ egg = ρ water)
- Float (less dense than liquid) (ρ egg < ρ water)
</td></tr>
<tr><td>Simulation</td><td>https://phet.colorado.edu/nl/simulation/legacy/density
Show the students this PhET simulation after doing the experiment. The simulation shows more examples.</td></tr>
<tr><td>Didactic suggestion</td><td>Switch the eggs so the students can see that the eggs are the same.</td></tr>
</table>

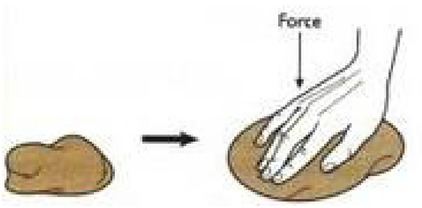
2. *Forces and their effects*

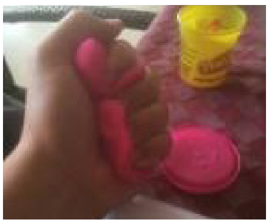
Competence-based Curriculum	S1 Physics - Mechanics - forces - unit 3 Force (I) Curriculum physics page 22.

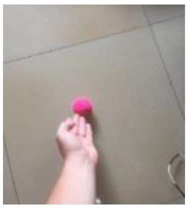
Main ideas	A net force can cause a change of motion and/or a change of shape.

Key question	What is the effect of a net force on an object?

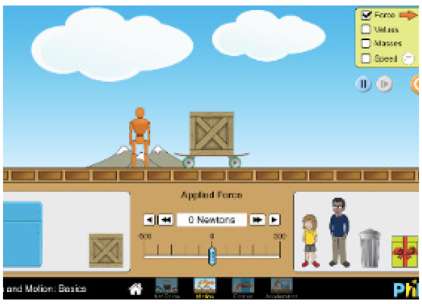
Necessary materials	You can use clay, plasticine or a piece of soil. If you make the soil wet, you can create the same effect of clay and plasticine.	

Schematic reference	1. A net force can cause a change of shape (The plasticine becomes flat when it's pressed)	 (Ting, 2012)
	2. A net force can cause a change of motion.	 (Ting, 2012)

Experiment		**Ask the student**
1. Lay down the clay on a desk. Let a student try to change the shape without touching it.		2. Can you change the shape of the plasticine without having contact? 3. Why can't you? 4. What do we have to do to change the shape?
5. Change the shape of the clay with your hand.		6. What can you also do with the clay, using a force?

7. Make a sphere of the clay and push it so it starts to roll. 	8. If the clay is rolling, what can you do to change its motion?
9. Let your sphere roll and give it an extra push so it can roll faster. 10. Let the clay roll and stop it.	11. Do you need a force to let the clay slow down?
12. Let the clay fall on the ground.	13. Do we have to keep contact with the clay so it can move downwards? 14. What kind of force caused the clay fall on the ground?

Possible student misconceptions	A force causes a movement.

Explanation	A net force can change the shape of an object or can cause a change of motion. A change of motion can be that you let an object accelerate, you can let an object in motion slow down or you can let an object in rest start to move. You must be in contact with the clay to use your force. The force created by your muscles is a contact force. Another kind of force is a field force, for example the gravitational force, where no contact is needed.
Simulation	https://phet.colorado.edu/sims/html/forces-and-motion-basics/latest/forces-and-motion-basics_en.html You can use this simulation to show that: • you need a force to get an object in rest into motion. • you need a force to slow down a moving object.  (University of Colorado, 2018)
Didactic suggestion	You can use this experiment at the beginning of the unit (as an engage and excite experiment). The application can be used in the explore fase.

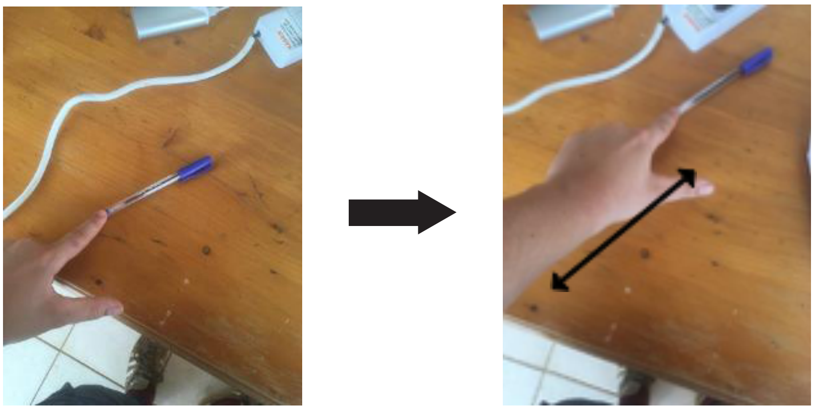
3. A force as a vector quantity

Competence-based Curriculum	S1 Physics - Mechanics - forces - unit 3 Force (I) Curriculum physics page 22.

Main ideas	A force is a vector quantity. Describing a force requires a direction, a magnitude (size) and the place where the force is applied.

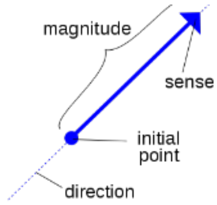
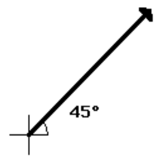
Key question	How can you describe the effect of a force on an object?

Necessary materials	A pencil, a ruler, a piece of chalk and a blackboard.

Schematic reference	

Experiment	Ask the student
The students put their pencil in the middle of their desks. Ask them to move their pencil.	Has everyone moved their pencil in the same direction? Why not? How can we make sure that every student moves his pencil to the same place at their desks? How can we indicate the direction?
Draw an arrow on the blackboard to describe the direction of the movement.	How can we indicate how far we move the pencil?
Give the arrow a specific length.	What is also important when we push the pencil away? • Is the effect the same when you push in the middle of the pencil and when you push at the end? • What are the necessary aspects that you must know about a force, so you can describe it?

Possible student misconceptions	A force can be described with only a magnitude and a unit.

Explanation	For the replacement of the pencil we use a force. Describing the effect of a force requires the size of the force, the direction and the position of the force. Those aspects of a force can be visualized by a vector which has:  a specific length The length of the vector depends on the magnitude of the force. The bigger the force, the longer the vector. You compare the length of the vector with a chosen length that represents the unit. For example, 1 cm = 1 N. In that case, the vector of a force of 5N has a length of 5 cm.  a direction The vector has a certain direction and makes an angle with a reference axis. the place of attachment The place of attachment describes the initial point. At that point, the force is applied. If you use your finger to replace your pencil, the place of attachment is the place where your finger is touching the pencil.

4. Density: dancing raisins

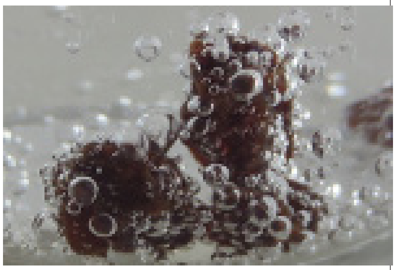
Competence-based Curriculum	S1 Physics - Mechanics - unit 1 Laboratory safety rules and measurements of physical quantities. Curriculum physics page 19.

Main ideas	A massive body can float, sink or suspend in a liquid. The behaviour of the body depends on the density of that body and the liquid.

Key question	Why do raisins sink and float in Sprite (lemonade)?
Necessary materials	Raisins, sprite (lemonade) and a glass.    (La Gaceta, 2015)
How to make **How to do**	1. Fill the glass with lemonade (sprite). 2. Add raisins (5 will be enough). 3. You can see that the raisins to the bottom of the glass. After a while they move upwards. Once they've reached the surface, they sink again.  (www.proefjes.nl,2004-2019)

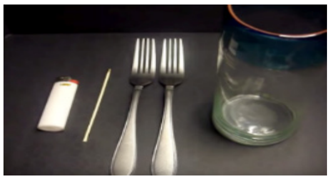
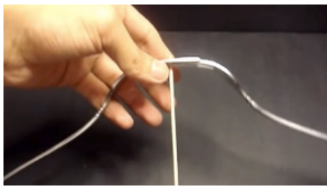
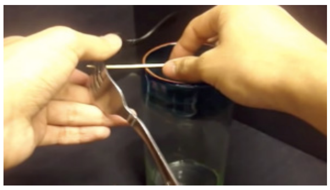
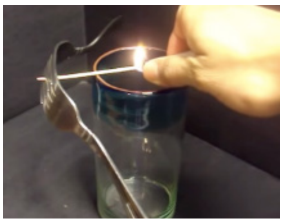
Experiment	Ask the student
1. Fill the glass with lemonade.	4. What will happen with the raisins when I throw them in the glass with sprite? Will they sink or float?
2. Add the raisins.	5. What do you see? Why are the raisins sinking?
3. Wait until the raisins start to rise.	6. Why are the raisins rising? What do you see if you look close to the raisins? What are the little bells around the raisin? Where do they come from? What are they made of? Why do raisins sink again once they've reached the surface?

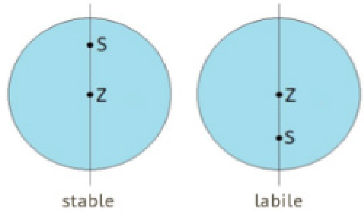
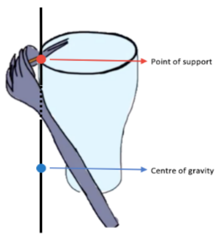
Possible student Misconceptions	An object sinks because it's heavy.

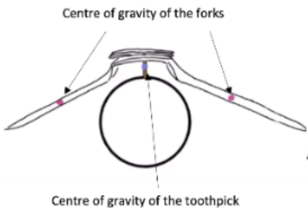
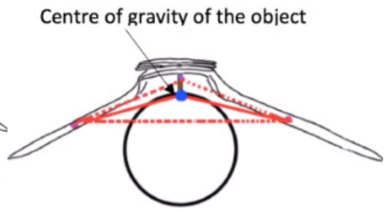
Explanation	If you throw the raisins in the glass, they will sink to the bottom, because the density of a raisin is bigger than the density of the lemonade.  (www.proefjes.nl, 2004-2019) After a while, you notice that the raisins are surrounded by little bells. Those bells are made of carbon dioxide, a gas that is dissolved in the lemonade. The carbon dioxide bubbles have a very low density. If there are enough bells attached, the total density of the bells and the raisin becomes smaller than the density of lemonade and the raisin rises until it floats. At the surface, the bells collapse and the raisin will sink to the bottom again. This is a dynamic process and repeats until there is not enough carbon dioxide in the lemonade anymore.

YouTube reference	https://www.youtube.com/watch?v=goKDM60JNjI&t=105s 0:36-2:25 This part of the movie shows the experiment.
Didactic suggestion	This can be a good elaborate experiment.

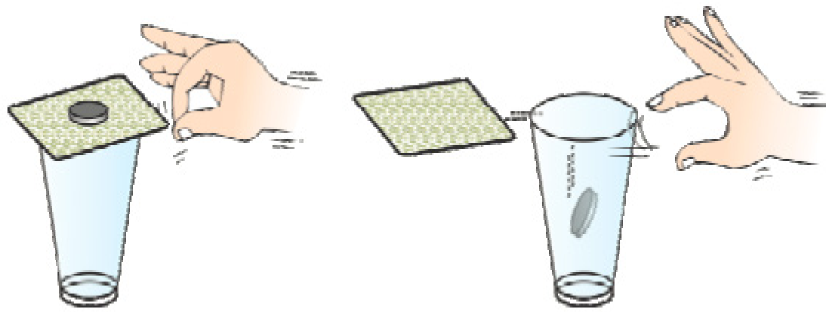
5. The centre of gravity

Competence-based Curriculum	S1 Physics - Mechanics - forces - unit 5 Centre of gravity Curriculum physics page 25.	
Main ideas	The centre of gravity of an object is not always in the centre of that object.	
Key question	What is the centre of gravity of an object?	
Necessary materials	A toothpick, two forks (equal size), a glass and a lighter (a matchstick).	 (MCExperiments, 2010)
How to make How to do	Take the two forks and interweave them in each other, like shown in the picture.	 (MCExperiments, 2010)
	Take the toothpick and push it through the middle of the interweaved forks, as far as you can.	 (MCExperiments, 2010)
	Try to balance the toothpick and forks on the edge of the glass.	 (MCExperiments, 2010)
	If the system is in balance, you can put the toothpick on fire.	
	 (MCExperiments, 2010)	 (MCExperiments, 2010)

Experiment	Ask the student
1. Show the object that you will try to balance (the forks and the toothpick which are interweaved).	
2. Balance the object at the edge of the glass.	3. What do you see? 4. Why is the object not falling? 5. What do you know about the point of the toothpick that is in contact with the glass? 6. What would happen if we make the side of the toothpick at the inside of the glass shorter? 7. Will the object fall or stay in balance? Why?
8. Put the side of the toothpick on fire.	9. What do you see? 10. Why is the object not falling? 11. Is the centre of gravity in the middle of that object?
Possible student misconceptions	The centre of gravity is always in the middle of an object.
Explanation	The centre of gravity is the point through which the resultant of the weight of all the particles of the body acts.  An object is in balance when it's supported in a point on the vertical axis through its centre of gravity. If the point of support (S) is localised above the centre of gravity (Z), the equilibrium is **stable**. If a stable object is brought out of balance, it will go back to its initial position. If the point of support is localised underneath the centre of gravity, the equilibrium is unstable or labile. If a labile object is brought out of balance, it will not go back to its initial position.  You can find the centre of gravity of a regular object (with a mass that is equally divided) in the geometrical centre. The centre of gravity of an irregular object is more difficult to find. In case of the glass and the forks, the equilibrium is stable, because the point of support is above its centre of gravity. Notice that this centre is outside the object.

	 (Ang, 2017)  (Ang, 2017)
YouTube reference	https://www.youtube.com/watch?v=bUeqQMUX3Ms (5:50-9:50) This movie shows how to conduct the experiment and gives a clear explanation.

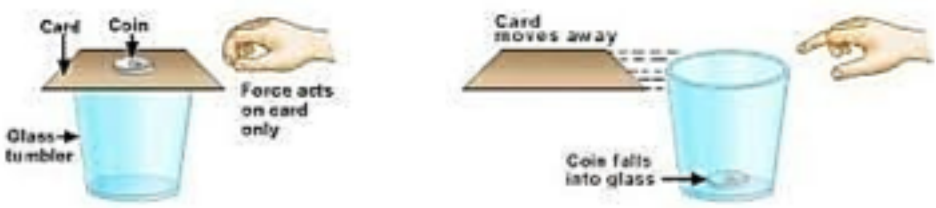
6. Newton's First Law

Competence-based Curriculum	S1 Physics - Mechanics - Force - unit 4 Newton's Laws of Motion (I). Curriculum physics page 23.
Main ideas	An object in rest stays in rest, or an object in motion stays in motion, unless it is affected by an external force.
Key question	Why does the coin fall in the glass?
Necessary materials	A glass, a coin and a piece of cardboard.
How to make it	1. Take an empty glass 2. Put a piece of cardboard on top (in the middle). 3. Put the coin in the middle of the glass and cardboard.  (stevespanglerscience, 2018)
schematic reference	 (tutorialspoint, 2019)

Experiment	Ask the student
1. Place the coin on top of the glass and cardboard. (Put the cardboard in the middle of the glass and the coin in the middle of the cardboard.) 2. Let a student try to make the coin fall into the glass without touching the coin or the glass.	
3. Move the cardboard slowly. (Do it in a horizontal movement, moving away from the glass.)	4. What happens with the coin? Where is it located? How can you make sure the coin falls in the glass?
5. Move the cardboard fast. (Do it in a horizontal movement, moving away from the glass. You can also give the cardboard a hard-horizontal kick.)	6. What happens with the coin? Where is he located? Why does it fall in the glass? Can you give another example where you have seen this phenomenon?

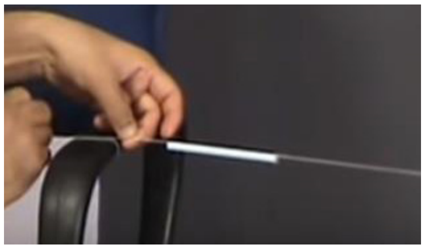
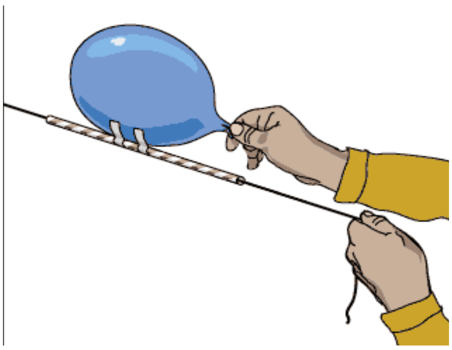
Possible student misconceptions	The coin always moves with the cardboard.

<table>
<tr><td>Explanation</td><td>
An object in rest stays in rest, or an object in motion stays in motion, unless it is affected by an external force = INERTIA.
The force is applied on the cardboard, not the coin. The coin stays at its original place and falls in the glass.



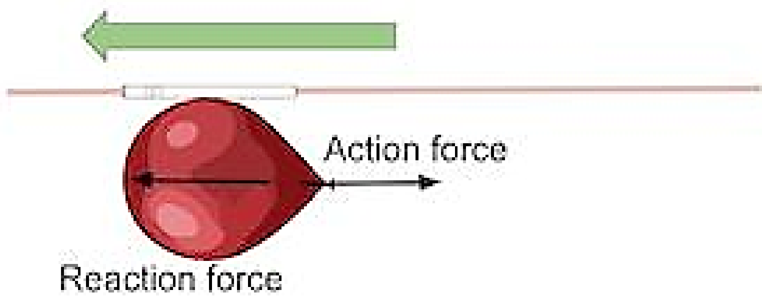
(hridhya32, sd)
</td></tr>
<tr><td>YouTube reference</td><td>https://www.youtube.com/watch?v=erghLWXDScI
In this YouTube reference, Newton's first law is explained. You can show the reference after the experiment.</td></tr>
<tr><td>Didactic suggestion</td><td>Let the students do the experiment themselves so they see what happens.</td></tr>
</table>

7. Newton's Third Law

Competence-based Curriculum	S1 Physics - Mechanics - unit 4 Newton's Laws of Motion (I) Curriculum physics page 23.	
Main ideas	For every action, there is a reaction equal to the first action but in the opposite direction.	
Key question	Why is the balloon moving forward?	
Necessary materials	A balloon, a straw, a long string, tape and a clothespin.	
How to make it	1. Put the straw over the string. 2. Hang the string out, connect one end to something. (a tree, a balk outside) 3. Blow up the balloon and close it temporarily with a clothespin. 4. Tape the balloon on the straw. (tape it preferably in the middle of the stray and the middle of the balloon.)	   (eKunji, sd)
Schematic reference	 (puddlewonderfullearning, sd)	

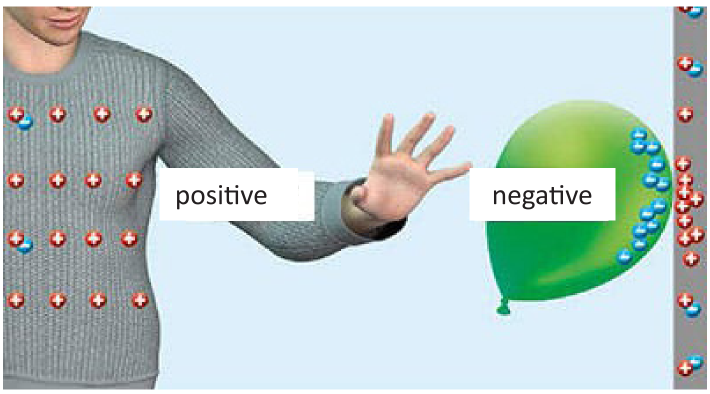
Experiment	Ask the student
1. Hold the string and the blown up, connected balloon on one end (make sure the opening of the balloon is pointed your way). Hold it at the beginning of the string.	2. What do you think will happen when we release the clothespin? In which direction will the balloon move? Why would this happen? What is the cause?
3. Release the balloon by disconnecting the clothespin from its opening. Keep holding the string.	4. What did you see? What happened? Which force caused the balloon to move forward? Can you draw the direction of the balloon? Can you draw the direction of the force that causes the balloon to move?

Possible student misconceptions	Not every action gives a reaction. Often nothing happens, for example when you press against a wall.

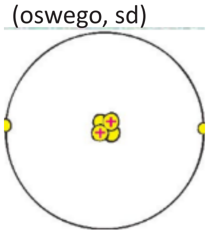
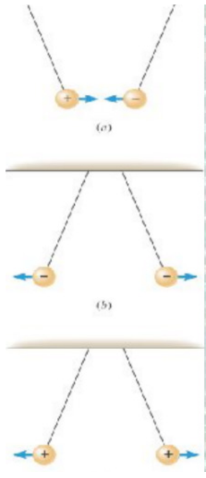
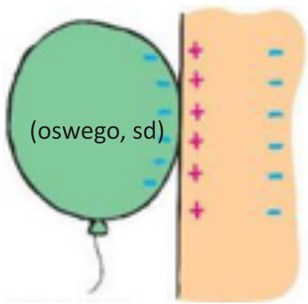
Explanation	For every action, there is a reaction equal to the first action but in the opposite direction. The action force is the force of the balloon on the air. The air is pressed out the balloon in the direction that is opposite to the direction of the final motion. That final motion is caused by the reaction force. The reaction force is the force of the air working on the balloon. F1 (action force) = - F2 (reaction force)  (study.com, 2003-2019)

YouTube reference	https://www.youtube.com/watch?v=TVAxASr0iUY In this YouTube reference, Newton's third law is explained. You can show the reference after doing the experiment. Only show the parts that we discussed during the experiment (0:00 – 2:07).
Didactic suggestion	Make a drawing of the experiment and draw the direction of the forces that are applied. (action force versus reaction force)

8. Electrostatics

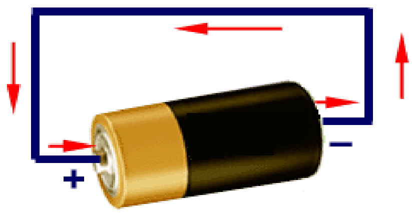
Competence-based Curriculum	S1 Physics – Electricity and magnetism - unit 11 Electrostatic (I) Curriculum physics page 35.	
Main ideas	When dissimilar substances are being rubbed together, they often get 'charged'. They get an ability to attract or repel other objects. We call this electrostatic force.	
Key question	Why does the balloon stick to the wall?	
Necessary materials	A balloon, a wall and a piece of cloth.	
How to make it	1. Blow up the balloon. 2. Tie the balloon. 3. Rub the balloon over a piece of cloth.	  (stevespanglerscience, 2018)
schematic reference	 (webnet.nl, 2016)	

Experiment	Ask the student
1. Hold the balloon next to the wall. Release the balloon.	2. What do you see? What happens with the balloon? Which position is it going to?
2. Rub the balloon over the clothing for about 30 seconds.	
3. Hold the balloon next to the wall. Release the balloon.	5. What do you see? What happens with the balloon? Which position is it going to? 6. What is causing the balloon to stick at the wall? What happened after we rubbed the balloon over the clothing?

Explanation	(oswego, sd)  An atom is made of a core with protons and neutrons. Protons are positively charged, and neutrons don't have any charge. Around the core there is a cloud of electrons, they are with as many as the protons but are negatively charged. When dissimilar substances are being rubbed together, they often get 'charged'. Rubbing causes a movement of net charge (electrons) from one object to another. That movement makes one object negative (with more electrons) and the other positive (with less electrons). Charged objects can attract or repel other objects.	 (oswego, sd)
	 (oswego, sd) When two objects have the same type or charge, they will repel each other. When two objects have a different type or charge, they will attract each other. The negatively charged balloon polarizes the wall (the electron cloud of the atoms of the wall is pushed away from the balloon) and creates a positively charged surface. The balloon sticks to positively charged layer of the wall, which is closer than the repulsive negative layer.	

Simulation	https://phet.colorado.edu/sims/html/balloons-and-static-electricity/latest/balloons-and-static-electricity_en.html Show the students the PhET simulation, let them look for other objects they can charge.
Didactic suggestion	If the students don’t remember the presence of protons and electrons, you need to introduce it to them again. Draw the balloon with the charges.

9. Heating effect of an electrical current

Competence-based Curriculum	S1 Physics - Electricity and magnetism - unit 12 Current Electricity (I) Curriculum physics page 37.
Main ideas	Electric current has a heating effect on a substance.
Key question	Why is the aluminium foil heating up?
Necessary materials	An AA battery and a piece of aluminium foil.
How to make it	1. Take a loaded AA battery. 2. Wrap the aluminium foil around the battery, make sure it's completely covered.  (youtube, 2018)
schematic reference	 Flow of electrons Aluminium foil (wire) Battery (source) (quickstudylabs, sd)

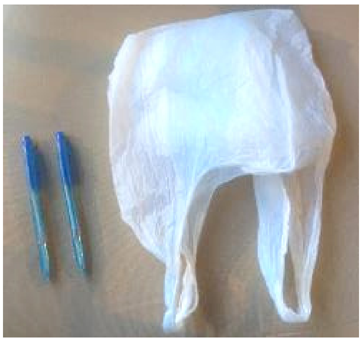
Experiment	**Ask the student**
1. Hold the battery without the aluminum foil around it.	2. What happens when you hold the battery? What do you feel? Does electricity come out of the battery?
3. Wrap the aluminum foil around the battery. Let the students feel the battery now.	4. What happens when you hold the battery? What do you feel? Does the electricity come out of the battery? Why do you think this? What can we link with electricity? What did you feel?

5. Now use a bit less aluminum foil to wrap around the battery	6. What happens when you hold the battery? What do you feel? What is the difference? What can we link with electricity? What did we change?

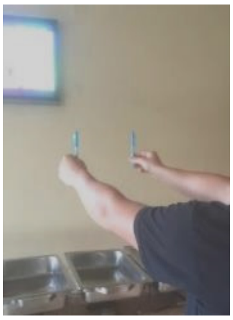
Possible student misconceptions	When a material heats up from electricity, it will keep heating up until it is on fire.

Explanation	Electrical energy can be converted into heat energy. Three elements affect the heat that is converted by an electric source. - Amount of current - The resistance of a conductor/substance - The time of the current flow. **Temperature** If a substance has a high resistance to an electrical current, it will not heat up (or heat up so minimal that you can't feel it) or take a longer time. If a substance has a low resistance to an electrical current, the substance can heat up fast. Conclusion: When the resistance of a substance through which electricity flows, is low, the substance will heat up.
Simulation	https://phet.colorado.edu/en/simulation/legacy/battery-resistor-circuit https://phet.colorado.edu/en/simulation/legacy/resistance-in-a-wire Show the students the PhET simulation after doing the experiment.
Didactic suggestion	Give a revision about electrical current and its symbols. Give them the table and name the different parts which are critical for this experiment.

10. Air resistance

Competence-based Curriculum	S2 Physics - Mechanics - Motion - unit 2 Quantitative analysis of linear motion (effects of air resistance on moving objects) Curriculum physics page 45. S2 Physics - Mechanics - Forces - unit 3 Friction force (other resistance forces) Curriculum physics page 46-47.
Main ideas	An object in motion experiences a resistance force, caused by the air it's traveling through. It's called the air resistance.
Key question	What factors affect the air resistance?
Necessary materials	Two pencils and one (plastic) bag. 

How to make	Attach a pencil to the bag, like shown in the picture.	

Experiment		**Ask the student**
1. Take a pencil in each hand. Hold them next to each other in front of you.		2. If I let the pencils fall on the ground, which one will reach the ground first? Why?
3. Let the two pencils fall on the ground from the same height.		

4. Attach the bag to one pencil. Hold it next to each other in front of you.		5. Which of the two objects has the biggest mass? 6. If I let both objects fall on the ground, which one will reach the ground first? Why?
7. Let both objects fall on the ground from the same height.		8. Why is the pencil with the bag falling slower? 9. Which variables are different if you compare both objects? Compare the surface of the pencil with the bag and the pencil without the bag. Which one is the biggest? Has the mass an influence on the falling object?

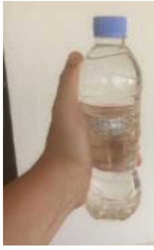
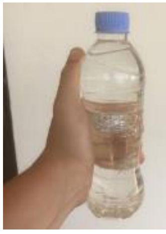
Possible student misconceptions	The pencil with the bag has a bigger mass than the pencil without a bag. The object with the biggest mass will reach the ground first.

Explanation	The pencil with the bag is falling slower because it has a bigger surface. The bigger the surface, the bigger the air resistance force. The pencil with the bag has a bigger mass than the pencil without the bag. The mass of an object has no influence on the air resistance force. Example: parachute	

11. Density: Cartesian Diver

Competence-based Curriculum	S2 Physics - Mechanics - Force - unit 4: Density and Pressure in Solids and Fluid (floating and sinking) Curriculum physics page 48-49.
Main ideas	A massive body can float, sink or suspend in a liquid. The behaviour of the body depends on the density of that body and the liquid.
Key question	Why is the aluminium object sinking and floating in water?
Necessary materials	Aluminium foil and a bottle of water. 
How to make **How to do**	Make a ball of the aluminium foil and put it into a bottle of water. Making the ball requires some trial and error. You should determine whether the ball is compressed enough or not. You can test by putting it in the bottle and closing it. If you don't press, the ball should float. If you press the bottle, the ball should sink. If the ball is always sinking, it's compressed too hard. If the ball isn't sinking when you press the bottle, it is not compressed enough.   

Experiment	**Ask the student**
1. Take the bottle and show it to the students. Don't press the bottle, the ball should float 	2. What do you see? What do you know about the density of the ball? 3. Compare the density of the ball with the density of the water.

4. Press the bottle. The ball will sink to the bottom.   	5. What have you observed? What happened? What do you know about the density of the sphere when it was sinking? 6. Why is the density of the sphere changing? What did I do? What happens with the volume of the ball when I'm pressing the bottle?
7. Press the bottle just hard enough so the sphere remains in the middle of the bottle. 	8. What do you know about the density of the ball when it was in suspension?

Possible student misconceptions	The ball is moving downwards because the pressure of the air above increases when the bottle is pressed.

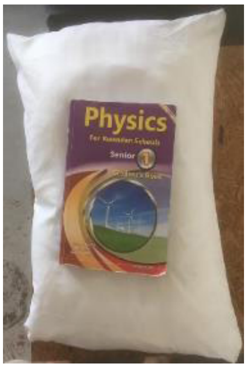
Explanation	If you hold the bottle without pressing it, the ball of aluminium is floating. Be aware that a ball made of only aluminium would sink, but the ball is not only made of aluminium. It also contains air. The ball is floating because the density of the aluminium + the air inside the sphere is lower than the density of the water. If you press the bottle, the ball starts to sink. When the bottle is pressed, the aluminium is pressed closer to each other and the air inside the ball is compressed. The volume is decreasing but the mass remains the same. That means that the density of the ball is increasing. The density of the sphere becomes bigger than the density of the water. The result is that the sphere starts sinking.

12. Pressure in solids

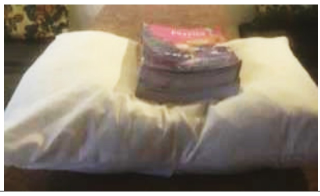
Competence-based Curriculum	S2 Physics – Mechanics – force - unit 4: Density and pressure in Solids and Fluid Curriculum physics page 48.

Main ideas	The pressure on a surface is the force that acts on that surface, divided by its area.

Key question	What is pressure? What are the variables of pressure?
Necessary materials	A pillow (soft) and two heavy books. 

Experiment		Ask the student
1. Lay the book horizontally on the pillow. 		2. What do you notice on the pillow if you put the book on top of it?

3. Place the book vertically on the pillow. Don't push, only help to stabilise.		4.What do you observe? Which quantity has changed? What changed about the contact area? Which quantity remained the same? Has the mass of the object changed? Has the force of gravity changed? When is the pillow more pressed in? What do you know about the pressure?
		

5. Lay the book horizontally again. Lay a second book on top.  	6. Which quantity has changed? What changed about the mass? What changed about the force of gravity? Which quantity remained the same? When is the pillow more pressed in? What are the variables of pressure?

Possible student misconceptions	Pressure depends only on the mass of an object.

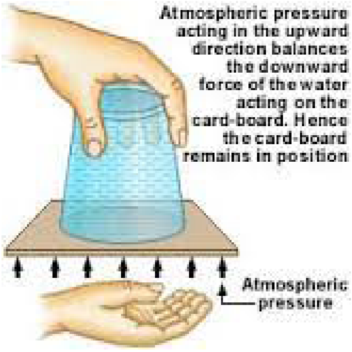
Explanation	$\text{Pressure} = \frac{\text{Force}}{\text{area}}$ $\left(P = \frac{F}{a}\right)$ When a book lays horizontally on a pillow, the pillow will fall in a little bit. But if you place the book vertically, the pillow will fall in more, because the contact area has changed. If the contact area decreases and the force remains the same, the pressure will increase. The force on the pillow is the force of gravity of the book. The force doesn't change, because the mass of the object stays the same and the object is in rest. The pressure can also change if the contact area remains the same and the force changes. The force of gravity increases when the mass increases. The pressure increases when the force increases, and the pressure decreases when the area decreases. The shape of the pillow does not change because of the force, but because of the pressure. The change of shape depends on the force and the surface area.
Didactic suggestion	This experiment is a good introduction to unit 4 of S2.

13. Atmospheric pressure: magic cardboard

Competence-based Curriculum	S2 Physics - Mechanics - Pressure - unit 7: Archimedes principle and atmospheric pressure Curriculum physics page 52.	
Main ideas	The pressure of the atmosphere works in all directions.	
Key question	What is air pressure? In which directions is air pressure working?	
Necessary materials	A glass filled with water and a piece of cardboard.	
How to make **How to do**	1. Fill the glass with water and put the cardboard on top of it. 2. Press the cardboard on the glass while turning everything around.	
	3. Release your hand from the cardboard.	

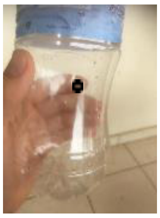
Experiment	Ask the student
5. Show the glass filled with water, covered with the cardboard to the students.	6. What will happen if I turn the glass over?
7. Turn the glass upside down.	8. What do you see? Why are the cardboard and the water not falling on the ground? What is pushing the cardboard downwards? What is pushing the cardboard upwards? Which pressure is bigger, the pressure of the water or the pressure of the air? In which direction is the air pressure working?

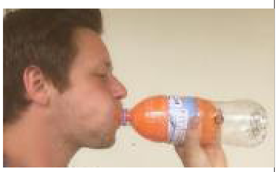
Possible student misconceptions	Atmospheric pressure is only pushing objects downwards. The water in the glass is sucking the cardboard upwards.

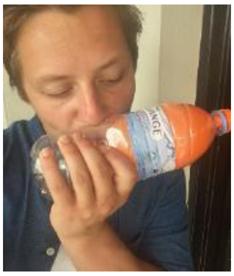
Explanation	The air pressure exerted on the cardboard from underneath is greater than the pressure of the water exerted from above. This way the card can hold up the water and doesn't fall.  (Enright, 2013)
YouTube reference	https://www.youtube.com/watch?v=65T4ReLkjCg This movie shows step by step how to do the experiment.
Didactic suggestion	This experiment can be used during the engage and excite phases.

14. Atmospheric Pressure: magic balloon

Competence-based Curriculum	S2 Physics – Mechanics – Pressure - unit 7: Archimedes principle and atmospheric pressure Curriculum physics page 52.
Main ideas	The atmospheric air has a pressure that works in all directions.
Key question	What is air pressure? In which directions is air pressure working?

Necessary materials	A plastic bottle and a balloon.	
How to make	1. Make a little hole in the bottle (diameter: 0,5 cm)	
	2. Put the balloon inside of the bottle and attach it to the top.	

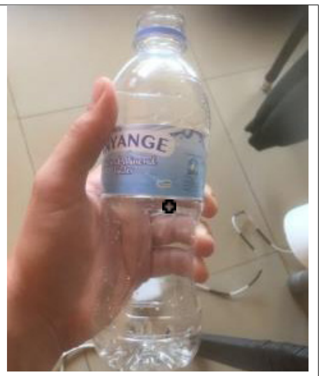
Experiment	**Ask the student**
Make sure that the students don't know anything about the hole in the bottle before you do the experiment. That way, they won't understand why you can blow up the balloon and they cannot. 1. Hold your finger next to the hole (marked in black) and blow up the balloon.  2. Now, let a student try to blow the balloon, but you hold the bottle. Press your thumb on the hole, so the air inside the bottle cannot escape.	3. Why can I blow up the balloon and the students not?

4. Show the hole to the students. Explain them what you did when you were blowing and why they were blowing.		5. Why is it impossible to blow up the balloon when the hole is covered? What do you know about the air inside of the bottle?
6. Take the air out of the bottle, through the hole, by ‘sucking’ with your mouth.		7. We were able to enlarge (make bigger) the balloon by blowing air inside of the balloon from the top. Is there another way to blow up the balloon? What will happen if the pressure around the balloon decreases? How can we let the pressure decrease?

Possible student misconceptions	The balloon is expanding because there is air ‘sucked’ into the balloon.

Explanation	You can only blow up the balloon inside of the bottle if the balloon has enough space to expand. If there is a hole in the bottle, the balloon can push the air that is inside of the bottle outside (through the hole). If the hole is covered, the air cannot be pushed outside, so it stays inside. It has a certain pressure that resists us to blow up the balloon. You can also enlarge the balloon, by taking the air, that is surrounding the balloon inside of the bottle, away. That way, you decrease the pressure inside the bottle. The atmospheric pressure is pushing the balloon deeper into the bottle, because it has a higher pressure than the pressure of the air inside of the bottle.
YouTube reference	https://www.youtube.com/watch?v=_CXd2h5O8OU This movie shows the last part of the experiment (taking out the air through the hole) and explains it.

15. Atmospheric pressure: hole in a bottle

Competence-based Curriculum	S2 Physics - Mechanics - Pressure - unit 7: Archimedes principle and atmospheric pressure Curriculum physics p. 52.
Main ideas	The atmosphere exerts a pressure in all directions.
Key question	What is air pressure? In which directions is the exerting pressure?
Necessary materials	A plastic bottle with a little hole (diameter = 0.5 cm) and water. 
How to make **How to do**	1. Make a hole with a diameter of 0.5 cm in the middle of the bottle. 2. Fill the bottle with water. Make sure that the level of water almost reaches the height of the hole. 3. Hold the bottle horizontal in front of you. (The water flows through the hole. If you push on the bottle, the water will even flow out faster) 4. Put your thumb into the bottle. (The water stops running)  

Experiment	Ask the student
1. Show the bottle (filled with water) to the students.	2. What will happen if I hold the bottle horizontally, with the hole downwards? 3. Why will the water flow on the ground?
4. Conduct the full experiment.	5. What have you seen? What happened with the water after pushing in my thumb? Why is the water not dropping out the bottle when I put in my thumb? What is pushing the water upwards?

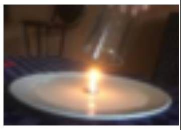
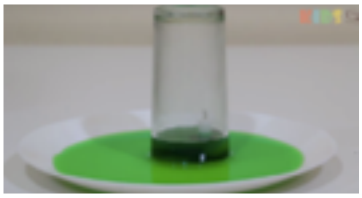
Possible student misconceptions	Atmospheric pressure is only working downwards.

Explanation	If the bottle of water is opened The water is flowing through the hole because the atmospheric pressure of the air inside the bottle and the hydrostatic pressure are pushing the water downwards. Together they are pushing harder downwards than the atmospheric pressure (from underneath, through the hole) upwards. If the bottle is closed (by pushing in your thumb) The water is not flowing through the hole anymore, because no fresh air can enter the bottle anymore. The air pressure inside the bottle together with the hydrostatic pressure (pushing the water downwards) is equal to the atmospheric pressure from underneath (which is pushing the water upwards).

Didactic suggestion	This is a very short experiment and can be discussed in 5 minutes. You can use this experiment as an explore experiment. Try to do it during the same lesson as the experiment 'atmospheric pressure: magic cardboard'.

16. Gas Laws

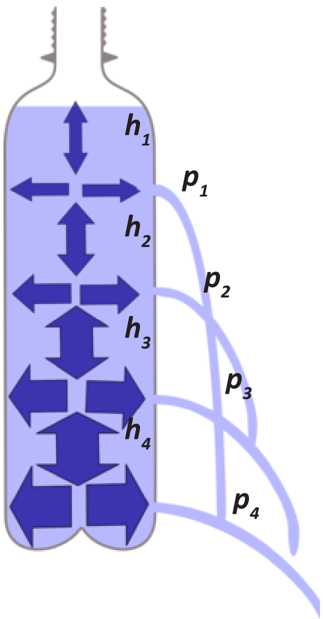
Competence-based Curriculum	S2 Physics – Thermodynamics – Gas laws - unit 10: Gas laws' experiments Curriculum physics page 58.
Main ideas	If the temperature of a gas decreases, the pressure and the volume of that gas will decrease. The atmospheric air is pushing the water into the glass.
Key question	Why is the water in the glass rising?
Necessary materials	A glass, a plate, water (coloured if possible), a candle and matches (or a lighter)

How to make **How to do**	1. Fill the plate with water. Coloured water is even better but isn't necessary. Let the candle float in the middle of the plate and light it.	  
	2. Cover the candle with a glass.	
	3. The candle stops burning. The level of the water inside the glass rises. (you can see this effect much better, if you use coloured water)	

Experiment	Ask the student
1. Let the candle float in the water and light it.	2. What will happen with the burning candle if I cover it with the glass? What will happen with the water?
3. Cover the candle with the glass.	4. What do you see? What happened with the candle? What happened with the water? Why is the water moving upwards in the glass? 5. What is different with the air in the glass before and after the light went off? What do you know about the pressure of the air before and after? What happened with the volume of the air inside the glass? What is pushing the water upwards?

Possible student misconceptions	The water is sucked up in the glass
Explanation	If you cover the candle with the glass, there will be a quantity of air that is locked up in the glass. During the first seconds, the candle is burning and the air that is locked up obtains a high temperature. After a few seconds, all the oxygen has been used and the light goes out. This means that the temperature of the air inside is decreasing. A decreasing temperature causes a decreasing pressure. So, the pressure above the water inside the glass becomes lower than the atmospheric pressure on the water outside of the glass. The result is that the atmospheric pressure pushes the water from outside the glass to the inside. The level of the water inside the glass is rising. The water is not sucked up, because 'sucking' doesn't exist. There must always be something that is pushing upwards instead of 'sucking' upwards. In this case, it's the atmospheric air that is pushing upwards.
YouTube reference	https://www.youtube.com/watch?v=HM4BIWFh6Xs This movie shows step by step how to do the experiment.
Didactic suggestion	The experiment is a good example of the formula $\frac{p1.v1}{T1}=\frac{p2.v2}{T2}$ In situation 1 (before covering the candle with the glass) there was a high temperature, a high pressure and a big volume. In situation 2 (after covering) the temperature, volume and pressure decreased. The solution of both divisions remains the same. It can be interesting to use this experiment to prove the formula.

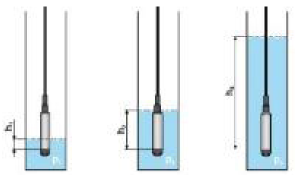
17. Hydrostatic Pressure

Competence-based Curriculum	S2 Physics - Mechanics – Pressure – unit 5 Measuring liquid Pressure with manometer. Curriculum physics page 50..
Main ideas	The lower the point in a liquid, the more pressure it feels.
Key question	Why is the lower water jet more powerful than the upper one?
Necessary materials	A plastic bottle, a needle and some water.
How to make it	1. Make holes in the bottle at different levels. 2. Fill the plastic bottle with water.  (winkelhage, 2019)
schematic reference	 (thenakedscientists, 2010) $p = h \times \rho \times g$ $p_1 < p_2 < p_3 < p_4$

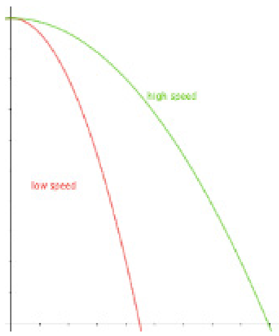
Experiment	**Ask the student**
1. Show the students the filled leaking bottle.	2. What do you see? What is the difference the water jets? Is it what you expected? What will happen when we perform some more pressure on the bottle? What will change with the water jets?

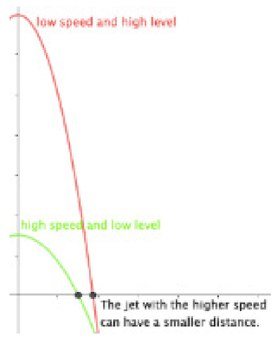
3. Perform some pressure on the bottle	4. What do you see? Is it different from what you expected? What could be the explanation? What is the difference between the holes in the bottle?

<table>
<tr><td>Possible student misconceptions</td><td>The pressure in a liquid is the same on each level</td></tr>
<tr><td>Explanation</td><td>Hydraulic pressure depends on the height of the liquid, the density and acceleration due to gravity. ($p = h \times \rho \times g$)
The deeper a point in a liquid, the more it is subjected to pressure. When a liquid is streaming through a hole, the water jet has a certain speed. The higher the pressure in the liquid on the level of the hole, the higher the speed of flowing out. This speed is a measure for the pressure.
The distance before the water jet reaches the ground is not a good measure of the pressure. This distance depends on both the speed and on the level of the hole. If the hole is close the ground, the speed will be high, but the distance can be smaller than a higher hole.



(pvl, 2019)





</td></tr>
<tr><td>PhET simulation</td><td>https://phet.colorado.edu/en/simulation/under-pressure
Show the students the PhET simulation after doing the experiment. In this simulation you can observe the amount of pressure at each level.</td></tr>
<tr><td>Didactic suggestion</td><td>Fill the bottle with enough water so students see the difference clearly. Draw the bottle and write the explanation with every level like it is done in the schematic reference.</td></tr>
</table>

18. Pascal's Principle

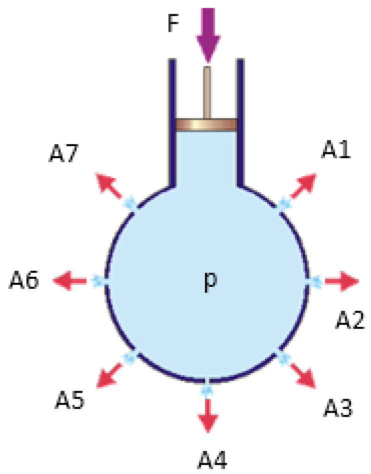
Competence-based Curriculum	S2 Physics - Mechanics - The theory of Pascal - unit 6 Application of Pascal's principle. Curriculum physics page 51.
Main ideas	If there is a force applied on a contained liquid, the pressure will increase equally and in every direction throughout the liquid.
Key question	If there is a force applied on a contained liquid, will the pressure increase equally in every direction through the liquid?
Necessary materials	A plastic bottle, a needle and some water.

How to make it	1. Make some holes in the middle of the bottle with a sharp material like a needle. Try to make the holes on the same horizontal level, as you see on the picture. 2. Fill a bottle with water. Make sure it is full. 3. Close the bottle with the cap.	 (Putte, 2014)

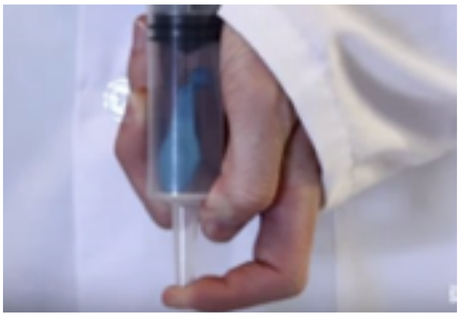
Schematic reference	

Experiment	Ask the student
1. Show the leaking bottle	2. What happens with the water in the bottle? Are the water jets everywhere the same or do you see a difference? Out of which hole flows the most water? What do you think will happen when we press on the bottle?

3. Press on the bottle	4. What happens with the water jets now? Out of which hole flows the most water? What happens with the pressure in the liquid? Is it the same everywhere or is it different? Why do you think that? How can you that?

Possible student misconceptions	The pressure applied on a liquid is transmitted unequally through the liquid. The fluid closest to the force will feel the most pressure.
Explanation	 (sialafisica, sd) A pressure applied to a liquid is transmitted unchanged in all directions. This means that if there is a pressure applied on a liquid, every point in the fluid, anywhere, feels the same pressure change. P= pressure change F= Force A= Surface (A1=A2=.....=A7) P=F/A1=F/A2=.....=F/A7
Didactic suggestion	Develop the formula together with the students during the experiment (write it on the blackboard). Use the image to make it clear.

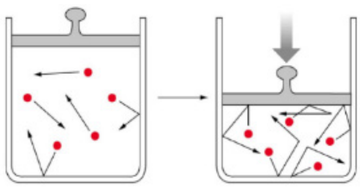
19. Boyle's Law

Competence-based Curriculum	S2 Physics - Thermodynamics - gas law's - Unit 10: Gas laws' experiments Curriculum physics page 58.
Main ideas	When you reduce the volume (of a closed place), the pressure increases. When you increase the volume (of a closed place), the pressure decreases.
Key question	Why is the balloon getting smaller when you put the syringe in? Why is the balloon getting bigger when you pull the syringe backwards?
Necessary materials	A big plastic syringe and a small balloon (=water balloon).
How to make it	1. Blow up the little balloon. (Don't blow it up too much, it must still fit in the syringe.) 2. Tie the balloon when you are sure it still fits into the syringe. 3. Open the big syringe and put the little balloon inside. 4. Close the syringe again.    (Guys, 2014)

Experiment	Ask the student
1. Put the syringe backwards and forwards without putting your finger on the opening	2. What do you see? What is in the syringe? What is in the balloon? What do you see? What don't you see?

3. Pull the syringe backwards (all the way) 4. Put your finger on the opening of the syringe Put the syringe in (with your finger still on the opening)	5. What do you see? What happens with the balloon when you put the syringe in?
6. Pull your finger off the opening of the syringe	7. What is happening with the air inside the syringe? What happens with the balloon? What is happening with the air inside the balloon when you release your finger?
8. Pull the syringe forward (all the way up until the balloon) 9. Put your finger on the opening of the syringe. Pull the syringe backwards (With your finger still on the opening)	10. What do you see? What happens with the little balloon when you put the syringe backwards? What is happening with the air inside the syringe?
11. Pull your finger off the opening of the syringe	12. What happens with the balloon? What is happening with the air inside the balloon when your release your finger?

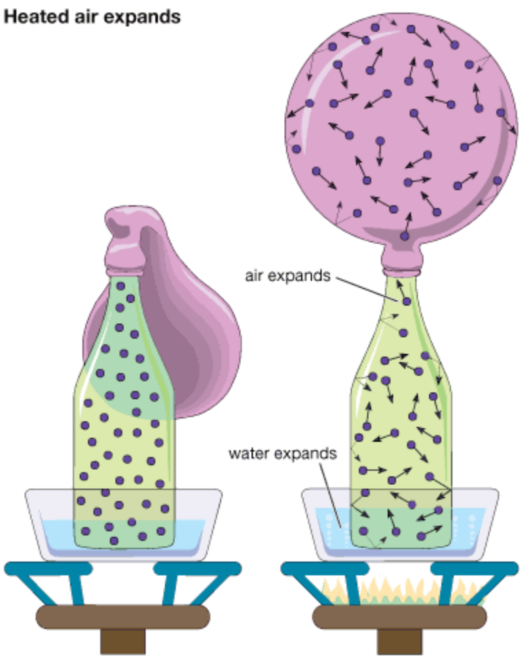
Possible student misconceptions	The air is pushed out of the balloon when pressure is exerted on the syringe. Conversely, there is air sucked into the balloon when you pull the syringe.

Explanation	Boyle's Law states $: p_1 V_1 = p_2 V_2$  (Madeline, 2014) When you increase the volume (of a closed space), the pressure is reduced. So, if you pull the syringe, the air pressure inside of the syringe decreases and vice versa. The air inside the syringe and outside the balloon is pressing on the balloon. The air inside the balloon is pressing back with an equal pressure. When the pressure from outside the balloon is decreasing, the air inside the balloon will expand until its pressure becomes equal gain. The volume of the balloon has become bigger. When you reduce the volume (of a closed space), the pressure increases. Because of that, the balloon is pressed to a smaller shape.

YouTube reference	https://www.youtube.com/watch?v=eR49g3ubTBg This video shows how to do the experiment.

Didactic suggestion	Let the students write down step by step what happens with the air inside. Make the formula together by using the drawings.

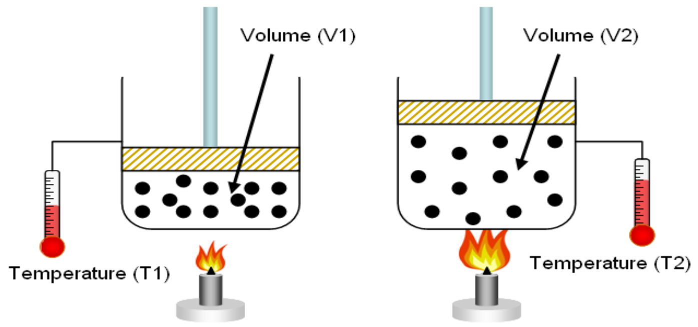
20. Charles' Law

Competence-based Curriculum	S2 Physics - Gas laws - unit 10 Gas laws' experiments Curriculum physics page 58.
Main ideas	Main ideas When you heat up gas (air), the gas expands when the pressure remains the same.
Key question	Why is the balloon expanding?
Necessary materials	A plastic bottle, a balloon and hot water (boiling water)
How to make it	1. Place the balloon over the top of the plastic bottle. 2. Place the plastic bottle in hot water or let hot water run over the bottle until the balloon expands.
	 (youtube, sd)
schematic reference	 (britannica, 2019)

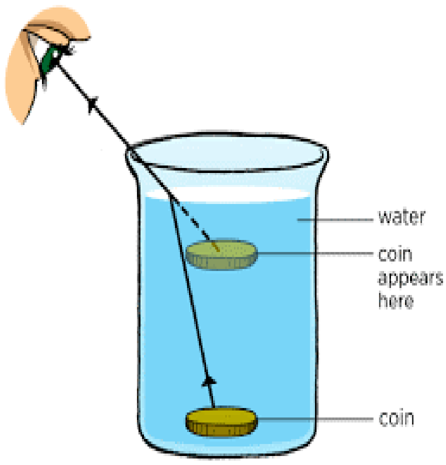
Experiment	Ask the student
1. Show the balloon which is installed over the glass bottle.	2. What do you see? What elements are present? What is present in the balloon and bottle?

3. Put the glass bottle in hot water. Or let hot water run over the plastic bottle until the balloon swells up.	4. What happens? What do you see? Why is the balloon expanding? What is expanding inside the balloon?

Possible student misconceptions	There is nothing in the plastic bottle. The plastic (where the balloon is made of) expands when heated.

Explanation	 (astrocampschool, 2015)  (slideplayer, 2019) When you heat up gas (air), the gas expands, and the pressure remains the same. When you cool down gas (air), under equal pressure, the gas volume increases.
Simulation	https://phet.colorado.edu/sims/html/states-of-matter-basics/latest/states-of-matter-basics_en.html Show the students the PhET simulation after doing the experiment to make it more clear.
Didactic suggestion	Use the images (draw them on the board) to make them more clear. Draw the particles and their behavior so that they see the difference.

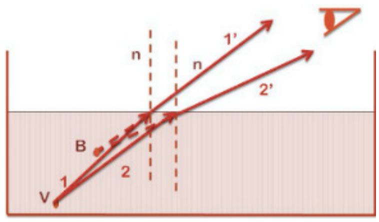
21. Refraction of light

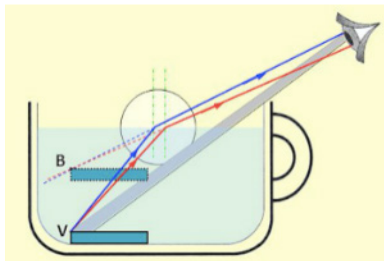
Competence-based Curriculum	S2 Physics - Light - unit 12 Refraction of light Curriculum physics page 86.
Main ideas	When light is moving from one medium to another, its direction will change. The angle of change of direction (the angle of refraction) depends on those two mediums.
Key question	Why does the coin appear higher in the glass when it is filled with water?
Necessary materials	A glass, some water and a coin.
How to make it **How to do**	1. Put the coin in the middle of the glass. (on the bottom) 2. Fill the glass with water.  (ceipfuentesclaras, 2018)
schematic reference	 (skiitians, 2006-2019)

Experiment	**Ask the student**
1. Show the students the coin in the glass without any water inside. Let the students look at the coin as indicated above in the picture. Make sure they are at the right position and don't move their heads.	2. What do you see? At what position lies the coin?
3. Slowly fill the glass with water. Make sure students see that the coin doesn't move.	4. What do you see? At what position lies the coin? Why do you think so?

5. Let the students look at the coin as indicated above in the picture. Make sure they are at the right position and don’t move their heads.	6. What is different from before? What could be the cause of this? Does the coin still lie at the same position?

Possible student misconceptions	The coin is not at the bottom but higher. The position of the coin has changed.

<table>
<tr><td rowspan="2">Explanation</td><td>When light is moving from one medium to another, its direction will change. The angle of the change of direction (the angle of refraction) depends on those two mediums.
Now we look at the case of the coin on the bottom of the glass. The beams of light depart from the coin (in point V on the pictures) and move in all directions. A lot of beams move upwards. They move from water to air. That results in a refraction. Some of the refracted beams reach our eyes, enabling us to see the coin.</td><td>

(Sanders, 2015)


(Desmet, 2015)</td></tr>
<tr><td colspan="2">However, our brains don’t “know” that beams refract when they cross from one medium to another and think that the beams are moving straight. So, what they do is lengthening them, until they cross (in point B on the pictures). The point where the brains think the beams cross, is higher than the point where they cross in reality.
If we draw the beams for every point of the coin, we can predict where our brains “thinks” the coin to be.</td></tr>
</table>

Simulation	https://phet.colorado.edu/sims/html/bending-light/latest/bending-light_en.html Show the students the PhET simulation after doing the experiment.

Didactic suggestion	This is a rather difficult experiment (difficult explanation). Make sure that the students understand the theory of refraction before conducting the experiment.

22. Hydraulic Press

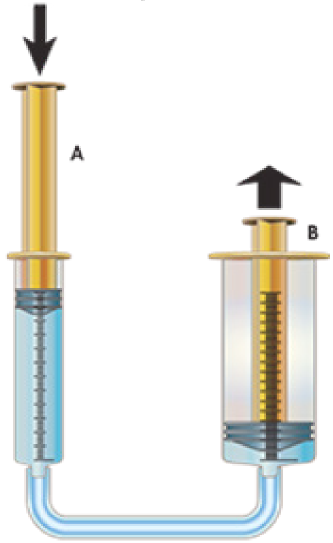
Competence-based Curriculum	S2 Physics - Mechanics - Force- unit 6 Application of Pascal's principle Curriculum physics page 51.

Main ideas	A small force on the small surface of a hydraulic press causes a large force on the larger surface. There is conservation of energy. The small force has to move over a large distance in order to move the large force over a small distance.

Key question	What happens if you exert a small force on a small surface with the force on a large surface (which are connected to the same liquid)

Necessary materials	Water, a connecting tube and 2 different sizes of syringes. You can use some water paint or ink.

How to make it	1. Take the 2 syringes (different size) and fill them both half full of water. Make sure there is no air left inside by pressing on the top syringe until the last bubble of air is gone. You can give the water a specific color, to make it more visual, but that is not necessary. You can use some water paint or ink. 2. Connect the syringes to each other. Use a tube to connect them. You have to push the tube on the top of the syringes. Make sure the tube is well connected, so it won't leak if you press in the syringes.	

schematic reference	(cellcode, 2019) 

Experiment	Ask the student
1. Show the hydraulic system.	2. What syringe would be the easiest to press in? Why do you think that?
3. The students try to press in the syringes and feel what happens	4. What did you feel? Which one was more difficult to push in? Is it different of what you expected? What can you conclude by this? What is the difference between the surface of the big syringe and the little one? What can you conclude by this?
5. Push in the back of the little syringe and show clearly what happens with the distance of the big syringe.	6. What do you see? Which syringe moves the most? Is there any link to the surface and the sizes of the syringes? What can you conclude by this?

Possible student misconceptions	Pushing at the back of the little syringe for a certain distance causes a movement of the backside of the other syringe with the same distance. It is harder to push the little syringe than the big one.

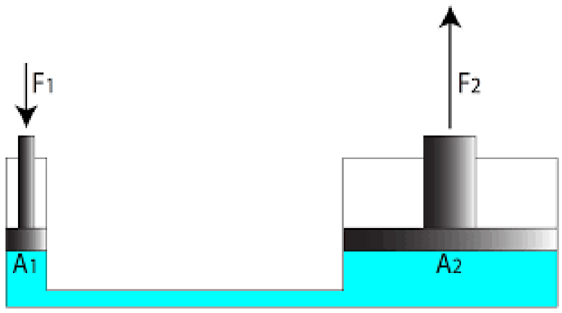
<table>
<tr>
<td>Explanation</td>
<td>
1. The pressure (p) is the same everywhere in the liquid. (See Pascal's Law.)

$$p1 = p2$$

$$(p = \frac{F}{A})$$

2. The replaced volume at both sides is also the same. If we exert a small force on a small surface, that force results in a large force on a large surface.

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$



(aplusphysics, 2017)

3. Based on that, we can bring in the distance x in the equation.

$$(A = \frac{v}{x}) \; F_1 * x_1 = F_2 * x_2$$
</td>
</tr>
</table>

Didactic suggestion	Develop the equation with the students during the experiment (write it on the blackboard). Use the image.

P.5 Practical application of 5Es and key aspects of STEM instruction in a Physics Lesson

In this video, https://youtu.be/hWAmgK36rUk , teacher Silas facilitated a physics lesson titled: "Application of Pascal's Principle". In the lesson, he used the 5E's model and applied some aspects of STEM instruction. As you watch the video, reflect on the questions below:

1. Explain to what extent the introduction is exciting and engaging learners.
2. Are learners engaged in practical activities? Are the activities related to the lesson concepts to address the key question? Explain your answer
3. Have the learners got an opportunity to elaborate on new challenges or application of learned concepts in real life experience?
4. What key aspects of STEM instruction were mostly used in the watched lesson? Are they relevant to the lesson?
5. What does the physics teacher need to do to make his physics lesson more inquiry based?

Appendix B: Biology materials

B.1 Examples of lessons plans with the 5E format

Lesson 1: Ecology and Conservation

School Name:				Teacher's name:			
Term	**Date**	**Subject**	**Class**	**Unit N°**	**Lesson N°**	**Duration**	**Class size**
2		**Biology**	**S2**	**2**	**3**	**40 minutes**	**44**

Type of Special Educational Needs and number of learners:	Special attention for learners with low English language skills
Topic area:	Ecology and Conservation
Sub-topic area:	Environmental biology
Unit title	Introduction to environmental biology
Key Unit Competence:	To be able to explain the concepts applied in environmental biology including interaction and interdependence of organisms.
Title of the lesson	Energy flow in ecosystems
Learning Objectives	
• **Knowledge & understanding**	Define the terms: food chain and food web Describe how energy is transferred between trophic levels.
• **Skills**	Construct and interpret simple food chains and food webs. Carry out analysis of the diagram showing a food chain.
• **Attitudes & Values**	Appreciate the role of green plants in terms of conversion and supply of energy to all living organisms. Appreciate the interdependence of living organisms.
Plan for this Class (location: in / outside	Inside and outside
Learning Materials (for all learners)	Chalk, chalkboard, pens, notebooks, 11 charts 'who eats what?' (self-made, instructions at the end of this lesson plan), 22 mini-white boards with erasable pens.
References	Student's Book Senior 2 Biology and Health Sciences for Rwandan Schools. p 35-37

Timing for each step	Description of teaching and learning activity		Core Ideas, competences and croscutting concept
	In excite/engage phase, students are asked where they obtain energy from and with a questioning they come to the key question: 'Which groups of organisms can be distinguished in a food chain?' In explore, the learners go outside (nature/garden) and collect organisms. Back in the classroom, they make food chains with the organisms found and a table that helps them to know who eats who. In explain, these food chains are discussed and the terms 'consumer, producer, heterotroph …' are taught. In elaborate phase, learners make a food chain as long as possible. In evaluate phase we check if they understand the content.		
	Teacher activities	Learner activities	
Introduction **5 min**	**Excite/Engage** Asks students: • Where do we obtain energy from? • What is the origin of our food? • Where do plants and animals get their energy from? *1. see under the lesson plan: Teacher tells students. • Write a chain of example organisms that feed each other (=food chain), with humans on top, on the mini whiteboard.	• Answers to questions: - from food: meat, vegetables, rice, potatoes, … - plants and animals - animals: from the animals or plants they eat, plants? - Plants make their own food by converting sunlight into chemical energy through the process of photosynthesis • think about the key question of the lesson. • Write on a mini white board a 'hypothesis' chain of organisms that feed on each other (=food chain), with humans on top	Start from daily life observations to introduce the key question of the lesson.

Develop-ment of the lesson **18 min**	**Explore** Teach concept 'food chain' based on their 'hypothesis'. Observe: Which groups of organisms can be distinguished in a food chain?' • outside: activity 2.4, steps 1., 2. (p. 38). • inside: activity 2.4, step 5. (p. 38) and the chart 'who eats what?'.	Learners take notes in their notebook. Learners do the activities in groups of 3-4 and note on mini whiteboards (or notebook).	Food chain: a chain of organisms that eat each other. Construct simple food chains.
10 min	**Explain** Ask for examples of food chains => note on blackboard *2. see under the lesson plan: Questioning + teaching + note on blackboard	Learners share their best examples of food chains Learners note in their notebook	Autotroph or producer: organisms that make their own food by converting sunlight into chemical energy through the process of photosynthesis. Heterotroph or consumer: organisms that feed themselves by eating other organisms. Herbivore: organisms that feed on plants Carnivore: organisms that feed on animals Omnivore: organisms that feed on plants and animals

5 min	**Elaborate** 'Make a food chain with the organisms in the table 'who eats who' that is as long as possible.'	Learners work in pairs and note their food chain on the mini-white board.	using a model (food chain) and data (table) to predict a possible food chain
Conclusion 2 min	**Evaluate** What is a food chain? Which groups of organisms can be distinguished in a food chain?	Answer: A food chain is a chain of organisms that eat each other and consist of a producer followed by an herbivore and a carnivore (consumers).	defining the core ideas of the lesson

*1. Teacher tells students: There is a chain of organisms that provide each other with the energy that these organisms consist of. Energy is transferred through this chain of organisms. We call such a chain of organisms a food chain. Therefore, if we want to examine how we and other organisms get energy, we have to examine what a food chain consists of. We examine this by looking closer at food chains: 'Which groups of organisms can be distinguished in a food chain?'

*2. Questioning + teaching + note on blackboard:

- Look at the first organism of each food chain. Which similarity do you see? (start all with plants)
- So, plants don't eat food, they make their own food. We call plants producers. The scientific name for producers is autotrophs. 'Auto' means 'myself' and 'troph' means 'food'. Write on the blackboard.
- Explain consumers, heterotroph, primary/secondary/tertiary consumer. Write on the blackboard.
- Is there a difference between the primary and secondary consumer? (1° eat plants, 2° eat animal)
- Explain herbivore and carnivore + write on blackboard.

Table: Who eats what?

Organism	Food of organism
blackbird	earthworms, berries
mole	insects, worms
grasshopper	grass
shrew (mouse)	insects, spiders, frogs, small birds
hawk	medium-sized birds
frog	snails, insects (dragonflies, caterpillars…)
beetle	caterpillar
caterpillar	leaves, roots of plants, grass
spiders	insects
snails	fresh parts of plants, death (parts of) plants
worms	death (parts of) plants
herbivore insects	roots, leaves, stems, fruits…
heron	frogs, moles, fish
bacteria	death plants and animals
mould / fungus	death plants and animals
small and medium-sized birds	insects (grasshoppers, caterpillars…), fruits, worms
mongoose	birds, snakes
chameleon	caterpillar, insects
snake	chameleon, mouse, frog…
tadpole	algae
dragonfly	tadpole
turtle	frog
owl	mouse
lizard	frog, spider, locust, insects

Blackboard schedule

- groups of 3-4 persons

- outside, 10 min: list all organisms you find.

- inside: construct several food chains using the organisms you have listed and the chart 'who eats who?'

Which groups of organisms can be distinguished in a food chain?

grass –> cow –> human
plants –> pig (pork) –> human
plants –> cucumber/potatoes/... -> human

Autotroph   Heterotroph

leaf –> caterpillar –> beetle -> frog –> shrew
plants –> herbivore insects –> spiders
plant –> caterpillar –> chameleon –> snake –> mongoose

producer | primary consumer | secondary consumer | tertiary consumer | quaternary consumer

food chains = chain of organisms that eat each other

Autotroph = producer: organism that make its own food by converting sunlight into chemical energy through the process of photosynthesis.
Heterotroph = consumer: organism that feed itself by eating other organisms.

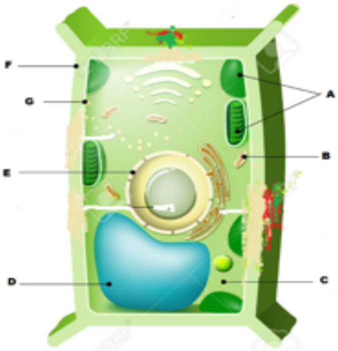
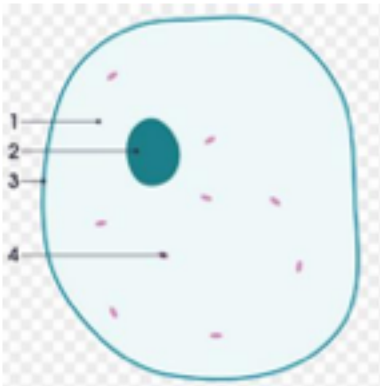
- Herbivore: organisms that feed on plants
- Carnivore: organisms that feed on animals

Lesson 2: Structure of the Cell

Term	Date	Subject	Class	Unit Nº	Lesson Nº	Duration	Class size
2		Biology	S1B	5	2	40 minutes	
Type of Special Educational Needs to be catered for				Slow learners: Special attention in teaching and learning			

Unit title	Cell structure
Key Unit Competence	To be able to differentiate between plant cell and animal cells using the photos of what is seen under the light microscope
Title of the lesson	Comparison between plant cell and animal cell
Instructional Objective	In this lesson the learner of S1 B should be able to: 1. To describe the structure of a cell membrane, nucleus, mitochondria and vacuole in a cell 2. To explain the function of a cell membrane, nucleus, mitochondria and vacuoles in a cell
Plan for this Class (location: in / outside)	Inside the Classroom
Learning Materials (for all learners)	Drawings (pictures)of plant and animal cell
References	G. Matenda and E. Ritchie (2016). Biology and Health Sciences for Rwanda S1 Student's Book, page 56-61

Timing for each step	**Description of teaching and learning activity**	**Generic competences and Cross cutting issues**
	In excite/engage; students in groups are given figures of animal and plant cells for them to label and they come to the key question: 'How do different functions of animal and plant cells result in differences in their structures? In explore, the learners compare the parts of photos of both plant and animal cells from their books to those seen under a light microscope. They answer the key question by completing a table. In explain, the function of each part for animal and plant cells is discussed to help students to know differences and similarities between the two types of cells. In elaborate, learners answer some challenging questions to expand their understanding. In evaluate, check what they learnt through questioning.	

	Teacher activities	**Learner activities**	
Introduction 10 min	**Excite/ Engage phase:** Teacher presents the figures and asks learners to label figures A and B in groups of 4 **Figure A**  **Figure B**  **Key question:** How do different functions of animal and plant cells result in differences in their structures?	Learners form teams of 4 people and answer the question by labeling the parts of figures A and B **Figure A: Plant cell** A: Chloroplast B: Mitochondrion C: Cytoplasm D: Vacuole E: Nucleus F: Cell wall G: Cell membrane **Figure B: Animal Cell** 1: Cytoplasm 2: Nucleus 3: Cell membrane 4: Mitochondrion Learners think about the key question of the lesson.	**Communication:** Through giving answers **Cooperation:** They cooperate in their groups

<table>
<tr>
<td>Development

30 min</td>
<td>15 min: Explore phase:
Teacher forms teams of 2 desks
Distribute the photos of plant and animal cells seen under a light microscope and ask learners to compare with the figures in their book to indicate which parts were seen under the microscope and which ones they didn't see.

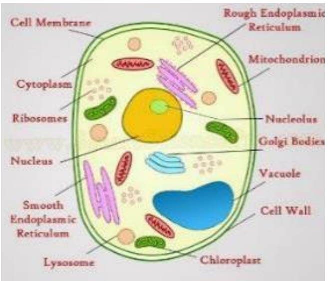


Fig 3: Plant cell seen under light microscope

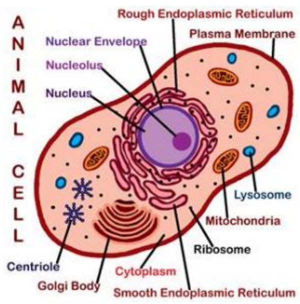


Fig 4: Animal cell seen under light microscope

Teacher helps students to answer the key question.</td>
<td>Learners try to find similarities and differences between structure of a plant and animal cells by indicating common organelles (similarities) to both plant and animal cells and those which are particular to each type of the cell. They should compare the pictures given by the teacher and those found in the student's book.

To answer the key question, students start by identifying common organelles (similarities) to both plant and animal cells and those which are particular to each type of the cell by filling the table below.
<table>
<tr><td>Organelle/ Parts of a cell</td><td>Plant cell</td><td>Animal Cell</td></tr>
<tr><td>Cell wall</td><td></td><td></td></tr>
<tr><td>Nucleus</td><td></td><td></td></tr>
<tr><td>Mitochondrion</td><td></td><td></td></tr>
<tr><td>Vacuole</td><td></td><td></td></tr>
<tr><td>Cytoplasm</td><td></td><td></td></tr>
<tr><td>Chloroplast</td><td></td><td></td></tr>
</table>
Answer:
<table>
<tr><td>Organelle/ Parts of a cell</td><td>Plant cell</td><td>Animal Cell</td></tr>
<tr><td>Cell wall</td><td></td><td></td></tr>
<tr><td>Nucleus</td><td></td><td></td></tr>
<tr><td>Mitochondrion</td><td></td><td></td></tr>
<tr><td>Vacuole</td><td></td><td></td></tr>
<tr><td>Cytoplasm</td><td></td><td></td></tr>
<tr><td>Chloroplast</td><td></td><td></td></tr>
</table>
Similarities between plant and animal cells: Cytoplasm, Mitochondrion, and Nucleus.
Cell wall, Chloroplast and large vacuole are specific to the plant cell.</td>
<td>Gender: boys and girls will give answers

Critical thinking: They think critically</td>
</tr>
</table>

<table>
<tr>
<td></td>
<td><u>10 min: Explain phase:</u>

Teacher explains the function of each part of the cell identified and how each part makes an animal or plant cell look different from another.

<u>5 min: Elaborate:</u>

Teacher asks questions to the learners

1. In which cell do we find large vacuole?
2. Answer by true or false: The cell wall is common between animal and plant cells.
3. Why do animal cells lack chloroplasts?</td>
<td>Learners will take notes on the function of each part of the cell.

Learners answer to the questions asked by teacher.

1.Plant cell
2. False
3. Because they do not do photosynthesis.</td>
<td>Communication: Through giving answers

Cooperation: They cooperate in their groups</td>
</tr>
<tr>
<td>Conclusion

5min</td>
<td><u>5 min: Evaluate:</u> Teacher asks questions to the learners to summarize the lesson.

Exercises

1. Identify 2 differences between plant and animal cells
2. Identify 3 similarities between plants and animal cells.
3. Fill in the gaps in the following table:

<table><tr><td>Parts of cell/ Organelle</td><td>Function</td></tr><tr><td>(a)------------------</td><td>Controls what enters</td></tr></table></td>
<td>Learners summarize the lesson

Answers

1. Differences
Animal cell: Cell membrane, small vacuole, centrioles/ centrosomes, flagella/cilia, small size (10-30 Micrometers) irregular or round shape
Plant cell: large vacuole, chloroplast, cell wall, large size (10-10 Micrometers in length) rectangular or cubic shape
2. Similarities
• They both have nucleus
• They both have Mitochondrion
• They both have cytoplasm
• They both have cell membrane</td>
<td>Communication: Through giving answers

Gender: Both boys and girls will give answer</td>
</tr>
</table>

<table>
<tr>
<td></td>
<td>
<table>
<tr><td></td><td>or leaves the cell</td></tr>
<tr><td>b)-------------</td><td>It is the site of chemical reactions that occur in the cell</td></tr>
<tr><td>Cell wall</td><td>(c)--------</td></tr>
<tr><td></td><td>Contains chlorophyll and carries out photosynthesis</td></tr>
<tr><td>Vacuole</td><td>(e)-------------</td></tr>
<tr><td>(f)------</td><td>Contain genetic material</td></tr>
</table>
</td>
<td>3. Answers:
(a) Cell membrane
(b) Cytoplasm
(c) Protect and give the plant cells a definite shape
(d) Chloroplasts
(e) Break down complex molecules
(f) Nucleus</td>
<td></td>
</tr>
<tr>
<td>eacher self-evaluation</td>
<td colspan="3"></td>
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</table>

B.2 Peer Instruction Examples

Example 1: Origin of Oil

Several friends are discussing where oil comes from. This is what they said:

A. It comes mostly from giant ferns and tress that lived millions of years ago.
B. It comes mostly from inside ancient rocks that changed into oil after millions of years.
C. It comes from shallow ocean water that turned into oil millions of years ago.
D. It comes from microscopic and other ocean organisms millions of years ago.
E. It comes from ancient mud, sand and soil that gradually turned into liquid millions of years ago.
F. It comes from gasoline trapped inside the Earth's crust for millions of years.

The best answer is D. Oil comes from the fossil remains of tiny marine organisms (plankton). As they died, their bodies collected on the seafloor and were gradually buried under layers of sediment. The remains of the organisms were gradually chemically transformed over millions of years into oil. Coal comes primarily from land vegetation (answer A). Gasoline is a product of oil and is not found naturally within the Earth like oil.

Example 2: Photosynthesis

Take a look at the trees outside. Where did most of the matter that makes up the wood and the leaves of the trees originally come from?

A. Sunlight
B. Water
C. Soil
D. Carbon Dioxide
E. Oxygen
F. Minerals

The best answer is D, but also B is partially correct. The test is designed to reveal whether students recognize that a gas from the air (CO2) is combined with water and transformed into the new material that makes up most of the matter in the tree. The mass contributed by CO2 is much greater than the mass contributed by the water.

Example 3: Digestive system

A group of students is discussing the main function of the digestive system. Which statement captures best your opinion?

A. The main function is to release energy from food.
B. The main function is to help us breathe.
C. The main function is to break food down into molecules that can be absorbed by cells.
D. The main function is to break food down in the stomach into small pieces of food that can be used by the body.
E. The main function is to carry bits of food and nutrients to all the different parts of our body.

F. The main function is to store food so that we can get energy when we need it.

The best answer is C. The digestive system has two major purposes: to break down food and to prepare nutrients for absorption by cells. The digestive system carries out 6 basic functions: taking food in (ingestion), secretion, movement of food and wastes, break-down of food, absorption from the gastrointestinal tract to the cells and the removal of waste products. Responses A and D are partially correct. Answer E is incorrect since the digestive system doesn't move food and nutrients through different parts of the body. That is the function of the circulatory system.

Example 4: Catching a cold

Four students discuss how you catch a cold (get sick). Here are their answers:

A. You can get a cold when you're having a fever.
B. You can get a cold from being cold and wet.
C. A cold is caused by germs (virus)
D. Not getting enough sleep can make you catch a cold.

The correct answer is C. Viruses and bacteria are agents of infection. A fever is a physiological response from the body to the infection. Being cold and wet and not getting enough sleep can weaken your immune system and thus make it easy for viruses to infect your body.

Example 5: Antibiotics

Many strains of bacteria are now resistant to antibiotics. How has antibiotic resistance among bacteria become so widespread?

A. Since a lot of people use antibiotics, bacteria need resistance to survive. As a result, they develop resistance.
B. Antibiotic resistance is the next natural step for bacteria. This stage just happens to be occurring now.
C. Now that many people use antibiotics, most non-resistant bacteria are dead. Most of the bacteria that are left are resistant.
D. Individual bacteria that are exposed to antibiotics over and over eventually become resistant.

Answer C is correct. It contains the idea of random mutations. Mutations that are strengthening the bacteria's chance on survival and reproduction (here resistance to antibiotics) will become more dominant in the population. The other options consider the development of resistance as a kind of deliberate process or suggest that bacteria can somehow decide to become resistant.

Example 6: Covid-19

A group of friends discuss how Covid-19 is passed on between people. Here are their ideas:

A. Through droplets that come from your mouth and nose when you cough or breathe out.
B. Through sexual fluids
C. By drinking unclean water
D. By mosquito bites

E. By all the above.

Answer A is correct. When a person with COVID-19 coughs, breathes out or sneezes, droplets come out from their nose and mouth which can contain the virus. These can be breathed in by people who are nearby or land on surfaces which other people can then touch. Regularly washing your hands and keeping your distance from others is the best way to prevent COVID-19.

Example 7: Covid-19 (2)

A group of friends discuss the main symptoms of the new coronavirus disease (COVID-19). Here are their ideas:

A. fever and high pressure

B. Loss of appetite

C. Vomiting and diarrhoea

D. Fever, dry cough, and shortness of breath

The correct answer is D

B.3 Concept Cartoons

1. Growth direction of plants

Source: Brenda Keogh and Stuart Naylor, adapted by VVOB

Explanation

Did you ever wonder why plants in nature always seem to grow the upwards, even though their seeds have landed on the ground in a random manner? It doesn't matter which way up the seeds are when they start to grow. There are mechanisms - called tropisms - inside the plant which ensure that the shoots always grow upwards or towards the light and the roots always grow downwards or towards water. Seeds can be grown in suitable conditions to find out whether the orientation of the seeds makes any difference to how they grow. It is necessary to provide the conditions that they need for germination to occur (air, moisture and warmth). The seeds can be planted in various orientations, including letting them begin to grow and then inverting them. Large seeds are easiest to manipulate. The answer from the character at the bottom right is correct.

2. *Heavy plants*

Explanation

A common misconception is that plants feed on soil through their roots in the same way that animals take in food through their mouths. This is not correct. Although it seems unlikely that air and water turn into new cells in the plant, this is exactly what happens through the process of photosynthesis, where carbon dioxide (from the air) and water (from the soil) produce glucose with the aid of light energy. With the formula for photosynthesis, you can show that the highest proportion of the weights comes from the carbon dioxide. The various factors can be separated to some extent to show that the soil is not necessary for plant growth (though small quantities of minerals from the soil are necessary). Weighing the soil before and after a period of plant growth will demonstrate that soil is not taken up through the roots. This means the characters at the top right and bottom left are both correct.

3. *Rotten Apple*

Explanation

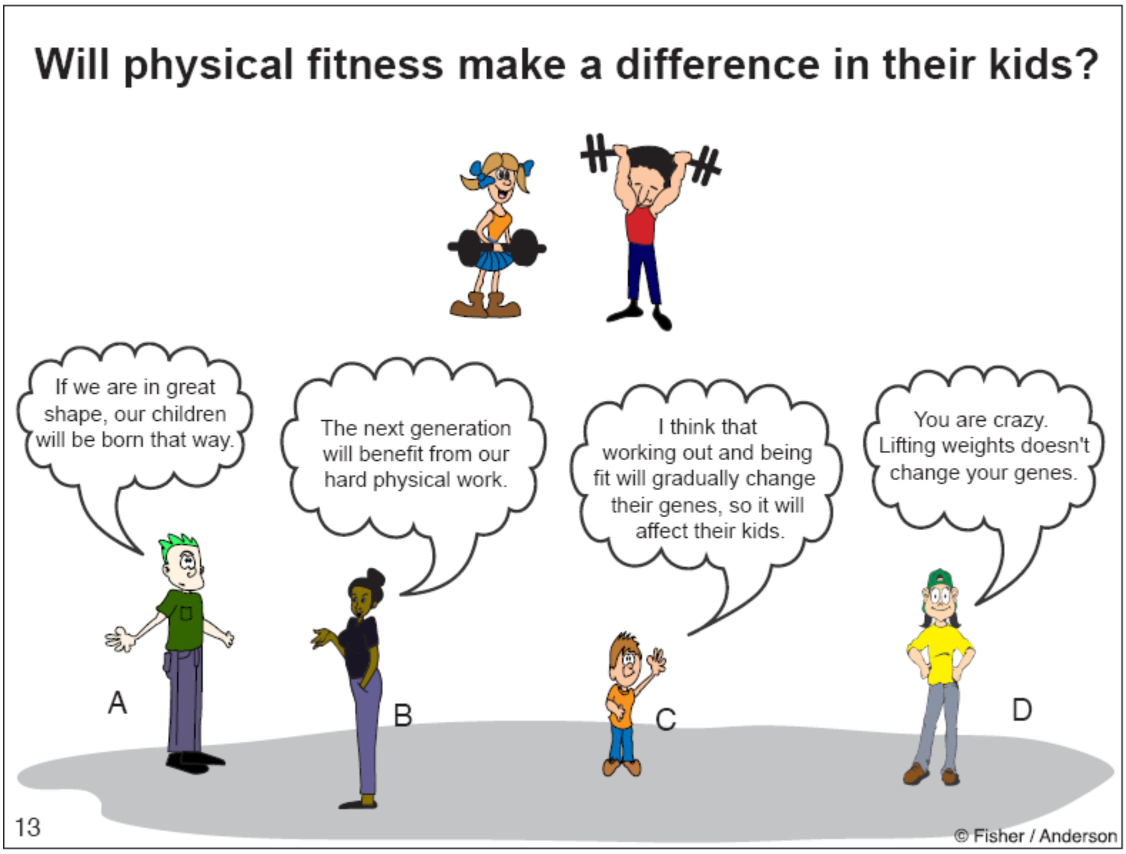
A common misconception is that rotting is caused by bad environmental conditions that attack organic material. Few students are able to explain what happens during the rotting process. Organic material rots because microbes (general term for microscopic organisms such as bacteria) feed on it. This may not be obvious because microbes are invisible to the naked eye. However, the amount of moisture, the temperature and acidic conditions all influence how rapidly microbes can feed on the apple and cause it to rot. The speed of rotting of an apple can be investigated by leaving it on the surface of different types of soil and in a range of different conditions. The feeding of microbes can be prevented by a disinfectant solution or a bactericidal spray to sterilize the fruit every few days. The character at the bottom left is correct.

4. *Pond Life*

Explanation

In normal conditions it is unlikely that fish will use up all the oxygen and die. Fish have been living in ponds and lakes for ages without using up all the oxygen, so they must be getting oxygen from somewhere else. The fish get a continuous supply of oxygen from the air as it dissolves in the water. They also obtain oxygen from plants that release it into the water during photosynthesis. This is not a situation which can be investigated practically. There are useful parallels in how aquatic plants obtain carbon dioxide for photosynthesis from carbon dioxide dissolved in the water. The character at the bottom left is correct.

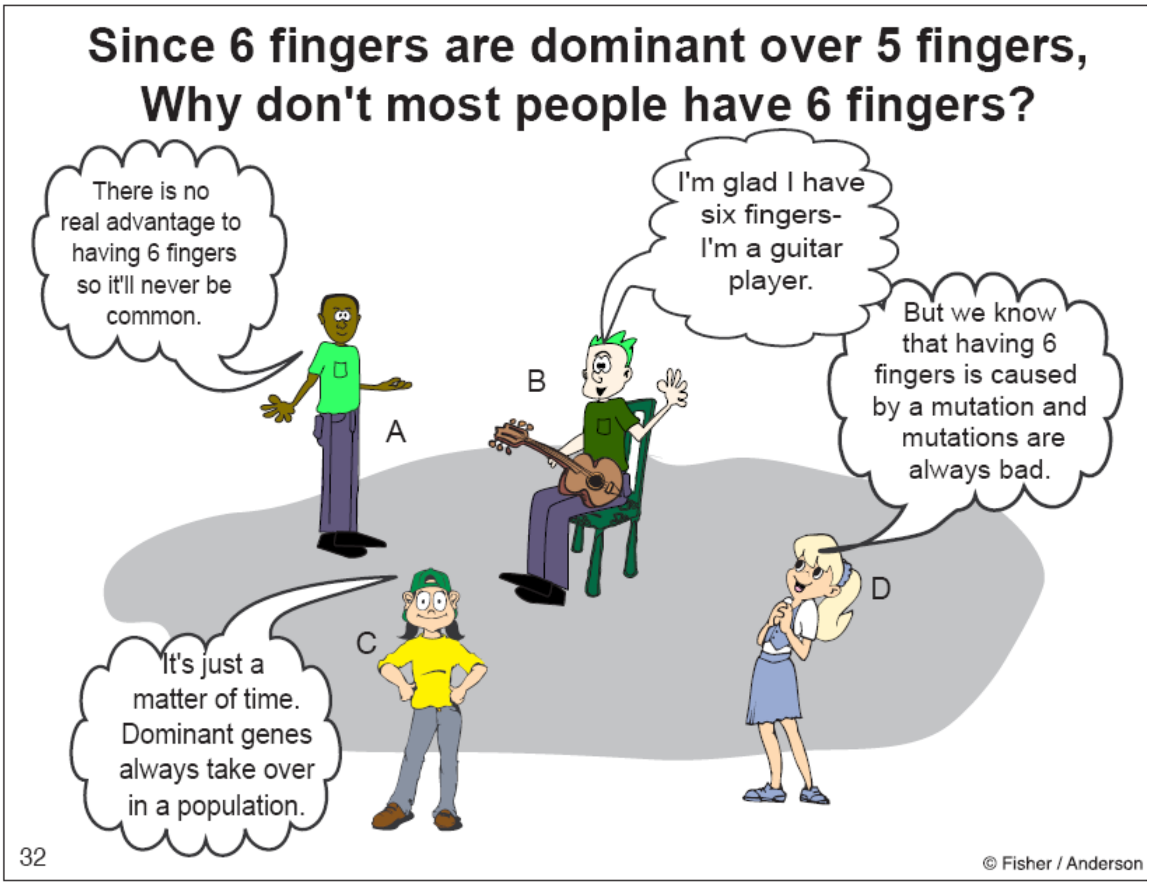
5. Acquired Traits



Explanation

Answer D is correct, because an individual can't change his/her own genes in a certain way through certain activities. Mutations certainly occur during an organism's lifetime, but they are completely unpredictable and very unlikely to take place in reproductive cells like eggs and sperm. Answers A, B and C are all related to the discarded Lamarckian idea that traits acquired during the lifetime can be passed to offspring. This is important to bring up with students several times because it is a common misconception.

6. Dominance



Explanation

Character A has the best answer. A trait typically becomes more common if there is some advantage to organisms that have that trait. Answer C reflects a common idea among students that dominant alleles are somehow stronger. Answer B is irrelevant, and answer D brings up the erroneous, but very common, idea that mutations always have negative effects. Another example of a dominant but rare trait is dwarfism.

7. Competition

Explanation

Answer C is the correct answer and acknowledges that some ducks may starve. Answer A is inaccurate, because cooperation amongst members of a population is very rare. Answer B implies that an individual is capable of changing to meet needs. Character D makes the mistake of assuming that it is always the biggest and strongest ducks that will get the most food. In reality, the ducks with a slightly different beak, or a slightly more efficient metabolism could have a competitive "edge" and survive.

B.4 Example of an inquiry-based practical work

Topic: Growth direction of plants

Purpose: Learners experience how scientific research is done.
Preparation: The experiments should be set up a <u>week in advance</u>.

Materials needed

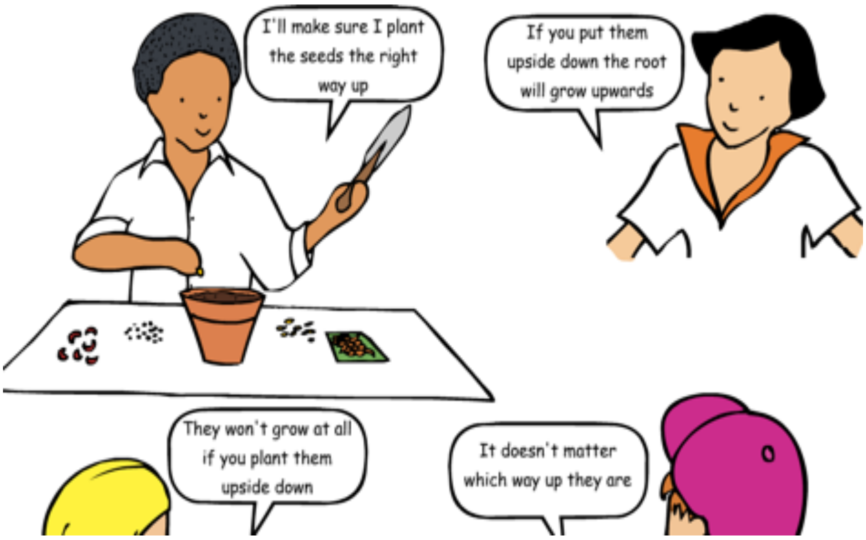
- 5 petri dishes
- cotton wool,
- coloured napkins
- watercress (or lettuce) seeds, black board

Lesson Introduction

We familiar with plants. Some of them are big and others are small. A plant has two main parts, the aerial part, and the underground part. It is very important to know how these two main parts are different from one another.

Process

Introduce the problem with the **concept cartoon** "reverse seeds" (See B.3.1) (5 min)
Learners reflect individually on the **research question** that is proposed by this cartoon.



<u>**1st research cycle**</u>

1. Ask learners for suggestions about the research question. Continue questioning until they formulate a good research question. Write the research question on the blackboard:

   'Do seeds have to be placed in a certain direction to germinate and grow?'

2. Learners share their hypothesis and the teacher writes them on the blackboard.
3. Learners think about an experimental set-up, the materials needed and draw the experimental set-up.

The teacher should prepare this experiment one week in advance, so we can observe immediately.
experimental set-up:
· Soak watercress seeds for 1 night
· Fill a petri dish with wet cotton and put the seeds on it in 3 zones according to the chosen direction: 1 zone with pointed side upside, 1 zone with pointed side downwards and 1 zone with seeds that lay flat. Label the zones.
· Put the seeds in the dark to speed up germination and give water daily.

4. Observation: All the seeds from the 3 zones germinated and grew upwards, in the same direction.
5. Conclusion: it does not matter in which direction the seeds are, they germ anyway and grow in the right direction.

Reflect

1. Learners think about a new research question. There must be a mechanism which ensures that the seedling "knows" the direction in which to orientate the roots and stem. The seedlings must be able to interact with the environment in order to respond to it.
2. Learners form a new research question: "Which stimuli make the seedling recognize the right growth direction?"
3. Learners formulate hypotheses and the teacher writes them on the blackboard. Some hypothesizes can be eliminated through good questioning. Keep these possibilities:
   - The direction of the light serves as a stimulus and determines the growth direction.
   - The gravity determines the growth direction.

The two research questions above lead to 2 new research cycles:

2nd research cycle

1. Research question: Is the direction of the light determining the growth direction of the germ plants?
2. Learners plan the experimental set-up.

Experimental set-up:
• Fill 2 petri dishes with wet cotton wool and seeds
• Put 1 petri dish in full light, the other in a box that is open on 1 side = > one-sided exposure to light
Observe after 1 week

3. Observation: the seedlings from the first petri dish grow straight up, the ones that grew in the box bend towards the light. (Observe the roots: the roots grow away from the light).
4. Conclusion: the light direction determines the growth direction of the stem. . This process is called phototropism.

3rd research cycle

1. Research question: Is the direction of gravity determining the growth direction of the germ plants?
2. Learners plan the experimental set-up.

Experiment: · Fill 2 petri dishes with wet cotton and seeds (or place a coloured napkin for contrast with the white roots) · Place the petri dishes vertically · Turn after 3 days of germination 1 dish by 9O ° Observe what happened after 1 week

3. Observation: the roots are crooked in the rotated dish. The roots grow towards the Earth and the stems grow upwards.
4. Conclusion: The growth direction of the seedlings is also determined by gravity: the roots grow in the direction of gravity (positive geotropism) and the stems against the direction of gravity (negative geotropism).
5. **General conclusion:** the growth direction of (germ) plants is driven by the direction of the light and gravity. It doesn’t matter in what direction seeds are placed.

B.5 Demonstration of the anatomy of a mammalian heart

Introduction

It is useful to start the lessons about the anatomy of the heart with a dissection of a heart. The heart of a pig has about the same size as a human heart. The heart of a cow is twice as big and for that reason more useful for a demonstration. The heart of a goat is too small to be useful for a dissection. The following description guides the teacher and includes observation questions for the learners.

Materials needed

- heart of a cow (or pig),
- dissection scalpel or scissors
- 2 thin sticks
- tweezers
- towel or paper to clean
- dissection shelf (optional)
- gloves (optional)

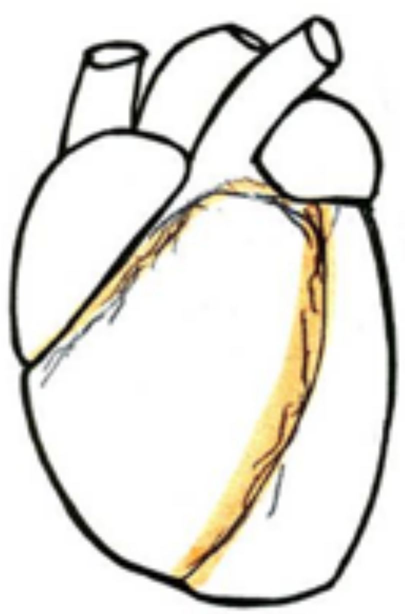
External anatomy

Rinse the heart with water before starting the dissection. The dissection will be less bloody.
Locate the heart in our body:

- Where is our heart located in the body?
- Which side from the heart is the front and back?
- Which side from the heart is the left and right?
- Left and right side or like they appear in the body.

→ Left and right side or like they appear in the body.

Make the following **observations and ask questions to the learners:**



- *How can you recognize the front side of the heart?*

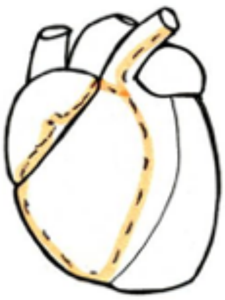
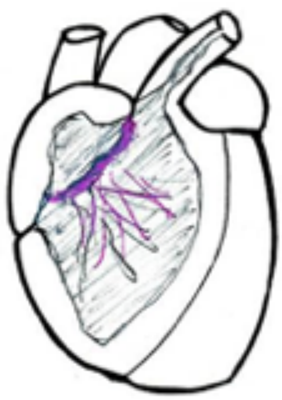
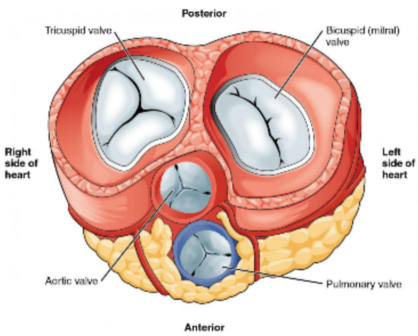
Put the heart on the dissection dish (or desk) with the front side upwards. You recognize the front side by the grey line that goes from the left upper side of the heart to the right under side of the heart. This line is the connective tissue. The veins from the heart lay near the surface and the coronary arteries lay deeper. The connective tissue also forms the division between the 2 ventricles.

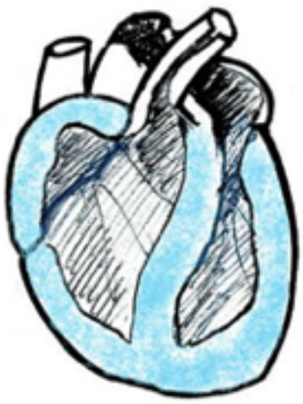
- *What is the role of the coronary arteries?*

The coronary arteries provide the heart with oxygen and nutrients, whereas the veins remove waste materials.

	The connective tissue passes around the heart, goes under the atria and goes at the back site of the heart almost straight to the heart point. Point out the 2 atria and the 2 ventricles.
	Put the small stick in the thickest blood vessel (white colour, stands open and bends to the left. This is the **aorta**. • *Where does the stick end?* ---> In the left ventricle. Put the second stick in the second thickest blood vessel. This is the **pulmonary artery.** • Where does the stick end? ---> In the right ventricle. • Can you move the stick from the first ventricle to the other? ---> No. • *Is there a connection between the left and right ventricle?* ---> No. • If you leave both sticks in the arteries, how do they lay against each other? ---> The sticks make a cross, so the arteries cross too. Search the veins (flaccid (weak), red blood vessels or just an opening). Put the small stick in it. • *Where does the stick end?* ---> In the atria. **The superior vena cava** and **the inferior vena cava** end in the right atrium. **The 4 pulmonary veins** end in the left atrium. Veins bring blood to the heart, whereas arteries carry the blood away from the heart.

Internal anatomy

	Cut the wall of the pulmonary artery as in the figure. Use the stick to guide you. • *What do you observe?* You see the semilunar valve at the junction to the ventricles. You can find them by gliding with the stick or tweezers along the wall of the artery. You will end in an empty space looking like a "bucket". This is a valve. Search the 2 other "buckets". The 3 "buckets" together form the semilunar valve and prevent that the blood coming from the heart flows back to the heart.
	Cut the right ventricle open as in the left figure. • *What do you observe?* You see the bicuspid valve with tendons. The blood flows from the atrium to the ventricle. The bicuspid valve prevents that the blood flows back into the atrium
	 ***Source: OpenStax College, Anatomy & Physiology, 2013***
	Cut the wall of the aorta. • *What do you observe?* You see again the semi lunar valve at the junction to the ventricles. You can find at the "buckets" a small hall in the wall of the aorta. It is the beginning of the coronary artery. Keep on cutting through the wall of the aorta. You will cut the mitral valve.

	• *What is the role of the mitral valve?* This valve prevents that blood from the left ventricle flows back into the left atrium. Point out the difference in thickness of the ventricle walls (left and right ventricle) and the volume of the ventricle.
	Cut along a lateral line and remove all the front parts of the heart. You made a “cross section” of the heart, just like in the figure.

Conclusion

The heart is made of different parts that play different roles. Figure 1 shows all parts that we observed during the dissection, even though some other parts could not be observed during the dissection. (a) The heart is primarily made of a thick muscle layer, called the myocardium, surrounded by membranes. One-way valves separate the four chambers. (b) Blood vessels of the coronary system, including the coronary arteries and veins, keep the heart musculature oxygenated.

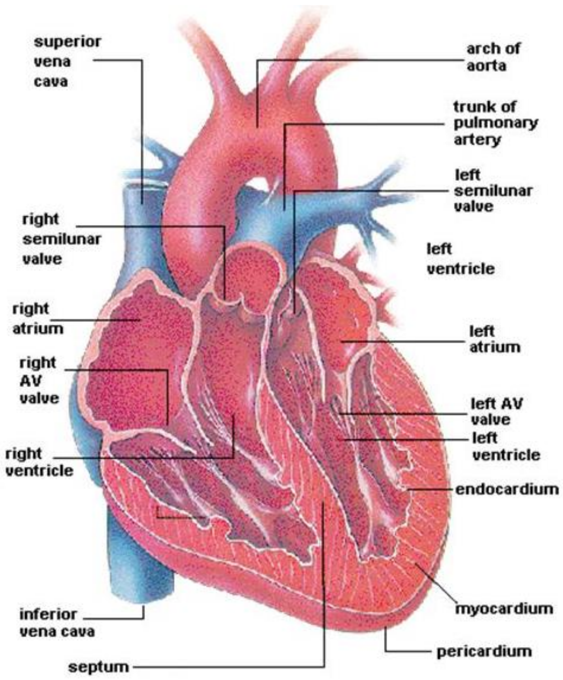


Figure 1: Structure of the mammalian heart (source: BiologyMad.com

B.6 Examples of the use of models for biology

Using low-cost 3D models in biology

Biology needs a lot of visualizations. Models that show the structure of an organ are difficult to make as the structure has to be correct and as 'real' or close to reality as possible. Such models are best purchased. However, models that try to explain how an organ or phenomenon works don't have to be looking 'real' as they are focusing on the function. These models can be made by yourself. We give some suggestions.

1) Example: Models to illustrate breathing

There are two ways to breathe in, meaning that there are two ways to enlarge the chest cavity and lower the air pressure in the lungs: by contracting the diaphragm (diaphragmatic breathing) and by contracting the rib muscles (chest breathing). Normally, we combine both ways of breathing. To explain both ways clearly, we use two different models.

Model of diaphragmatic breathing

a) Description of the model (Figure 2)

The orange balloons represent the lungs, the tube that comes out of the bottle is the trachea and the 2 smaller tubes are the branches. The plastic bottle is a representation of the chest (ribs and muscles between the ribs) and the big red balloon underneath is the diaphragm. Make sure that no air can escape from the connection between the trachea and chest, trachea and branches and the branches with the smaller balloons.

Figure 2: low-cost model for diaphragmatic breathing

b) Use of the model

As shown in Figure 3, when you pull down the "diaphragm" (diaphragm contracts), a lower pressure is created in the chest. The lungs stretch out and more air comes automatically in the lungs. This is inhaling by diaphragmatic breathing or inhalation. When the diaphragm relaxes (push the "diaphragm" upward), the pressure in the chest increases and air moves out. This is called exhalation.

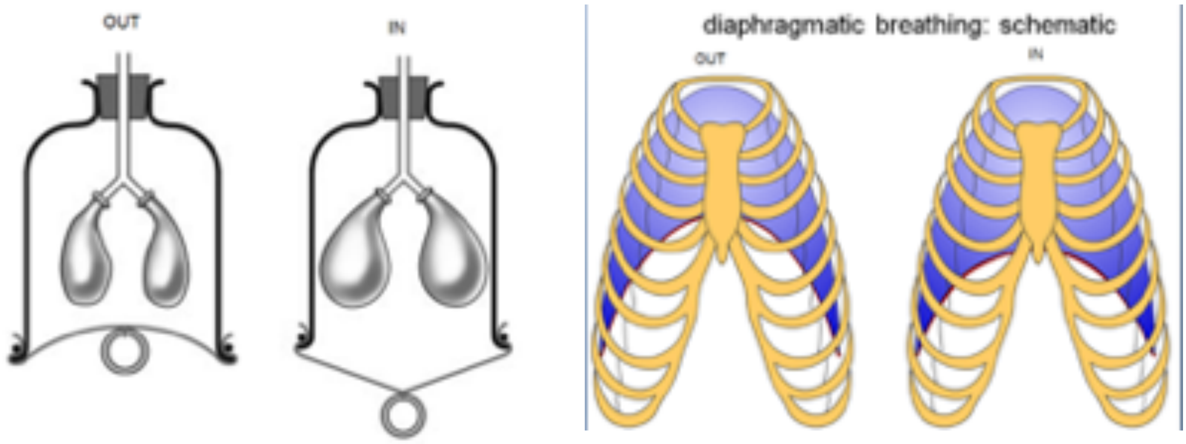


Figure 3: schematic representation of diaphragmatic breathing

Model of chest breathing

a) Description of the model

The model consists of two bars in wood and some circles in metal that go through the wood (Figure 4). The longest bar represents the spine and the shortest one represents the breastbone (sternum). The metal circles are the ribs.

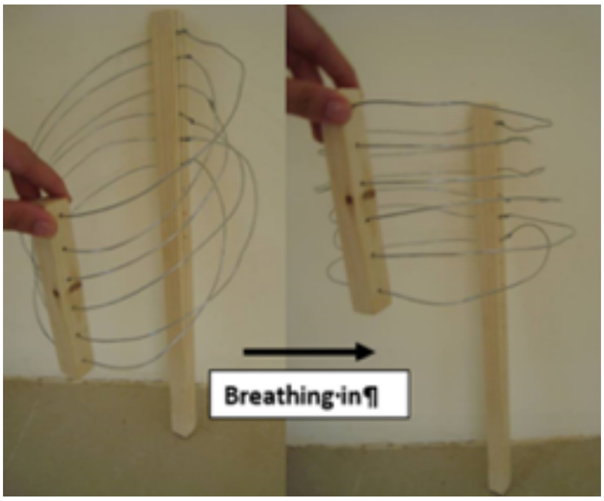


Figure 4: Low-cost model for chest breathing

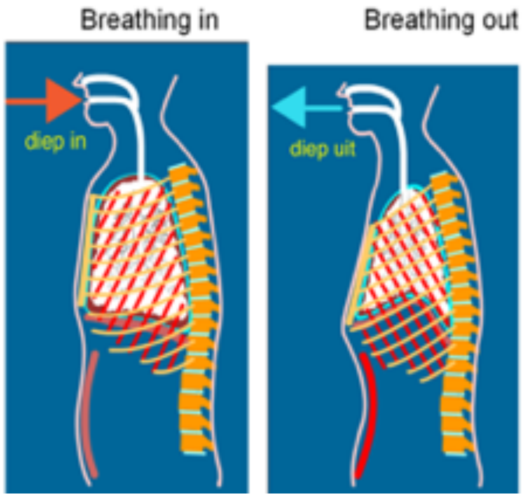
Use of the model

As shown in the left photo, when the intern intercostal muscles (red lines in left figure beneath this text) between the ribs contract, the ribs and breastbone are moved upward and forward. When we move the breastbone of the model upwards, we observe (look from above at the model) that the space inside the chest becomes bigger. As a result, the lungs stretch out and air enters the lungs.

In Figure 5Breathing in: red lines = internal intercostal muscles

Breathing out: red lines = external intercostal muscles

Figure 5, the combination of both ways of breathing is shown.



Breathing in: red lines = internal intercostal muscles

Breathing out: red lines = external intercostal muscles

Figure 5: schematic representation of combination of diaphragmatic and chest breathing

Spirometer

A spirometer is an apparatus for measuring the volume of air that enters and leaves the lungs (Figure 6). In medicine, it is useful to test the condition of the patient's lungs. Lung diseases such as asthma, bronchitis and emphysema can be ruled out from the test.

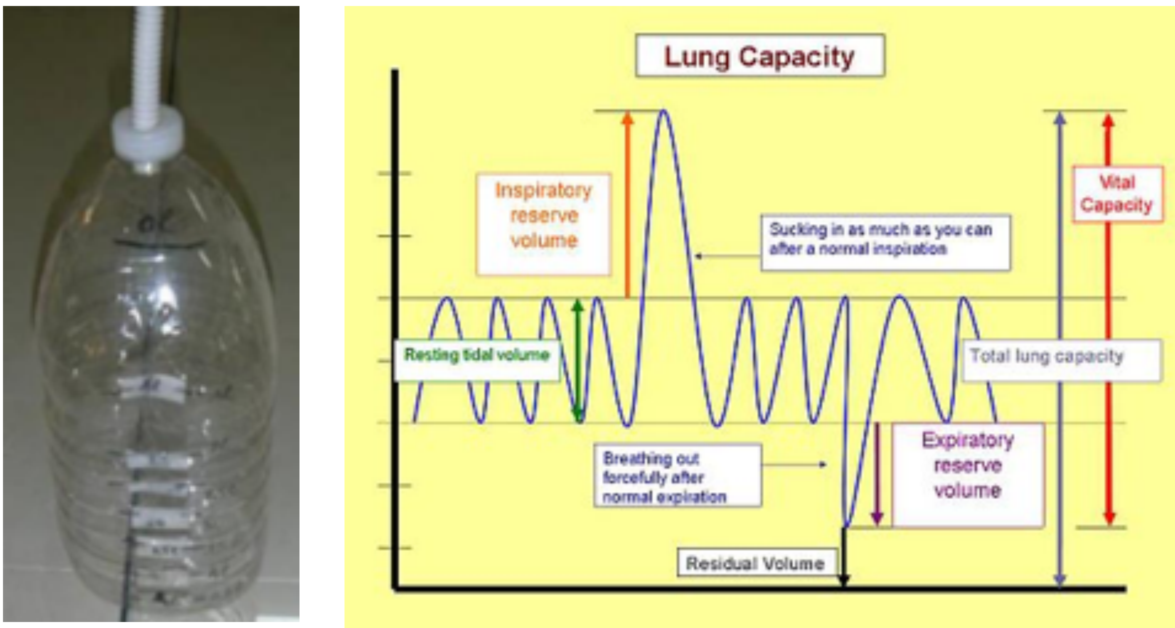


Figure 6: A low-cost spirometer enables measuring a person's lung capacity (source: public domain)

a) Description of the model

The model is made of a big plastic bottle with a volume of 5 litres. To put the marks of the volume, fill the bottle with exactly 1 litre of water and put a line on the bottle with the mark '4 litre'. Add 1 extra litre and indicate the mark '3 litres' and so on … End with 0 litres at the top of the bottle. Make a hole in the top of the bottle to fit a tube in it. Cut and remove the bottom of the model.

b) Use of the model

Put the model in a big basin containing water (Figure 7). The level of water in the basin needs to be equal to the 0-litre mark of the bottle. Breathe in and breathe out deeply into the tube. The water will rise in the bottle. When you have completely breathed out, verify which mark is closest to the water level. If this is for example 3,5 litre, then your vital capacity is 3,5 litres.

Figure 7: functioning of the low-cost spirometer

2) Models for the digestive process

Model: increasing the surface area of food particles (cube model)

We use our teeth to cut food into small pieces. By doing so, we increase the surface area that is available for chemical digestion. To help learners understanding the concept of increasing the surface area, you can use a simple cube model.

a) Description and use of the model

Make a few cubes of the same size. Lay the cubes together to form a big cube (Figure 8, left). This big cube represents a food bite (for example: 1 piece of meat). After some biting, the large piece of meat will turn into multiple smaller pieces of meat, represented by the small cubes (Figure 8, right). The total surface of all small cubes is higher than the surface area of the big cube.

Figure 8: Cubes as a model for surface area

Model: peristaltic movement of food particles

a) Description of the model

The model consists of a small ball and a panty (Figure 9) or long sock. The panty or long sock represents the digestive track, the ball represents a food particle.

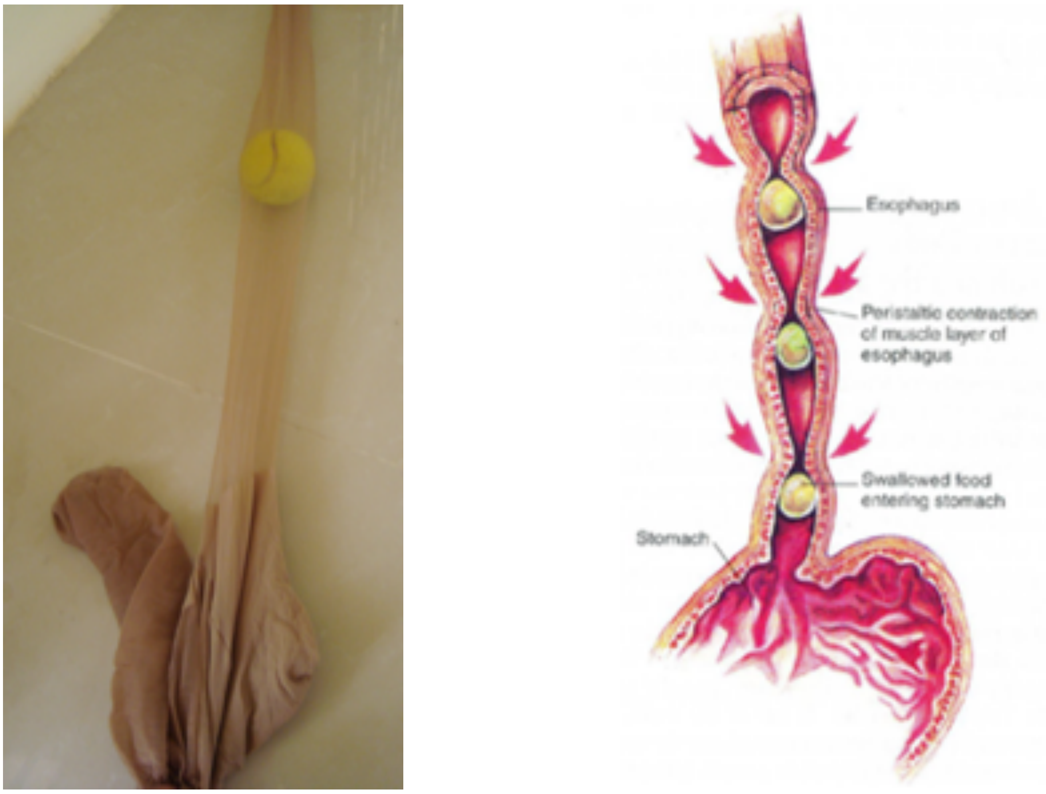


Figure 9: Model for the peristaltic movement of food particles

b) Use of the model

The ball doesn't 'fall' down when the panty is held vertically. Ask learners to move the ball forward inside the panty (without moving into the panty with their hands). They discover that contracting the space with their hands above the ball, will move the ball slightly forward. If a second learner opens the panty a little bit underneath the ball, the ball will also go faster. Those represent the two movements that take place in the digestive tract, called peristalsis or peristaltic contraction.

3) Models of the human heart

Model of the semi-lunar heart valves

a) Description of the model

The semi lunar valves consist of three flaps that look like a pocket (Figure 10). The flaps form a ring in the arteries just outside each ventricle. The model shows the function of the semi lunar valves. Stick two sheets of paper to form a tube (that represents the artery). Stick to this tube 3 coffee filters, representing the semi lunar valves, or 3 pieces of paper placed in a similar way.

Figure 10: Model for the semi-lunar heart valves

b) Use of the model

When the ventricle contracts, the pressure increases, pushing the flaps up and blood flows through the arteries. Imitate the bloodstream in the model with your hand and arm. Go through the paper tube like the blood does in the ventricular systole. This is easy, the 'valves' go flat.
When the ventricle relaxes, some blood is moving backward towards the ventricle, fills these pockets and causes the valves to bulge. This prevents blood moving back into the ventricles. Imitate this as well with the model. Your hands pull the valves open, preventing your arm from moving through.

Using 2D models (drawings, puzzles) during the explore phase of a biology lesson

Although many biological concepts can be shown or examined by experiments, there are still a lot of concepts that can't. However, these concepts can be 'explored' by students by offering them well-chosen **diagrams, videos, animations, simulations… combined with a good questioning sequence or an inquiry enhancing instruction.**

We give some inspiring examples of specific instructions with certain materials to make the lesson more inquiry based. We use the abbreviation 'T' for 'what the teachers says or 'what the instruction is for the task' and 'L' for 'what the learners is expected to answer.' **Get inspired by the examples and invent your own activities, not only for biology, but also for chemistry, physics and mathematics.**

1. Learners construct a model in their exercise notebooks or on mini white boards

Biology Senior 2. Unit 2: Introduction to environmental biology. Pyramids of biomass and energy.

T: Estimate the numbers of organisms per food level (producers, primary consumers, secondary consumers) that are needed to maintain this food web and visualize this by drawing a diagram that is visible for me at the front of the class.

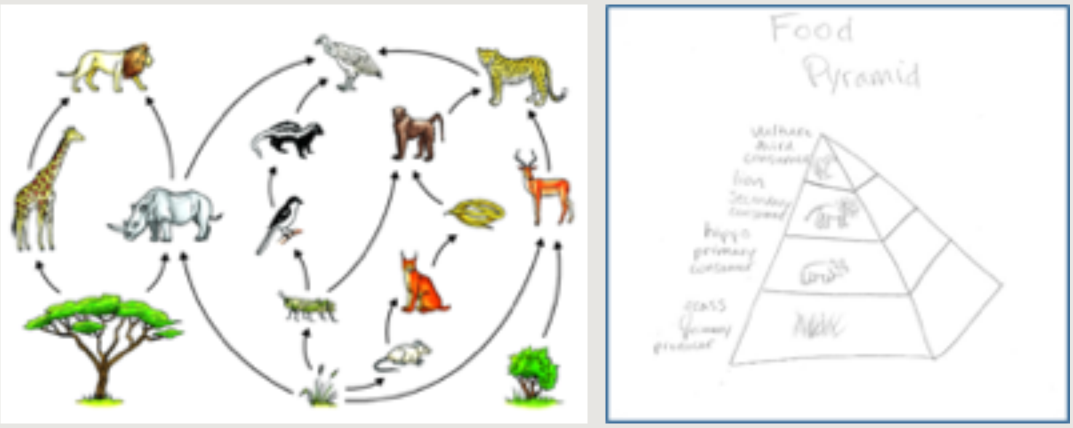


Figure 11: Diagram of a food web shown to learners (left) and diagram drawn by a learner (right)

2. Putting a process into words by using a drawing or poster

Biology Senior 3. Unit 12: Response and coordination in animals. From stimulus to effect

T: Try to make a story of what is happening in this drawing (Figure 12). You get 1 minute to think about it.

L: The girl sees the fruit with her eyes. The reflected light is the stimulus and is converted in a nerve impulse in the retina. The brain interprets the impulse and sends another impulse to the arm muscles to touch the fruit. The brain also sends an impulse to the saliva glands to make and release more saliva.

Figure 12: Using a picture and questioning to create subtle shifts to inquiry

Biology Senior 3. Unit 12: Response and coordination in animals. From stimulus to nerve impulse in the ear

T: Make a story of what is happening in the drawing below.

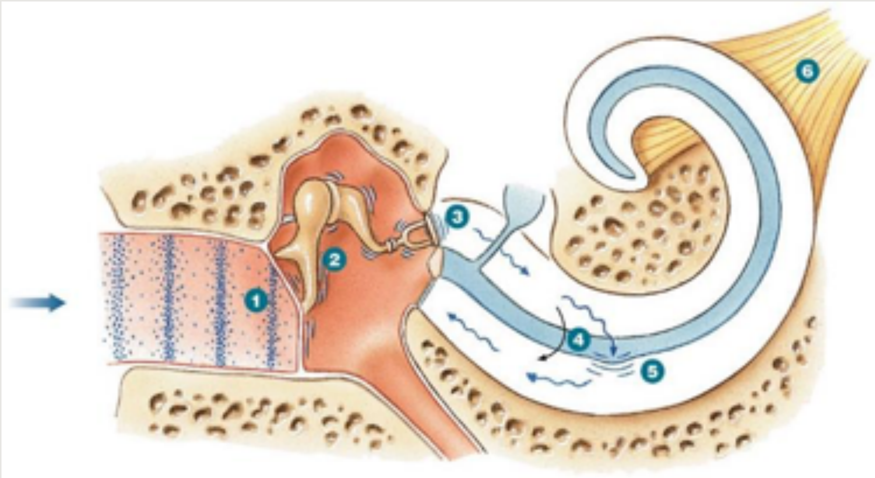


Figure 13: From stimulus to nerve impulse in the ear

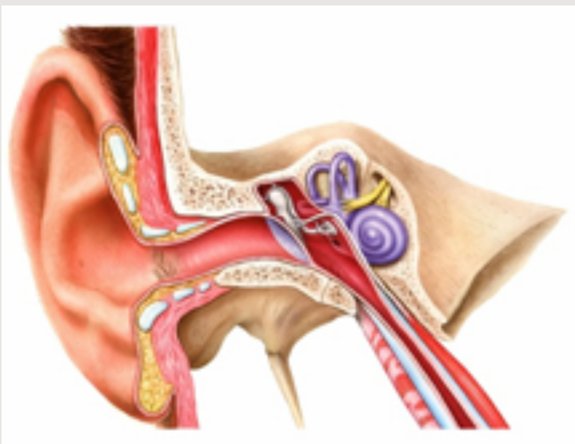
3. Making a hypothesis of the functioning of an organ, based on its structure

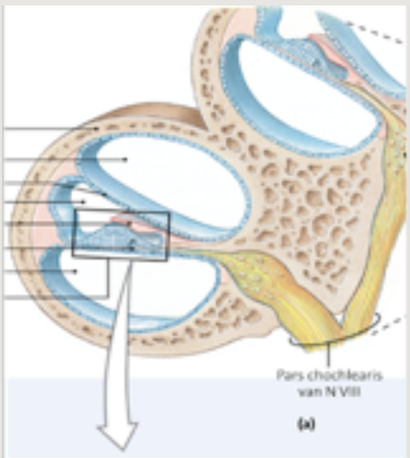
Learners can only formulate a hypothesis of how an organ is working if they know its structure.

Biology Senior 3. Unit 12: Response and coordination in animals. From stimulus to effect.

In this example, the learners learn about the structure of the ear by using these diagrams.

T: Try to 'discover' how our ears are working: from stimulus to nerve impulses.





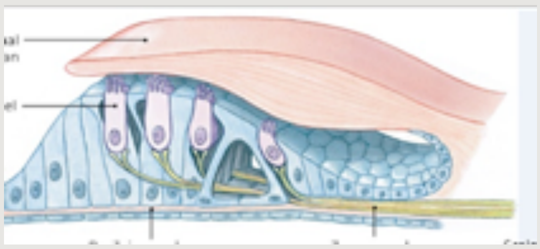


Figure 14: Structure of the ear

Biology. Learners studied already the structure of the salivary gland.
T: Try to describe how the salivary gland is working, based on how it is built.

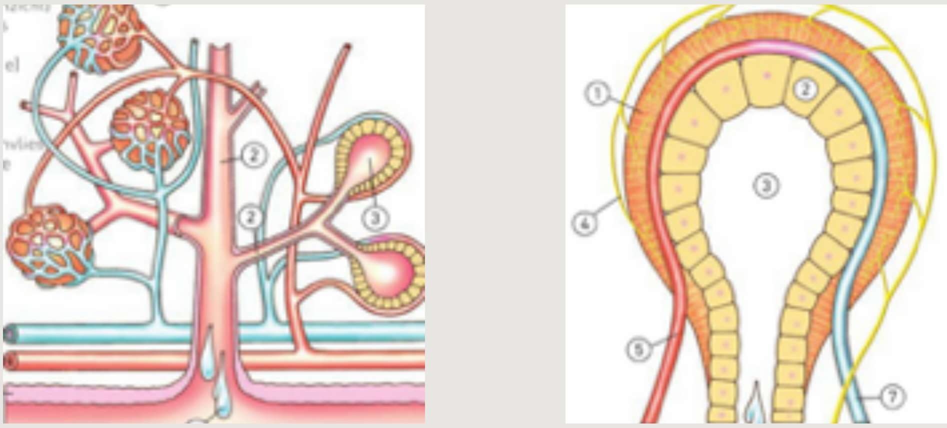


Figure 15: Structure of the salivary gland

4. Make a hypothesis of an organ's function

Biology Senior 3. Unit 12: Response and coordination in animals.

T: An injury on the spinal ganglion and dorsal (grey) horn on the 6°, 7° and 8° vertebra of the neck results in a loss of feeling in the fingers. What kind of neurons are placed in the spinal marrow?
L: the neuron that is passing there is a sensory neuron.

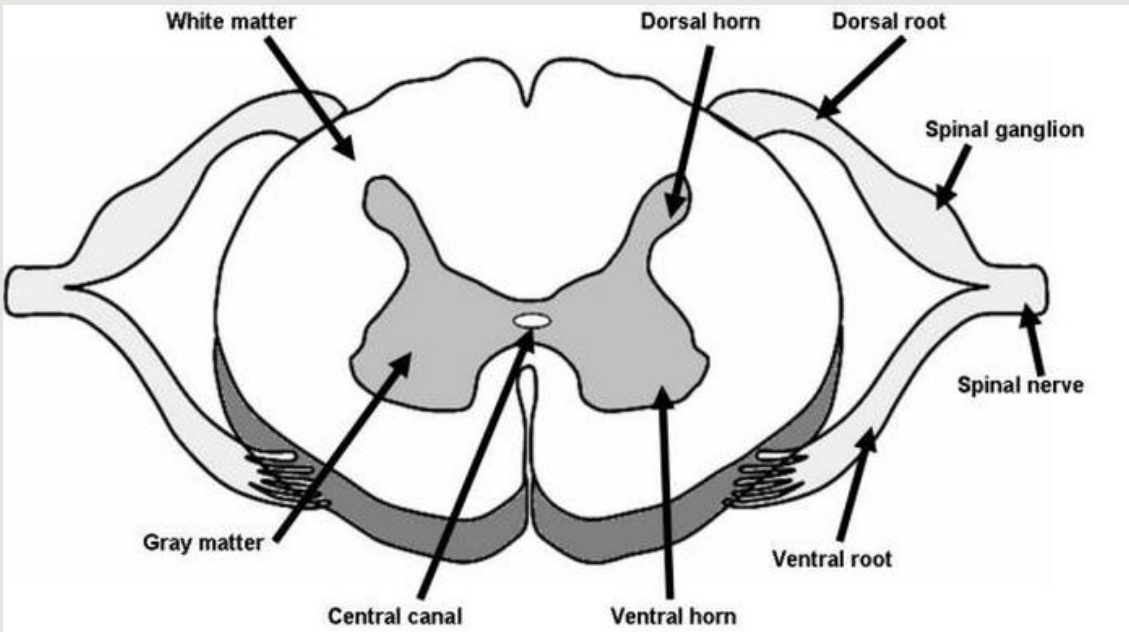


Figure 16: structure of spinal marrow

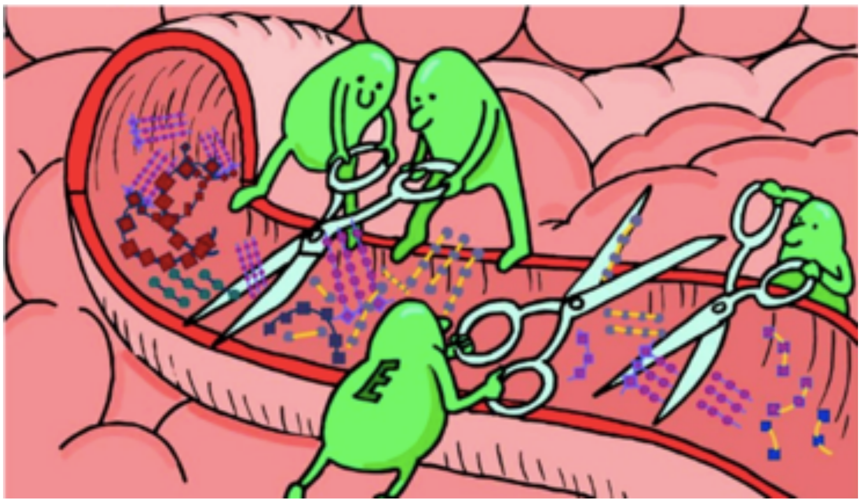
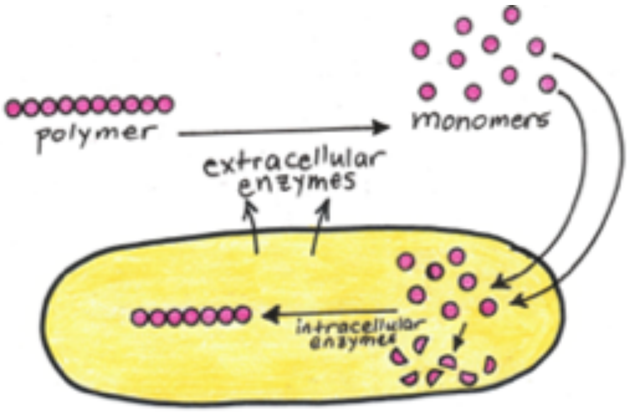


Figure 17: Cartoon representing the functioning of enzymes in the digestive tract

T: You see the small intestine that is cut open. The green men (having the letter E on their back) are enzymes. What are the enzymes doing?
L: They are cutting small things
T: They are working in the small intestine, so what are they cutting?
L: Food
T: Are there still food particles, like rice, in the small intestine?
L: No, the food particles became already smaller in the stomach.
T: Correct. In the intestine, we find proteins, carbohydrates and fat, all components of food. Why do these particles have to be cut?
L: Because they are too big to go through the wall of the small intestine and enter a blood vessel.
T: Correct! This is one type of enzymes. Enzymes that cut particles in smaller particles.



T: This yellow figure is a cell inside an animal or human. Do you find in this diagram the same type of enzyme as in the previous diagram?
L: Yes, the extracellular enzyme
T: Try to understand what its name is saying: where can we find these enzymes?
L: Outside the cell.

T: Why is it logical that these enzymes work outside the cell?
L: The polymers are too big to enter the cell, so the enzymes have to move to the polymers to cut them in monomers. The monomers can enter the cell.
T: Correct. There is also an intracellular enzyme inside. What are they doing?
L: They are putting small particles together to form a long chain.
T: Correct. Is this the only thing they do?
L: No, they also change the small particles into other small particles.
T: Correct!

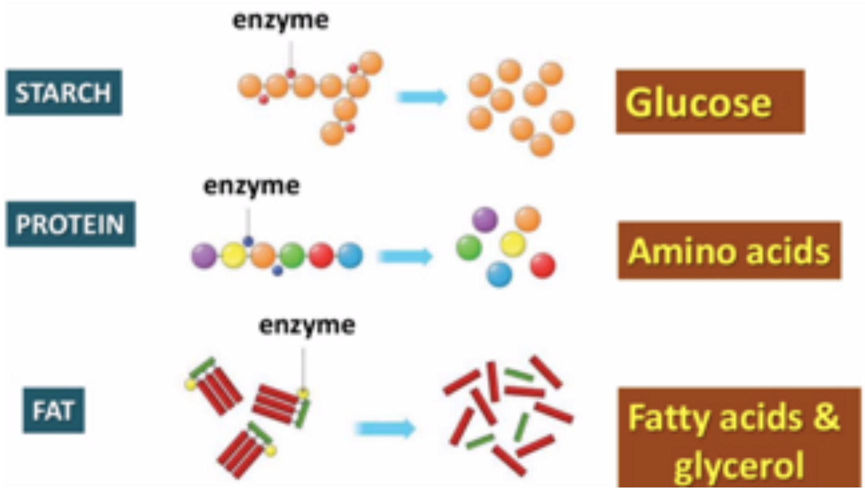


Figure 18: Functioning of enzymes

T: What can we learn from this diagram?
L: Enzymes can break down starch, proteins and fat into glucose, amino acids, fatty acids and glycerol.

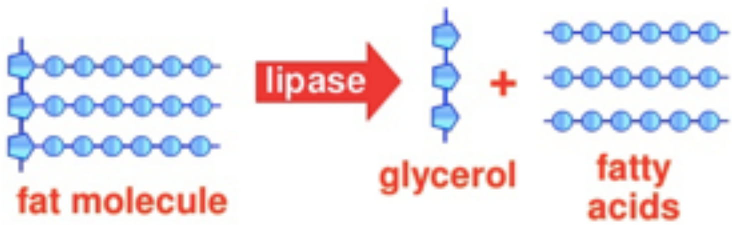


Figure 19: Functioning of lipase

T: Very good. Is it the same enzyme that breaks down starch and protein?
L: No.
T: How do you see that?
L: The colour of the enzymes is different.
T: Correct. The enzyme that cuts starch into glucose is called carbohydrase. The one that breaks down proteins is called peptidase and the enzyme that breaks down fat is called lipase.

6. Building knowledge through observing and reasoning about a drawing

Biology S3. Unit 12: Response and coordination in animals. From stimulus to effect

At this point in the CBC, learners haven't learned yet how impulses move through the body. By reasoning on this drawing, they can construct this knowledge by themselves. The required prior knowledge is that senses convert stimuli to impulses and that muscles and glands react because they receive impulses from the brain or spinal cord.

T: A sting is hurting your skin. Describe the way from stimulus to the feeling of the pain using the numbers of the drawing.

T: A sting is hurting your arm and immediately, you pull back your arm. Describe the way from stimulus to effect.

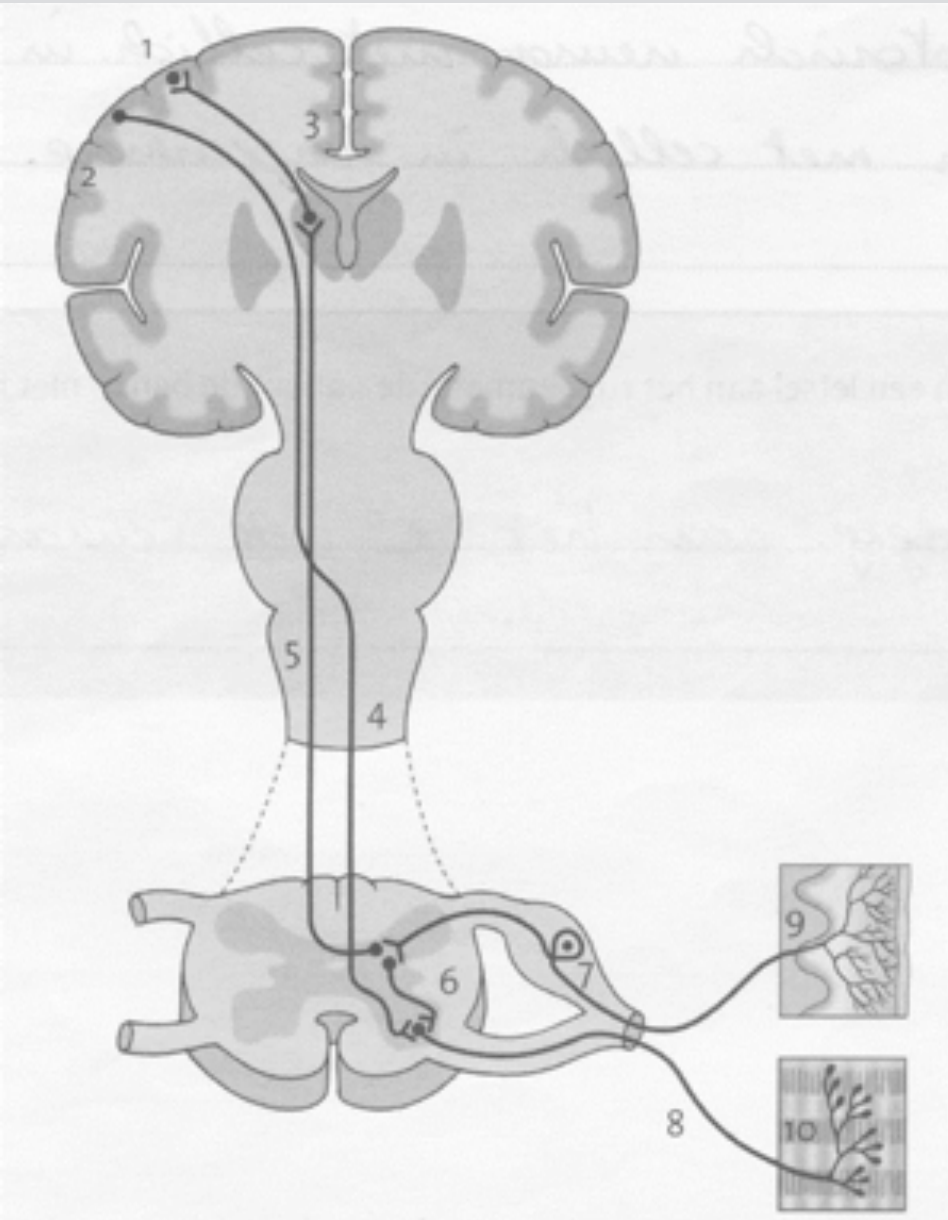


Figure 20: structure of the nervous system

7. Building knowledge using reasoning skills and a puzzle

Biology S3. Unit 4: Effects of human activities on ecosystems 1. Effect of pollution on a food chains and ecosystem.

We start with an experiment. The teacher provides water of a lake or pond with phytoplankton and zooplankton. The plankton can be seen with (cheap) magnifying lenses (4 x).

T: Look to the water of the lake with a magnifying lens. What do you observe?
L: small 'animals' that move in the water. Some small green dots. (not always seen)
T: Search the photo(s) of these organisms in the envelop.
Learners take the photos of phytoplankton and zooplankton
T: Take all photos and discuss within the group how the freshwater food chain would be and make it. Use the legend because each arrow has another meaning! Place the extra figures of a microscope (magnifying lenses) on the correct place.
Learners get 10 minutes to make the food circle. Visit each group and coach them if necessary ('help' them with questions, not with answers).
T: In 2 minutes, I will ask 1 group to present their puzzle to the class and tell us why they made the circle in that way. Prepare yourself.
The learners stand around the group that will present their food chain. Afterwards, everyone discusses: is it correct? Why not? Learners go back to their places and correct their own food chain if necessary.
T: We have a look at a special property of fresh water. Fill, in your group, a glass with water and put a drawing pin 'with the head' on the surface of the water.

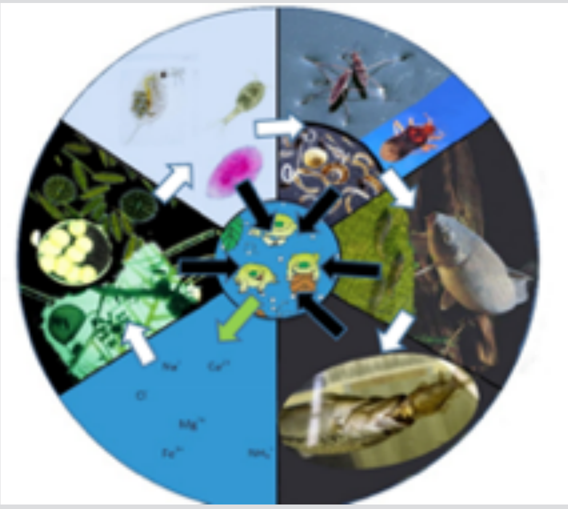


Figure 21: Fresh water food cycle

T: Observe and try to explain the observations.
If learners didn't learn yet about cohesion, then the teacher explains that, because of cohesion, the pin floats on the surface of the water.
T: Now, put a drop of liquid soap on the water surface (try-out first at home, it only works if the soap contains surfactants). Observe and try to explain the observations.

The surfactants in het liquid soap lower the surface tension, causing the pin to sink in the water.
T: If soap enters the freshwater ecosystem (puzzle of food chain), what will happen? Discuss in your group.
One group presents findings to the class. Everyone discusses: Correct? Why not?

Effect of pollution within a food chain on humans: bio-accumulation of poison
Learners complete the strip cartoon that consists of 5 pieces. There is only one version of the first and last piece, so these are correct. For the other pieces, there are more versions, each time one correct and one or two false. The learners must observe different versions and discuss which ones are correct to make a correct strip cartoon.

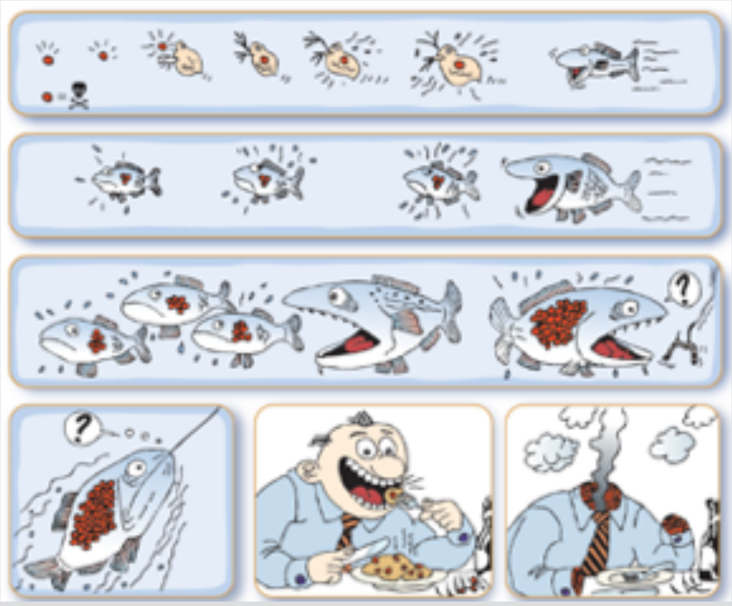
- 1° and last piece are correct

- 2° piece: 3 options: discuss which one is correct!

- 3° piece: 2 options: discuss which one is correct!

- 4° piece: 2 options: discuss which one is correct!

T: Put into words what happens in the cartoon, tell the story.



One group presents the puzzle by telling its story to the whole class. Everyone discusses: Correct? Why not?

Correct your own puzzle if necessary

Figure 22: Strip cartoon illustrating bio-accumulation of poison

Why is the strip cartoon of bio-accumulation of poison an inquiry-based activity?

The correct puzzle is the original strip cartoon. The strip cartoon was not divided in pieces. It was just one piece of paper that was made into a puzzle in order to make it into an inquiry-based activity for learners.

That strip cartoon could have been used as mentioned above: 'Building knowledge with observing and reasoning on a drawing'. By turning some pieces with the computer program Photoshop into 'incorrect' pieces you can make the task more challenging. Learners must think and discuss to find out which pieces are correct and by doing this, they will understand about the concept of bio-accumulation. Once they understand how the process works, the teacher can name it as 'bio-accumulation'.

B.7 Practical application of 5Es and key aspects of STEM instruction in a Biology Lesson

In this video, https://youtu.be/FL5B9IA__eo, teacher Jean Damascene facilitated a biology lesson titled: "Mechanism of breathing in humans". In the lesson, he used the 5E's model and applied various aspects of STEM instruction. As you watch the video, reflect on the questions below:

1. Explain to what extent the introduction is exciting and engaging learners.
2. Are learners engaged in practical activities? Are the activities related to the lesson concepts to address the key question? Explain your answer
3. Have the learners got an opportunity to elaborate on new challenges or application of learned concepts in real life experience?
4. What key aspects of STEM instruction were mostly used in the watched lesson? Are they relevant to the lesson?
5. What does the physics teacher need to do to make his physics lesson more inquiry based?

Appendix C: Materials for Chemistry

C.1 Examples of lesson plans with the 5E instructional model

Lesson 1: Rate of reactions

Term	Date	Subject	Class	Unit N°	Lesson N°	Duration	Class size
2		Chemistry	S3	4	1+2	80’	36
Type of Special Educational Needs and number of learners				Special attention for slow learners			
Topic area:		Chemical reactions					
Sub-topic area:		Types of reactions					
Unit title		**5. Rate of reactions**					
Key Unit Competence:		The learner should be able to describe and explain the effect of different conditions on the speed of reactions					
Title of the lesson		Which conditions affect the speed of reactions?					
Learning Objectives (inclusive to reflect needs of whole class)							
• **Knowledge & understanding**		• define the rate of a reaction • describe the effects of different conditions on the speed of reactions					
• **Skills**		research and scientific reporting skills					
• **Attitudes & Values**		• Develop a culture of working in a team during discussions and research • appreciate everyday phenomena such as burning and rusting involve chemical reactions • respect for the procedures in an experiment.					
Plan for this Class (location: in / outside)		• Inside the class					
Learning Materials (for all learners)		Student book chemistry, Senior 3, Unit 5: rate of reactions (p. 157 – 161) Experiment sheets (see end of this lesson plan) Notebook					
References		Student book chemistry, senior 3, Unit 5: rate of reactions (p. 157 – 161)					

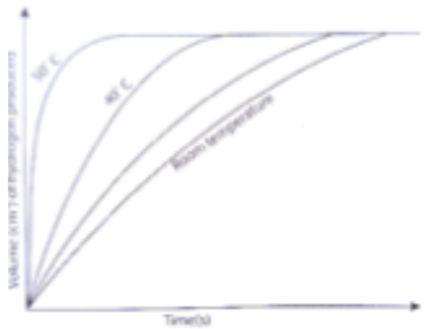
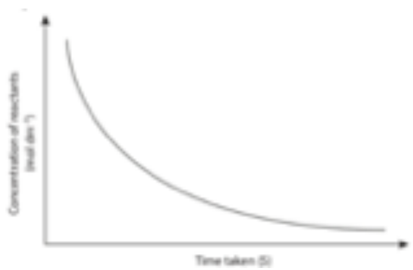
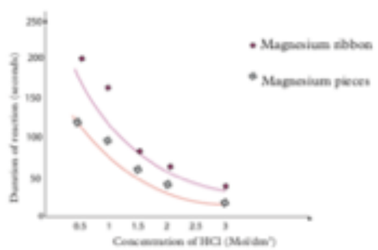
<table>
<tr><th rowspan="2">Timing for each step</th><th colspan="2">Description of teaching and learning activity: Students will be shown examples of quick and slow reactions to excite them. Thereafter, they will perform themselves other given reactions and draw conclusions about factors influencing rate of reaction. Finally, they will be given graphs to interpret and answer the key question.</th><th rowspan="2">Competences and cross cutting issues to be addressed</th></tr>
<tr><th>Teacher’s activities</th><th>Learner’s activities</th></tr>
<tr><td>Introduction
5 min</td><td>Engage/excite

Teacher (T.) shows a new not rusted and (the same but older) rusted nail. T. also takes a sheet of paper and burns it. Then she/he asks:
• Answer with the A/B cards: Is the rusting a chemical (A) or physical (B) phenomenon? The same question for the burning of paper.
• What happens in a chemical reaction?
• What is the difference between the two reactions?
• Try to describe what the reaction rate might be.
• How can we accelerate the rusting/burning?
• How can the rusting/burning be slowed down or stopped?
T. tells: We can measure how fast a reaction takes place. This rate of reaction is the speed at which reactants are converted into products. The rusting of iron is a slow reaction that can take many years, but the combustion of paper in a fire is a reaction that takes place in a second. So, the reactants determine the rate of reaction. But for a certain reaction, which conditions can influence the rate of a reaction?</td><td>• All learners (L.) answer with A/B cards or left/right hand.
• L. answer: In a chemical reaction there is a collision between reactants, resulting in another formation of the particles. New molecules are the products.
• L: the speed of the reaction
• L. try to form a description of reaction rate (as the name itself makes this clear)
• L: Maybe by placing the material in a place with more or less water/ air/…
(hypothesis => don’t have to be correct)</td><td>Knowledge:
Recalling knowledge on physical or chemical phenomena

Skills:
formulating hypothesis

Attitude et value:
link with daily life</td></tr>
</table>

	Teacher writes this key question on the blackboard. (**This key question** is also the research question.)	Learners write the key question (= research q.) and their hypothesis (answer key q.) in their notebook.	
Development of the lesson 10 min	**Explore (+ explain by learners)** T. writes the hypothesis on blackboard and points out which ones will be examined: the influence of: 1. temperature 2. concentration of reactants 3. particle size of reactants The T. divides the class in 9 groups of 4 learners. Each group will perform each experiment in 10 min. After 10min, the T. will give the signal that each group has to go to another desk to perform the next experiment. There are 3 spots for each experiment. The needed materials and the 'experiment sheet' with procedures and questions are placed in these spots.	Learners formulate a hypothesis Learners listen to the instructions.	
30 min	The T. draws the organization of the practicum on the blackboard. T. asks that learners note observations, answers on the questions, conclusions and possible explanations for each experiment in their notebook. After the practical work, T. explains how to clean the desks and put the materials on the right place.	Learners do the practical work and note observations, answers on the questions and conclusions in their notebooks. Learners put the materials back on the correct place and clean their desks.	

15 min	**Explain** T. asks learners to formulate their written observations, answers and conclusions of each experiment. Classical correction. The T. guides learners (questioning) to find the explanations and helps to write the equations of the reactions.	(obs: The yellow precipitations occur faster in the warmest test tube. concl: The reaction occurs faster in a warmer environment. Temperature influences the rate of reaction.	
15 min	**Elaborate** T. gives these graphs (found in student book) of other experiments and asks to interpret the graphs in groups.    T. let some learners formulate the interpretations of their group and asks which other groups have the same interpretations.	expl.: The molecules have more energy with higher temperature, so they move faster. This makes the chance of a collision between the reactants higher. and so on…) Learners discuss in groups what is shown in each graph. Learners answer.	

Conclusion 5 min	**Evaluate** T. asks learners to answer the key question.	Learners answer.	
Teacher self-assessment			

Experiment sheets on the desk of the learners

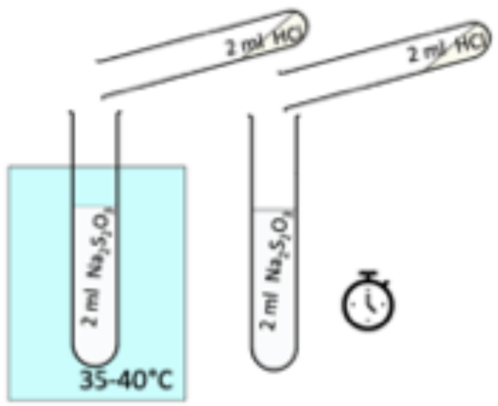
Key question: Which conditions can influence the rate of a reaction?

<u>Experiment 1</u>

Research question 1: What is the influence of temperature on the reaction rate?

Materials:
Flask, used as a warm water bath – heater – thermometer - 4 measuring cylinder of 10ml (or 2 measuring cylinders and 2 test tubes) – hydrochloric acid (HCl) – sodium thiosulphate solution ($Na2S2O3$)

Method:



- Heat water in the flask until the temperature is between 35°C and 40°C.
- Take 2 measuring cylinders or test tubes and add in each 2 mL $Na2S2O3$
- Put 1 test tube in the warm water. Wait a little bit, the warmth of the water has to warm up the $Na2S2O3$ in the test tube.
- Take the 2 other test tubes and add in each 2 mL HCl
- Pour at the same time the 2 test tubes with HCl in the 2 test tubes with $Na2S2O3$
- Observe.

Observations:

Describe what you observe.

………

In which test tube is the fastest rate of reaction?

………

Conclusion:

……………………………………………………………… has an influence on the rate of reaction.

Explain: try to explain these observations (hint: What is happening on molecular scale?)

………

………

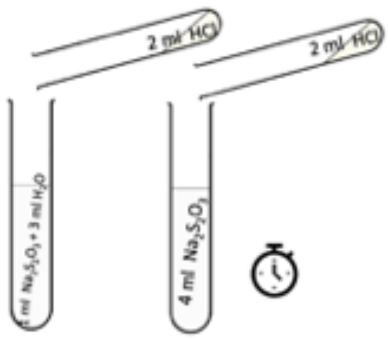
Experiment 2

Research question 2: What is the influence of concentration on the reaction rate?

Materials:

2 measuring cylinders - 2 test tubes in a rack – pipette – water - hydrochloric acid (HCl) – sodium thiosulphate solution (Na2S2O3)

Method:



- Prepare two cleaned test tubes and label them 1 and 2 and two measuring cylinders 1 and 2.
- Using a pipette, add 1mL Na2S2O3 and 3mL water in the test tube 1.
- Add in the second test tube 4mL Na2S2O3
- Pour in each measuring cylinder 2mL of HCl
- Pour at the same time the HCl in each test tube
- Wait approximately 1 minute
- Write down your observations.

Observations:

Describe what you observe.

………

In which test tube is the fastest rate of reaction?

………

Conclusion:

………………………………………………………… has an influence on the rate of reaction.

Explain: try to explain these observations (hint: What is happening on molecular scale?)

………

………

………

Experiment 3

Research question 3: What is the influence of particle size on the reaction rate?

Materials:

2 beakers of 400 mL – 2 measuring cylinders of 50mL – mortar and pestle – balance – vinegar (CH3COOH) – piece of chalk (from blackboard) (CaCO3)

Method:

- Break the chalk in 2 pieces.
- Weigh the smallest piece: m = …………………g and put it in a beaker.
- Flatten the other piece of chalk in the mortar.
- Weigh the same amount of chalk as the other piece and put this amount in the other beaker.

- Put in each measuring cylinder 20 mL of vinegar
- At the same time, pour the vinegar in the two beakers.

Observations:

Describe what you observe.

……

In which test tube is the fastest rate of reaction?

……

Conclusion:

The rate of reaction is faster when the particle size is ……………………………………………………

Explain: try to explain this conclusion

……

……

……

Experiment sheets on the desk of the learners

Which conditions influence the rate of a reaction?

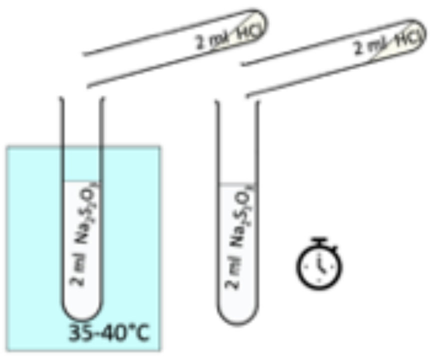
<u>Experiment 1</u>

Research question 1: What is the influence of temperature on the reaction rate?

Materials:

Flask, used as a warm water bath – heater – thermometer - 4 measuring cylinder of 10mL (or 2 measuring cylinders and 2 test tubes) – hydrochloric acid (HCl) – sodium thiosulphate solution (Na2S2O3)

Method:



- Add 100 mL water in each of two flasks (250 mL)
- Heat water in the flask until the temperature rises to between 35°C and 40°C.
- Take 2 measuring cylinders or test tubes and add in each 2 mL Na2S2O3
- Put 1 test tube in the warm water. Wait a little bit, the warmth of the water has to warm up the Na2S2O3 in the test tube.
- Take the 2 other test tubes and add in each 2 mL HCl
- Pour at the same time the 2 test tubes with HCl in the 2 test tubes with Na2S2O3
- Observe.

Observations:

Describe what you observe.

...... A yellow precipitate is formed ....

In which test tube is the fastest rate of reaction?

......In the warm test tube ....

Conclusion: ....Temperature has an influence on the rate of reaction.

Explain: try to explain these observations (hint: What is happening on molecular scale?)

......A higher temperature means that the particles get more energy and therefore move faster. This increases the frequency of fruitful collisions between reacting particles. The greater the number of collisions, the faster the rate of reaction.

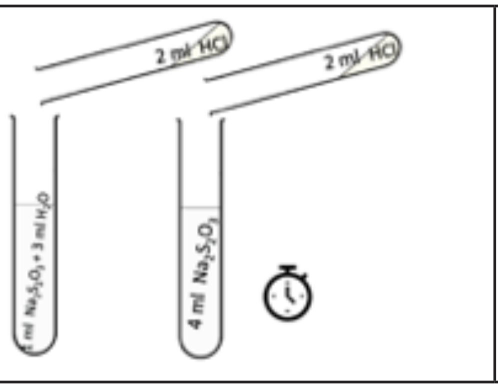
Experiment 2

Research question 2: What is the influence of concentration on the reaction rate?

Materials:

2 measuring cylinders - 2 test tubes in a rack – pipette – water - hydrochloric acid (HCl) – sodium thiosulphate solution (Na2S2O3)

Method:

	- Using the pipette add in the first test tube 1mL Na2S2O3 and 3mL water - Add in the second test tube 4mL Na2S2O3 - Add in each measuring cylinder 2mL HCl - Pour at the same time the HCl in the 2 test tubes - Wait more or less 1 minute

Observations:

Describe what you observe.

...... A yellow precipitate is formed in both test tubes...

In which test tube is the fastest rate of reaction?

.........The second test tube...

Conclusion:

…The concentration of the reactants has an influence on the rate of reaction.

Explain: try to explain these observations (hint: What is happening on molecular scale?)

Increasing the concentration of reactants increases the frequency of successful collisions between reacting particles. The greater the number of collisions, the faster the rate of reaction.

Experiment 3

Research question 3: What is the influence of particle size on the reaction rate?

Materials:

2 beakers of 400 mL – 2 measuring cylinders of 50mL – mortar and pestle – balance – vinegar (CH3COOH) – piece of chalk (from blackboard) (CaCO3)

Method:

- Break the chalk in 2 pieces.
- Weigh the smallest piece: m = ………………..g and put it in a beaker.
- Flatten in the mortar the other piece of chalk.
- Weigh the same amount of chalk as the other piece and put this amount in the other beaker.
- Put in each measuring cylinder 20 mL vinegar
- Pour the vinegar at the same time in the to beakers.

Observations:

Describe what you observe.

……Gas is formed. The chalk reacts and therefore disappears……………………………………….

In which test tube is the fastest rate of reaction?

………..test tube 2 ……………………………………………………………………………………………………

Conclusion:

The rate of reaction is faster when the particle size is ……smaller…

Explain: try to explain this conclusion

…Many smaller pieces of the same mass of solid provide a greater surface area compared to larger pieces. This increases the contact surface of the reactants colliding with each other so there will be more collisions that result in products in the same amount of time. This means that the reaction rate increases.

Lesson 2: Types of mixtures

Term	Date	Subject	Class	Unit N°	Lesson N°	Duration	Class size
2		Chemistry	S1	4	4	80’	

Type of Special Educational Needs and number of learners:	Special attention for learners with low English language skills
Topic area:	**Scope of chemistry and particulate nature of matter**
Sub-topic area:	Classification of substances and separation techniques
Unit title	**Pure substances and mixtures**
Key Unit Competence:	To be able to separate mixtures and determine their composition
Title of the lesson	Types of mixtures: • Homogenous mixtures • Heterogenous mixtures
Learning Objectives (inclusive to reflect needs of whole class)	By the end of this lesson, learners should be able to: • Describe what a homogenous and heterogenous mixture is • Identify a given example as homogenous or heterogenous mixture
• **Knowledge & understanding**	Describe the different types of mixtures with examples
• **Skills**	Classify different types of mixtures into homogeneous and heterogeneous
• **Attitudes & Values**	Appreciate the importance of mixtures in daily life.
Plan for this Class	In class
Learning Materials	Water, salt, plant leaves, oil, ethanol, lemon soda, iron filings, perfume, honey.
References	S1 Student Textbook (Chemistry for Rwandan schools) Attention point: There is a content error in the book “A mixture is a substance who components……” **Instead** “A mixture is a material made up of two or more different substances which are mixed. A mixture refers to the physical combination of two or more substances in which individual substances keep their properties and are mixed in the form of solutions, suspensions and colloids.

Timing for each step	**<u>Description of teaching and learning activities</u>** After engaging learners in the lesson using a discrepant event, they are divided in groups and each group is assigned an experiment to do and present their findings.		**Competences and crosscutting issues to be addressed with a short explanation.**
	Teacher's activities	**Learner's activities**	
Introduction 10 min	**Excite/engage:7min** →Teacher shows a beaker and different chemical substances: chloroform, distilled water, ethyl acetate, copper sulphate and Iodine →Teacher pours 5 mL of chloroform into the beaker, then adds 5 mL of distilled water and uses a spatula to stir. →Teacher adds 5 mL of ethyl acetate to the same beaker and stirs again. →Teacher adds 5 mL of copper sulphate to the mixture and stirs again. →Finally, the teacher adds 5 mL of Iodine to the same mixture and stirs. In groups of 3, learners raise any three questions related to their observations. Each group shares one question they would like to get an answer to from the 3 questions. The teacher helps with correct formulation and records them. Based on the questions from learners, try to come to the key question of the lesson. **Key question:** What happens when we mix pure substances?	The learners observe what the teacher is doing  *Image of how the cocktail would look like. Retrieved from:* https://www.youtube.com/watch?v=UJMfPrB8kGk The learners write down the questions related to their observation. Learners correct the formulation of their question.	Critical thinking while thinking on what they observe. Communication skills in official language while answering to the teacher

Development of the lesson **60min**	**Explore: 20min** **The teacher gives instructions and assigns tasks in groups of 6 learners** **Experiment 1:** - In 50 mL of water, add one teaspoon of salt and mix with a stirring rod (**solid-liquid mixture**). **Experiment 2:** In a beaker containing water, add plant leaves and shake. (Mixture of **solid- liquid mixture)**. **Experiment 3:** In 20 mL of water add 5 mL of oil and shake. (**Liquid-liquid mixture**). **G4.** In 20 mL of water, add 10 mL of lemon soda and shake. **(Liquid-liquid mixture).** <u>**Explain:**</u> **30min** **Groups present their findings:** →The teacher asks one group to present their observations for the first experiments and asks which group had the same observations. Then he asks another group for their observation on experiment 2, until all experiments are presented. →The teacher uses the following questions to help learners conclude: o Can you differentiate the substances mixed in the experiments? Why or why not?	Learners work in groups of 6 and answer the questions as they are performing the experiments: ▪ What is the state of matter of both substances that you mix? ▪ What happens while mixing the substances? ▪ What do you observe directly after mixing? ▪ What do you observe 1 minute after mixing is finished? ▪ Can you differentiate the substances mixed in the experiments? Why or why not?	Cooperation, interpersonal management and life skills while working in group Gender education: All groups' boys and girls are mixed with different tasks Environment and sustainability education while learners exercise caution and care when disposing products and waste during experiments Peace and values education: Working in peace, in harmony. Communication skills while formulating their observations.

	The teacher summarizes learners' ideas and introduces the scientific names of the 2 types of mixtures: Homogenous and Heterogenous mixtures. The teacher helps learners to differentiate some of the scientific terms used: o Mixture of salt and water is a homogeneous mixture (solid-liquid mixture) also called a **solution**. o Mixture of lemon soda and water (liquid-liquid mixture) is homogenous mixture. Homogenous mixture of two liquids is known **as miscible liquids**. o when you mix salt and water, the solid (salt) seems to disappear in the water. This process is called **dissolving**. o When a solid is dissolved in a liquid, we call the liquid a **solvent** and the solid is called the **solute**. o Mixture of plant leaves and water (solid-liquid mixture) is a **heterogeneous mixture**. o Mixture of oil and water is heterogenous as they form two separate layers. Heterogenous mixture of two liquids is known as **immiscible liquids**. o The plant leaves float over water: this phenomenon of floating solid in liquid is called **suspension**.	• Learners present their findings • Learners record the definitions in their notebooks.	Inclusiveness: slow and quick learners are mixed and involved equally.

	Elaboration:10min The teacher takes a bottle containing honey and pours it in a glass. The teacher questions the learners as follows: ▪ What type of mixture is honey? ▪ Is the mixture of water and petrol homogenous or heterogenous? Explain your answer The teacher sprays perfumes in air and asks learners about what they observe: ▪ Does the smell in air change? ▪ If yes, why? If no, why not?	• In pairs, learners discuss about the questions provided and give answers. • Learners provide the answers and explain the reasoning behind each answer.	
Conclusion 10 min	**<u>Evaluation</u> :13min** The teacher asks questions to the learners. They answer by voting (through raising hands). Ask a few to give arguments for their answer. End each question with giving the correct answer and explanation. Q1. Are the following mixtures homogenous or heterogenous? a. Water and ethanol b. Beans and oil c. Fresh milk and water d. Iron filings and water Q2. In an aqueous solution of glucose, what is the solute and what is the solvent? Q3. Is air a mixture? Yes, or not? Explain your answer.	For each question, learners answer by raising their hands. Q1. Answers: a. Homogenous b. Heterogenous c. Homogenous d. Heterogenous Q2. Answers: - Solute: Glucose - Solvent: Water Q3. Answers: Yes. Air is a mixture of gases like oxygen, nitrogen, carbon dioxide, water vapour, …	

C.2 Peer Instruction Examples

Example 1: Dissolving Process

When you stir a teaspoon of sugar into a glass of warm water, the sugar completely dissolves in the water. Which statements are true (more than one correct answer is possible)?

A. The sugar melts.
B. The sugar turns into water molecules.
C. The sugar disappears and no longer exists.
D. The sugar molecules are spread among the water molecules.
E. The sugar breaks down into the individual atoms that make up sugar.
F. The sugar chemically combines with the water to form a new substance.

The best answer is D. When grains of sugar are added to the water, they form a mixture, called a solution. Sugar molecules become surrounded by polar water molecules, breaking apart the sugar molecule crystal. When sugar dissolves, it is physically, not chemically, combined with water and therefore, it does not form a new compound. Dissolving is different from melting because melting involves a change of state and does not require the interaction between two substances as dissolving does. According to the conservation of mass principle, the mass of sugar remains the same even though it cannot be seen in the solution.

Example 2: Chemical bonds

Three students were discussing their ideas about chemical bonds. This is what they said:

A. I think a chemical bond is produced by a molecule. It is a substance made up of matter that holds atoms together.
B. I think a chemical bond is an attraction between atoms. It is not made up of matter.
C. I think a chemical bond is a structural part of an atom that connects it to other atoms.

The best answer is B. Chemical bonds are formed between atoms as a result of an attraction between their outer electrons. The bond exists as an attractive force between the atoms where electrons are transferred or shared. Many students can define the different types of chemical bonds and the mechanisms behind it, yet still have the common misconception that a chemical bond is a structural component or a glue-like form of matter.

Example 3: Structure of Atoms

A group of friends is looking at grains of salt through a magnifying glass. They are wondering what they would see if they had a device powerful enough to see the individual atoms. These are their answers:

A. The atoms would be packed tightly together. They would look like a solid material without any empty spaces between the atoms.
B. I would see vibrating atoms arranged in an orderly way with spaces between them. There would be nothing in the spaces, not even air.
C. I think I would see atoms not moving and arranged in an orderly way. There would be space between the atoms. The space would be filled with air.

D. I think I would see atoms in the shape of small cubes. Each of these cubes would join together to form a larger cube of salt.

E. I think I would see lots of vibrating atoms connected together by little lines. The lines connecting each atom give them a definite cube shape.

F. I think I would see individual atoms moving from place to place. They would be moving all about the inside of the crystal shape.

The best answer is B. The salt is an example of a crystalline ionic lattice. A salt crystal is made up of a structure of orderly repeating sodium and chlorine ions. This structure is caused by the electrostatic attraction between negatively and positively charged ions and gives salt grains its cubic shape. The ions are closely locked into position and can only vibrate. There is empty space between the atoms in the crystal, but it is not filled with air. The material is pure salt, not a mixture of salt with air. The lines that are sometimes used in drawings or models are not the actual physical structures but the representations of the attraction among the ions.

C.3 Concept Cartoons

1. Liquids

Explanation

This cartoon deals with the nature of liquids. Scientifically a liquid is a substance with a fixed volume but a variable shape. It will take the shape of a container. Although modelling clay can also have its shape altered, it will retain its shape until something acts to change it. "Runny solids", such as sand or salt, seem to mimic the property of taking on the shape of the container. However individual pieces of sand or salt do not change shape like liquids do. Each piece is a small solid. Experience of a wide range of substances, (including some which cannot be categorized easily), discussion and reflection are necessary for students to develop understanding of different states of matter. It will be helpful to differentiate between pure substances, which are easily categorized and more complex mixtures. Mixtures more often combine the properties of solids, liquids or gases. This cartoon can be combined with a card sorts activity, in which students classify substances according to criteria they discuss.

2. *Scrambled Eggs*

Explanation

This cartoon deals with the nature of a pure element (a pure substance containing only one type of atom), a compound (two or more types of atoms combined) and a mixture (two or more elements or compounds mixed together). Confusion is quite likely because eggs are not made from a single pure substance. Eggs are made up of a complex mixture of compounds which are changed chemically during heating. You can review the definitions of elements, compounds and mixtures and let students find out more about the chemical makeup of eggs and to look at how the white and yolk are each affected separately by heat.

3. Condensation

Explanation

Although condensation is a daily life experience, it is not clear for many learners where the condensed water comes from. Water vapour is present in the air, but it is invisible. At higher temperatures, the water vapour is likely to remain as a gas, but at lower temperatures it condenses to liquid droplets. A glass containing ice is normally cold enough for water vapour in the surrounding air to turn into liquid droplets on the side of the glass.

You can use practical activities to explore the situation. Taking an empty cold glass can show that the ice in the glass is not essential for condensation to occur and that water is not leaking out of the glass. Comparing the amount of condensation in still air, moving air, warm air and moist air helps to make the connection with water vapour in the air clear. Exploring where and when condensation occurs is a useful way to learn about condensation.

4. *Rusty Nails*

Explanation

Rusting requires the presence of air and liquid water, so wet nails will rust quickly. If they are completely submerged, rusting will still occur because water contains dissolved air. However, it will take longer due to the lower concentration of oxygen in the water. Cold conditions will slow down rusting due to the lower concentration of water vapour in cold air. Although rust may look like a disease, it is not. The presence of other rusty nails does not make rusting more likely. You can let students investigate the situation by setting up various combinations of the different factors (let them first brainstorm to determine these themselves) that might be involved in rusting. Removing air completely is the most difficult part. A layer of oil or paint will keep the air out, but it will also prevent moisture getting to the nail. Boiling water for a few minutes to remove the air, then putting a nail in boiled water in a sealed container can provide water but no air as a comparison. Make sure to test one variable at a time.

5. *Rusty Nails (2)*

Explanation

As nails rust, they get heavier. This is an important indication that the process which is occurring is a chemical reaction and not just a physical change. If the jar does not have an airtight seal, the total weight of the jar and nails will be heavier as the iron nails react with oxygen in the air to form iron oxide (rust). The change of weight in the nails can be investigated. A useful extension is to find out where the additional weight came from. In a sealed jar, the total weight of the jar plus nails will be constant, even though the nails increase in weight. Setting up the situation with nails in a jar with a gas such as carbon dioxide (you can do this with a candle) will show that oxygen is essential for rusting to occur.

6. *Sweet Tea*

Explanation

A common misconception is that when substances dissolve, they just vanish. Even though the sugar is invisible when it is dissolved, the total weight of the substances in the tea and sugar does not change. This is the reason that the tea tastes sweet.

Weighing the tea and sugar before and after dissolving is easy and will indicate clearly whether the weight has changed. A lever balance can be used if sensitive scales are not available. The balance can be levelled with tea and sugar separately on one side, then the sugar is dissolved in the tea and the balance checked to see if it has altered. Completely evaporating some sweet tea will show that the sugar is still present in the tea.

7. Burning Candle

Explanation

Although watching a burning candle is a common experience, understanding what is happening when the candle burns is not easy for learners. A misconception is that the wick burns, and the wax is only there to hold up the wick. In reality, both the wick and the wax burn. The wax melting is visible, but the wax vaporizing and burning is not. Careful observation of the candle leads to the question of where the wax has gone. A useful approach is to find other ways of burning the wax, such as using a match or a piece of card as an alternative to a wick in some molten wax.

C.4 Practical application of 5Es and key aspects of STEM instruction in a Chemistry Lesson

In this video, https://youtu.be/QYo5F-Bn5nc , teacher Aloys facilitated a chemistry lesson titled: "Balancing chemical reaction". In the lesson, he used the 5E's model and applied various aspects of STEM instruction. As you watch the video, reflect on the questions below:

1. Explain to what extent the introduction is exciting and engaging learners.
2. Are learners engaged in practical activities? Are the activities related to the lesson concepts to address the key question? Explain your answer
3. Have the learners got an opportunity to elaborate on new challenges or application of learned concepts in real life experience?
4. What key aspects of STEM instruction were mostly used in the watched lesson? Are they relevant to the lesson?
5. What does the physics teacher need to do to make his physics lesson more inquiry based?

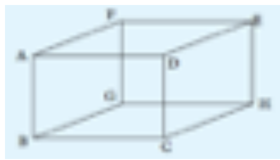
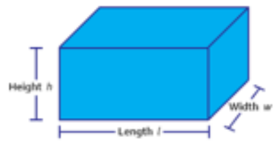
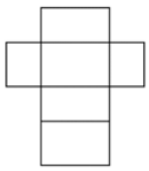
Appendix M: Materials for Mathematics

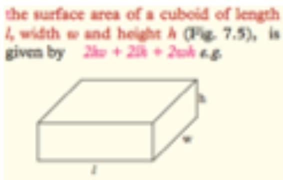
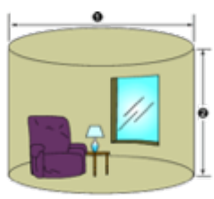
M.1 Example lesson plan with the 5E format (Level of inquiry 1)

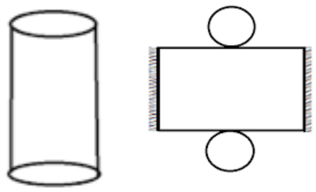
Term	Date	Subject	Class	Unit N°	Lesson N°	Duration	Class size
1		Surface area of solids	S1	7	2	80 min	

Type of Special Educational Needs to be catered for in this lesson and number of learners in each category	40 students, special attention for learners with low language skills
Topic area:	Mathematics
Sub-topic area:	Geometry
Unit title	Solids
Key Unit Competence:	To be able to select and use formulae to find the surface area and volume of solids
Title of the lesson	The surface area of solids, e.g. cuboid & cylinder
Learning Objectives (inclusive to reflect needs of whole class)	At the end of the lesson, every learner will be able to: ▪ Use drawings of the nets of solids (cuboid, cylinder) to derive the surface area. ▪ Describe the properties of solids cuboids, cylinders… ▪ Calculate the surface area and volume of a cuboid, cylinder... ▪ Use the formulae for surface area.
• **Knowledge & understanding**	Explain the surface area of a solid as the area of the net.
• **Skills**	Derive the surface area for cuboids and cylinders.
• **Attitudes & Values**	Recognize solids in the environment.
Plan for this Class (location: in / outside)	Inside
Learning Materials (for all learners)	1 model of cuboid in cardboard, like a cereal box. 1 model of cuboid in cardboard that can be unfold as demonstration set, preferably the same size as the model above. Ruler, pen (different colours) & paper for all learners
References	Mathematics for Rwandan school senior 1 Student's Book. Longhorn publishers, 2016. https://www.khanacademy.org/math/basic-geo/basic-geo-volume-sa#basic-geometry-surface-area

Timing for each step	Description of teaching and learning activity		Core Ideas, Competences and cross cutting concepts
	Student are challenged and excited by the problem how much paint we need to decorate our bedroom. Guided by the teacher they will come to the key question 'What is the surface area of a cuboid?'. They explore and try to derive a formula for a cuboid by drawing a well labelled net of the cuboid on a piece of paper. After summarizing and explaining the formula of the surface area they do some short exercises. They will deepen and elaborate their skills to a new solid, a cylinder. Finally, we will return to the initial problem (evaluate) and try to find out how much paint we need.		
	Teacher's activities	**Learner's activities**	
Introduction 15 min	**Excite/Engage** Present problem: How much paint does a painter need to decorate your bedroom (walls and ceiling)? - How can you know how much paint you need? Take a close look at the instructions on the paint. - How much paint is in this jar? - How much surface can you paint? We have to rephrase the problem: What is the total surface area of your bedroom that needed to be painted? - Imagine your room: What solid or polyhedron does your room looks like? - What is the difference between the surface area of a cuboid and the area that must be painted?	Thinking about the problem. Reading instructions on the paint, for example for this jar of 2,5 l.  Possible answers: 20m2/2,5 l or 8m2/l Possible answers: cuboid, cube, … Possible answer: the total surface area of cuboid is not equal to the surface area that is needed to be painted because we don't need to paint the floor.	Knowledge With 1 litre of paint, you can paint a fixed size of surface. The shape of your bedroom looks best like the polyhedron of rectangular box or a cuboid.

Development of the lesson 55 min	**Explore** Look at this **cardboard model of cuboid of our room**. It will help you follow these instructions, write *italic* on the blackboard (or give each group a worksheet) 1. *Draw a 3D model* of the cuboid on your paper, answer these questions: - *How many faces, edges and vertices?* - *Label each vertex with A. B. C, …* - *Point out the height, length and width.* - *Shade the area surface of 2 faces* 2. *Drawing of a well labelled net of* the cuboid: - *How can you draw the total surface of the cuboid on a piece of paper?* - *How can you make a net that visualises the total surface of the box?* Tip: Look at the 3D model in cardboard, and you have to unfold it in a way that it would become flat. - *Where you need to cut? Draw in a different colour the edges you want to cut.* - *Now make a 2D drawing so that all faces are unfold? Make sure that the corresponding vertices are correct!* Calculation of surface area: - *How would you calculate the area of the cuboid using the net?* - *Use the net to calculate its area in terms of l, w, and h.*	Learners work in pairs, take paper & pen and follow guiding questions on the blackboard. Possible answers: 6 faces, 8 edges and 8 vertices    + labelled with letters A, B, C, D, E, F, G, H, E Learners with trouble drawing a net can use extra info: https://www.khanacademy.org/math/basic-geo/basic-geo-volume-sa/basic-geometry-surface-area/v/nets-of-polyhedra Different solutions and drawings of learners are possible.	Knowledge: Faces, edges and vertices of a polyhedron Drawing a net of a cuboid. Connect the surface area of cuboid with the area of the net and derive the formula of the surface area of a cuboid.

	Explain Evaluate different drawings and formulas of the learners. It may be possible learners have different drawings, but in the end, they all would have the same formula. Use the foldable model to explain the connection between surface area of cuboid and area of the net. Bring a correct formula and on the blackboard. Revision for learners with difficulties: https://www.khanacademy.org/math/basic-geo/basic-geo-volume-sa/basic-geometry-surface-area/v/surface-area-of-a-box-using-nets	One group brings its drawing and formula in front of the class. Other groups compare their results with them.	
5 min	Extra (if time left): practice with these exercises: https://www.khanacademy.org/math/basic-geo/basic-geo-volume-sa/basic-geometry-surface-area/e/surface-area		Making short exercises to practice the formula of surface area of cuboid.
	Elaborate Suppose your room looks likes this (see picture), how would you calculate the surface area?	 	The shape of this room looks best like the polyhedron of cylinder.

	Use the paper toilet roll as a model and unfold it to create a net.		Formula of surface area of cylinder Open cylinder = $\pi r^2 + 2\pi rh$ Closed cylinder = $2\pi r^2 + 2\pi rh$
Conclusion 10 min	**Evaluate** Back to the starting problem: how much paint do we need if our room is 2,5-meter-high, and the floor is 5 meters by 4 meters? Reflection question: In reality, you will need less paint than calculated. Why?	Calculation of area surface of room (cuboid) – surface area of floor = total area that must be painted. Then you can calculate the amount of paint you need when you know how much area you can paint with 1 liter paint. Possible answers: doors, windows, …	
Teacher self-evaluation			

M.2 Example lesson plan (Level of inquiry 3)

Term	Date	Subject	Class	Unit Nº	Lesson Nº	Duration	Class size
		Maths	S1	7		80 min	
Type of Special Educational Needs and number of learners:							

Topic area:	Maths
Sub-topic area:	Geometry
Unit title	Solids
Key Unit Competence:	select and use formulae to find the surface area and volume of solids.
Title of the lesson	A mathematical morning
Learning Objectives (inclusive to reflect needs of whole class)	
• **Knowledge & understanding**	Use formulas to find the volume or surface of a solid
• **Skills**	Team spirit and collaboration
• **Attitudes & Values**	Recognise solids and their quantity in their environment.
Plan for this Class (location: in / outside)	Inside
Learning Materials (for all learners)	Chalk, chalkboard, pens, notebooks, A3 papers (2 per group of 4 learners), one or two calculators, if possible, provide a recipient to measure volume of a liquid and/or a balance
References	A mathematical morning in https://primas-project.eu/wp-content/uploads/sites/323/2017/11/primas_final_publication.pdf

Timing for each step	Description of teaching and learning activity		Competences and cross cutting issues to be addressed
	Teacher's activities	**Learner's activities**	
Introduction **(20 min.)**	**Excite/engage collecting question** Write down what things you usually do in the morning until you arrive at school. Discuss with the partner next to you what questions of mathematical nature you can raise about the morning procedures. Search for questions that quantify the impact of your habits. Teacher gives some examples of good questions (see learner's activities) and help individual pairs to find good questions. Bring your best question on the blackboard. Teacher discusses all the questions and in dialogue with the classroom some questions are improved. Key question: How do we know the quantity of what we drink every morning?	Learners make a list individually. Possible questions: How many litres of water (tea, juice...) do I, or does our class, or does the whole school drink every morning for breakfast?' 'How much toothpaste am I going to consume during my life-time?' Every group chooses its most interesting question and put it on the blackboard.	Recognizing solids and their quantity in their environment. Formulating mathematical questions related to daily life.
Development of the lesson **50 min**	**Explore** Divide the class group in group in groups of 4 learners.		

	Select your most favourite questions (max. 3) which you like to solve mathematically. Solve the questions as well as you can. If you cannot find an exact formula, make an educated guess or approximation. You get 30 min. Teacher gives every group one or two A3 posters.	Group select questions and tries to find an answer. Learners ask teacher for tips and ideas on how to solve the questions. Learners put their questions and their solutions on the A3 posters.	Think logically and creatively and coherently. Team spirit and collaboration
	Explain Teacher discusses the answers with the group. If necessary, some improvements and tips are formulated. If similar questions are chosen, the solution is compared. Differences are discussed. Posters are put on the wall of the classroom.	Learners present their posters. Learners discuss the results of other groups.	Listening skills
Conclusion **5 min**	Mathematics can be used to solve daily life questions. Mathematics is everywhere in our life.		
Evaluate **5 min**	Evaluate Exit ticket: 1. How much toothpaste is you going to consume during your life-time?” 2. what did you learn today? What questions do you still have?		
Teacher self-assessment			

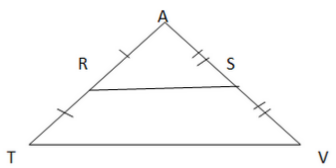
M3. Example lesson plan on Midpoint Theorem

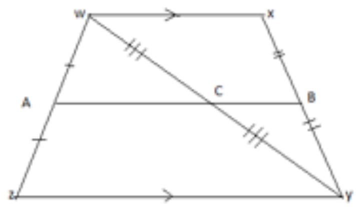
Term	Date	Subject	Class	Unit Nº	Lesson Nº	Duration	Class size
Term 2	29 May 2019	MATHEMATICS	S2	5	1 of 12	60 min	40
Type of Special Educational Needs to be catered for in this lesson and number of learners in each category							
Unit title	Thales Theorem						
Key Unit Competence:	To be able to use Thales' Theorem to solve problems related to similar shapes and determine their lengths and areas.						
Title of the lesson	Midpoint theorem						
Instructional Objective	By the end of the lesson, learners should be able to correctly state the midpoint theorem for a triangle and apply it in correctly solving problems for a given situation.						
Plan for this Class (location: in / outside)	Learning Materials (for ALL learners)						
Learning Materials (for ALL learners)	Meter ruler, sticks (each learner brings a stick of 50 cm of length at least and max. 1.5 m), 10 ropes with length greater than 50 cm (around 1,5 m) (availed by teacher)						
References	Mathematics for Rwandan school senior 2 Student's Book. Longhorn publishers, 2017.						

Timing for each step	**Description of teaching and learning activity**		**Generic competences and cross cutting issues**
	At the start (in class) the teacher invites learners to take their sticks and find the key question. Then they leave the class. Once outside, the teacher forms groups of 4 learners and distributes a rope to each group. Learners will follow teacher's instructions. This step aims at letting learners explore the midpoint theorem. After 20 minutes, learners come back in class and share findings.		
	Teacher activities	**Learner activities**	
Introduction 10 min	**Excite/engage** The teacher asks learners to show their sticks and asks few learners to say approximately the length of their sticks. The teacher leads learners to revise concepts of line, segment and triangle.	Learners show their sticks. Expected answers: 1m, 80 cm, 50cm etc.	Communication skills: answering questions and discussing.

	Teacher shows a piece of rope and asks one learner to come and demonstrate how to use the rope to identify the half of the stick. Teacher asks if somebody found a different solution. The teacher asks one learner to draw a triangle on the blackboard. The lesson challenge will be to find patterns in the triangle when the sides of the triangle are divided in half. Teacher formulates the key question: **what does the midpoint theorem tell us?** The teacher asks learners to get outside with their sticks, notebooks and pens.	One learner does demonstration in front of the class. Learners get out the class with their sticks	

Development of the lesson **40 min**	**Explore** The teacher forms small groups of 4. The teacher asks learners in their groups to form a triangle using their sticks and giving each group a piece of rope. Teacher asks learners to find the middle of two sides. Teacher asks to join these middle points using the 4th stick Teacher asks to observe the base and the middle segment in terms of (i) parallel segments (ii) length. Note their conclusions on a piece of paper.	Learners form groups of 4. Learners form a triangle with three sticks Learners find the middle of the stick of any two sides of the triangle Learners join the two midpoints of the two sides Learners compare by superposition or measuring using rope Possible conclusions: the two sticks are parallel, the stick in the middle is half of the base, the base is double, etc.	

	Note: While learners are doing activity in small groups, the teacher goes through groups and asks more challenging questions to those who are faster (How can you be sure that the middle is half the base? Can you use this method to draw parallel lines? …) The teacher invites learners to come inside the class		
	Explain The teacher asks some groups of learners to present their conclusions.	Learners enter the class Learners give answers	
	The teacher leads learners to formulate the **Midpoint Theorem**: “The segment joining two sides of a triangle at the midpoints of those sides is parallel to the third side and is half the length of the third side.”		Cooperation through group work.
	 /AR/=/RT/ and /AS/=/SV/ RS // TV /RS/=½/TV/	Learners formulate the **Midpoint Theorem** and then take notes	
	Elaborate The teacher asks learners in their groups to construct trapezium using a ruler accurately. Teacher asks learners to find the middle of two non-parallel sides.	Learners construct a trapezium and draw the middle of the two non-parallel sides of a trapezium. Learners join the middle point of the non-parallel sides of trapezium.	Critical thinking through making conclusion on trapezium.

	Teacher asks to join these middle points of the non-parallel sides of a trapezium. Teacher asks to observe the base and the middle segment of trapezium in terms of (i) parallel segments (ii) length. Note their conclusions on a piece of paper. AB// ZY Extra questions: • What is the difference between the midpoint theorem in a triangle and in a trapezium? • What do you notice if we draw triangle ZWY in the trapezium and apply the midpoint theorem on this triangle?	Learners answer the questions and write the conclusions on a piece of paper. 	Problem solving through construction of triangle.
Conclusion: **10 min**	**Evaluate** Teacher leads learners to solve exercises related to midpoint theorem found in mathematics for Rwandan Schools Senior 2 student's Book page 98 question 1 (use questions 4 and 5 as extension). Collect the solutions of the individual learners. For homework, ask learners to search for information of Thales (his life, his findings, how he measured the height of pyramids, …) because he will be the subject of the next lesson.	Learners solve the questions individually.	Critical thinking Solving problems. Writing skills.
Teacher self-evaluation			

M.4 Concept cartoons

1. Rumours

Discussion:

Whenever a number is multiplied by a fraction, the answer isn't always small. Lots of numbers get smaller when multiplied by a fraction for instance, $10 \times \frac{1}{2} = 5$.However, there are some exceptions, depending on which numbers you multiply. These include multiplying by an improper fraction such as $2 \times \frac{7}{7} = 2$ or $10 \times \frac{22}{7} = \frac{220}{7}$. In these examples, the answer isn't smaller. Multiplying by a mixed number will produce a bigger number, for example $10 \times 4\frac{1}{3} = 43\frac{1}{3}$. What about multiplying two fractions together, such as $\frac{1}{4} \times \frac{1}{4} = \frac{1}{16}$?What about negative numbers? For a teacher to address the misconception, he/she may give several examples for learners to explore and identify the differences. (i.e multiply by improper fractions, mixed fractions, etc)

2. City temperatures

Discussion

A misconception in the cartoon above is to ignore the integer signs and look for two numbers which make a difference of 14 such as Kigali and Beijing. Another common mistake is to ignore the integer signs and look for two numbers with a total of 14 such as Moscow and Beijing. However, integer signs should be considered (For example, the difference between Kigali and Beijing is 18-(-4)=18+4=22; the difference between Moscow and Beijing is -10-(-4)=-10+4=-6. In the cartoon above, the two cities with a difference of 14 degrees are London and Moscow (4-(-10)=4+10=14. To address the misconception, learners should not forget integer signs.

3. *Piles of cans*

Discussion

The cartoon is about operations on consecutive numbers. Some possible misconceptions/ mistakes would be to multiply the cans in the stack by 10 to make 100 cans because there are ten layers or rows. Another mistake is to multiply the four cans on the bottom row in the picture by 10. However, it is not possible to work out the number of cans by a simple multiplication sum. For instance, one way to solve the puzzle is to draw the cans row by row on a mini-whiteboard. In a ten row stack, there will be 1+2+3+4+5+6+7+8+9+10= **55 cans**. A quick way to work out this is $(1+N)\times\frac{N}{2}$ with N the quantity of consecutive numbers or rows. For the stack of cans we get $(1+10)\times\frac{10}{2} = \mathbf{55}\ \textit{cans}$ will be needed to make a stack of cans ten rows high.

4. Tile it

Discussion

The cartoon above introduces different geometrical shapes. For learners to solve the puzzle above, give them different shapes and ask them which ones will tessellate. Tessellation is a repeating pattern made of identical flat shapes that cover a plane completely without overlapping. They fit perfectly together without leaving any gaps. A misconception is that many people believe that only regular pentagons will tesselate. However, some irregular pentagons can tessellate as well. Only three regular polygons do tessellate: triangles, squares and hexagons.

5. Banana beer

Discussion

The cartoon above discusses multiplication and division of fractions. Try with simple examples such as ½ of 4 and write this in different orders such as 2 : 4 × 1, or 1 × 4: 2 or 4 : 2 × 1 or 1 : 2 × 4 and so on. Which order gives the correct ? For the given cartoon, it is possible to solve 3/4 of 80 in different ways. It could be solved as (3 × 80) : 4 or (80 : 4) × 3 or 0.75 × 80. All of these give the same answers. Three quarters of 80 is 60 bananas. It is important to understand the word " of" as meaning of multiply, so ¾ of the banana means multiply the number of bananas by ¾. Brackets help to organize the numbers to identify which part of the sum should be worked out first. Does the same order work for improper fractions, such as 12/5 of 65? The correct answer is (80/4)x3=60. The expression in parenthesis is evaluated first.

6. *Milk boxes*

Discussion

To sort the puzzle out, the volume of the biscuits box is V=18 ×5 ×12=**1080cm³**. The volume of the parking crate is V=60 ×60 ×60=**216 000cm³**. So, the number of boxes that should fit in the crate is 216 000: 1080 = **200 boxes**. However, it is not as simple as this. The shape of the boxes means that not all the space in the crate can be used. The boxes don't stack exactly to use all the space. The most that will fit in the crate is 198 boxes.

7. Weed killer

Discussion

To solve the question, find the area of a circle which is ∏ × radius squared. ∏ being 3.14. The area of the circular lawn will be 3.14 × 16.5 × 16.5 = 854.865 sqm. Each box of the gallon (or container) treats 100 sqm, so 854.865 sqm : 100 sqm= 8.54 gallons. This is more than 8 boxes, so 9 boxes are needed.

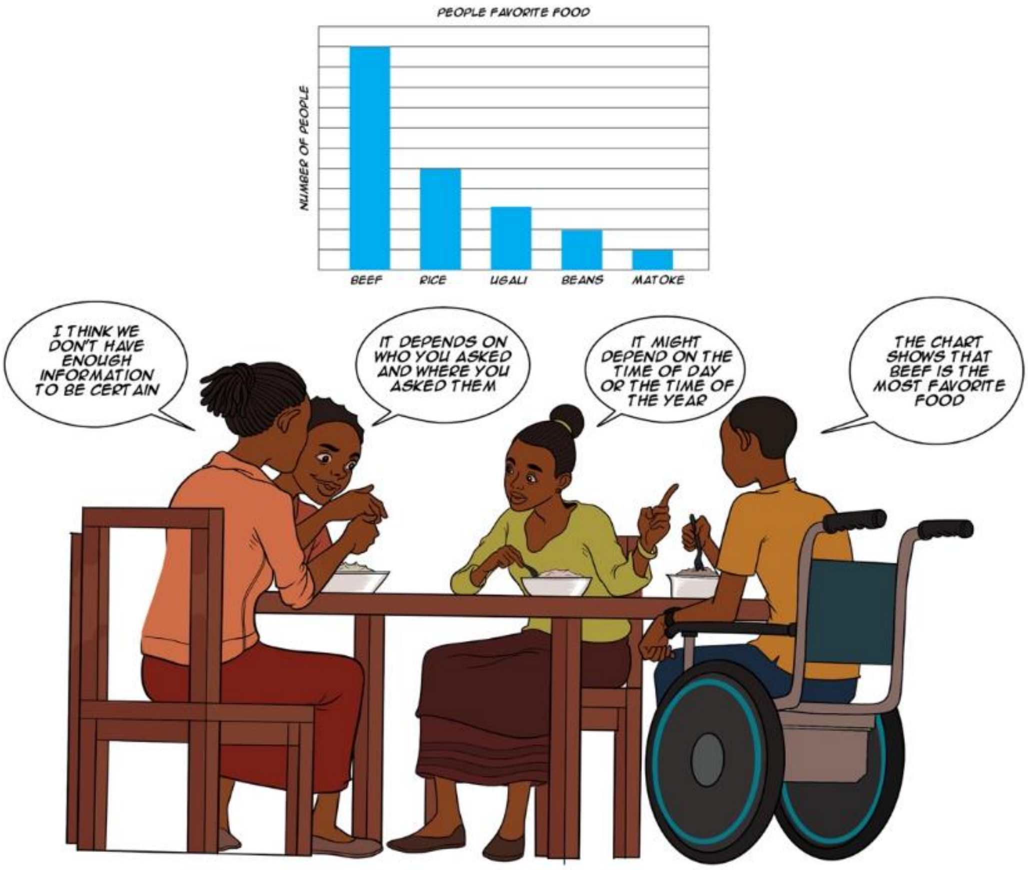
8. Newspapers and magazines in Rwanda

NEWS WEBSITES	NUMBER OF READERS
IGIHE	15
INYARWANDA	45
RWANDA TODAY	10
THE NEW TIMES	20
TOTAL	90

Discussion

The carton above discusses the data representation and analysis using a pie chart. A pie chart looks like a pie cut into slices. In the cartoon, each slice will represent the number of readers who read a newspaper. If most people read the same paper, its slice will be very big. To get the size of the slices we need to work out how much degrees of the circle to use for each one. There are 90 readers altogether. They will fill the whole circle. To turn through a complete circle, we rotate 360^o. So, to work out each reader's slice, we divide the rotation of a complete circle by the total number of readers: 360^o: $90^o = 4$. If 15 people read Igihe.com, then this is $15 \times 4^o = 60^o$. If 45 people read Inyarwanda.com, then this is $45 \times 4^o = 180^o$. If 10 people read Kigali Today, then this is $10 \times 4^o = 40^o$. If 20 people read the New Times, then this is $20 \times 4^o = 80^o$.

9. People's favorite food



Discussion

The cartoon above discusses and interprets data using a bar chart. Which food seems to be most popular? Which one seems to be the least popular? While analysing, a misconception which might arise is to conclude that beef is the most favourite food. However, we don't have enough information to be certain. People's favourite food might depend on who was surveyed (e.g if people who were surveyed stay in the countryside and do not always afford money to buy beef then they may be more likely to prefer beef over anything else). It could depend on where the people who were surveyed were and what time of the year (e.g if they were in a butchery or it was during festive seasons). Therefore, all the answers could be correct.

10. *In the money*

Discussion

For real world problems that involve ratios, the formula is to add ratios e.g 2+3=5 to find out how much money will be needed altogether. Find the value of one share 60,000Rfw: 5= 12,000Rfw. Then find amount for each person. David will get 3 lots which are worth 12,000Rfw × 3= 36,000Rfw while his brother will get 2 lots which are worth 12,000Rfw × 2 = 24,000Rfw. This method would also work for ratios involving 3 people.

11. Playing cards

Discussion

The cartoon above discusses the probability using playing cards. You can start this by making a small pack of 20 cards consisting of the Ace, King, Queen, Jack and the ten of all suits. What is the probability of selecting an Ace from this pack? What about the Queen of Spades? A red card? Any King or Queen? Any card except a 10? What is the probability of selecting each of these cards from the full pack of cards? To work out these questions, the probability of drawing a Spade from a deck of cards is 13 in 52 as there are 13 Spades in a pack of 52 playing cards. This can be simplified to ¼. If the Ace of Spades has already been drawn out, there are only 12 spades left in the next 51 cards. So the probability of the next cards being a spade is 12/51 . If the Ace of Spades is put back in the pack and the pack is shuffled, the probability of the next card being a Spade is now 13/52 or ¼.

M.5 Example Practical Work for Algebra (Senior 2 Unit 2: Polynomials)

Algebraic identities such as $(a+b)^2$, $(a-b)^2$, (a+b) (a-b) can be explained and illustrated using surface areas of a square and a rectangle.

Explanation: Instruction video (using negative terms):
https://www.khanacademy.org/math/algebra2/x2ec2f6f830c9fb89:poly-arithmetic/x2ec2f6f830c9fb89:mono-by-poly/v/area-model-for-negative-terms?modal=1
Explanation or Exploration: Simulation
https://phet.colorado.edu/sims/html/area-model-algebra/latest/area-model-algebra_en.html
(S2 Unit 2: Multiplication of a polynomial by a polynomial, p. 35)

Extension: also the algebraic identity $(a+b)^3$ can be expressed in terms of the volume of a cube and a parallelepiped.
Explanation: https://www.youtube.com/watch?v=pK5NBIkLXa4
Guideline: http://www.arvindguptatoys.com/arvindgupta/maths-handbook-ncert.pdf
(pp. 70-71)

Option 1: Demonstration (use of a model for explanation)

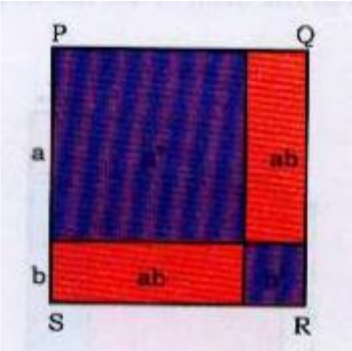
Materials for teacher: Manila papers, multiple colour markers, graph papers, geometrical instruments (rulers, T-squares).

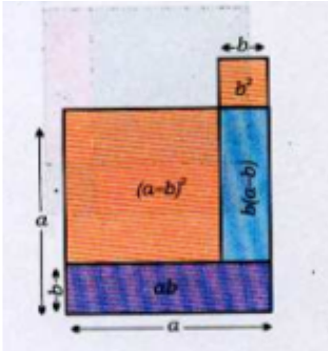
For $(a + b)^2$:

- Cut out 2 squares of sides a and b units such that a > b from the sheet of paper.
- From the same sheet, cut out 2 rectangles of length a and width b units respectively.
- The above cuts can be fixed with the help of some adhesive as shown in the figure.
- Use the model to demonstrate the algebraic identity $(a + b)^2 = a^2 + 2ab + b^2$
- The area of the square PQRS = $(a + b)^2$ and it is also equal to the sum of a^2, 2 times ab and b^2.

For $(a – b)^2$ you can use a similar procedure:

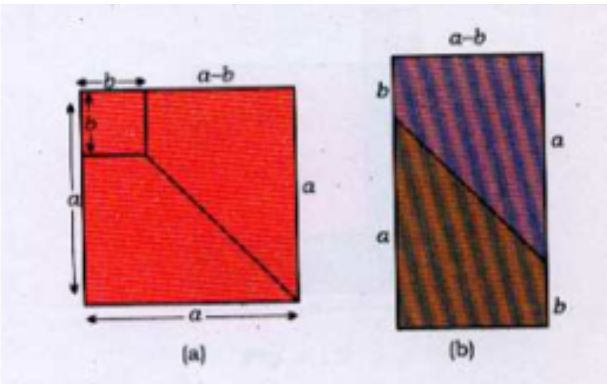
- Make a square with side a. Its area is a^2.
- Make a smaller square with side b. Its area is b^2.
- Make a square with side (a – b). Its area is $(a – b)^2$.
- Make two rectangles with length a and width b. The area of each rectangle is ab.
- Keep the smaller square (b^2) on the right corner of the bigger square (a^2).
- On the model, show a^2 and b^2.
- take the square of side (a – b) and put it on a^2. The area of this square will be $(a – b)^2$.
- this square will be equal to the sum of squares a^2 and b^2 minus 2 rectangles of area ab.



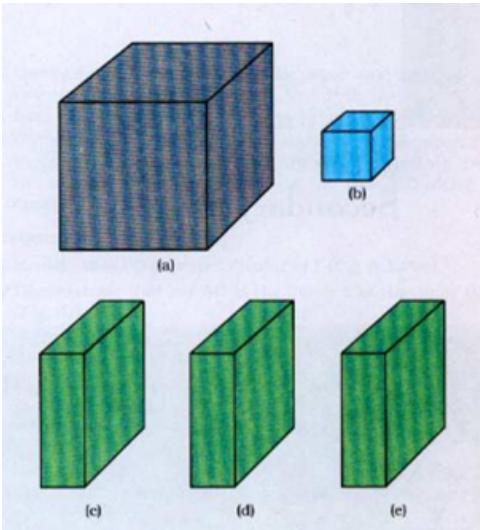


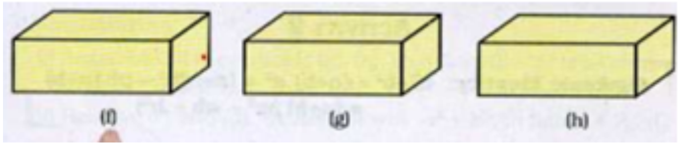
Also for (a + b) (a – b) you can use a similar procedure

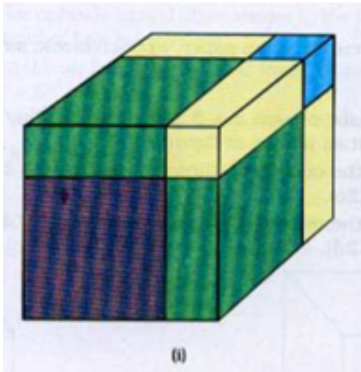
- Make a square with side a. The area of this square is a^2.
- Make a second square with side b, with b < a. The area of this square is b^2.
- Place the smaller square b^2 on the bigger square a^2.
- Cut the remaining portion of the square a^2 ($a^2 – b^2$) in the form of two trapezia as shown in the figure below.
- Put the smaller square with side b on the bigger square with side a.
- Join the remaining 2 trapezia covering the area of $a^2 – b^2$ in such a way that a rectangle is formed as shown in the figure below.



See also: https://www.youtube.com/watch?v=XlcYreirNxU
Source: http://www.arvindguptatoys.com/arvindgupta/maths-handbook-ncert.pdf
(pp. 31-34)
Even the algebraic expression (a + b) can be illustrated with concrete materials using cubes.
See: http://www.arvindguptatoys.com/arvindgupta/maths-handbook-ncert.pdf (pp. 31-34)

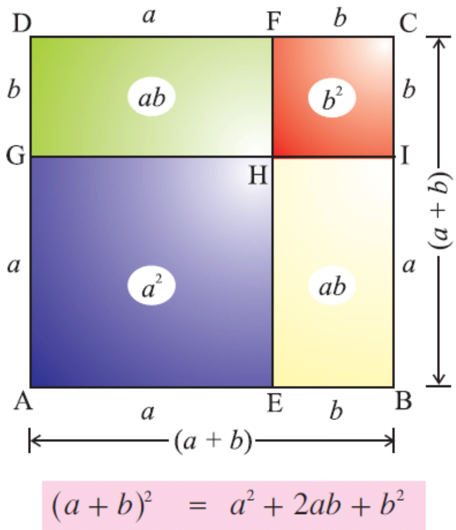


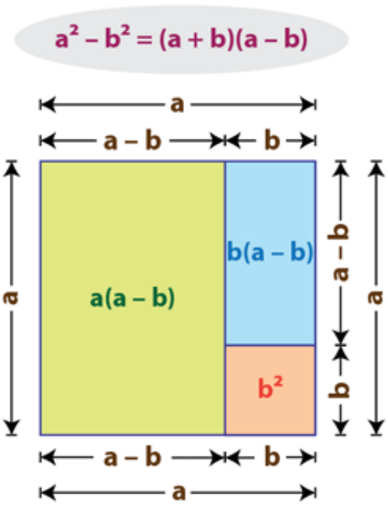


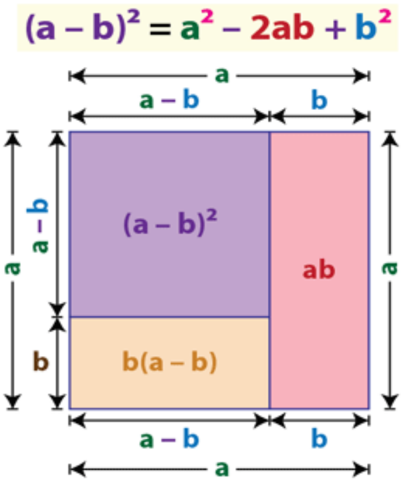


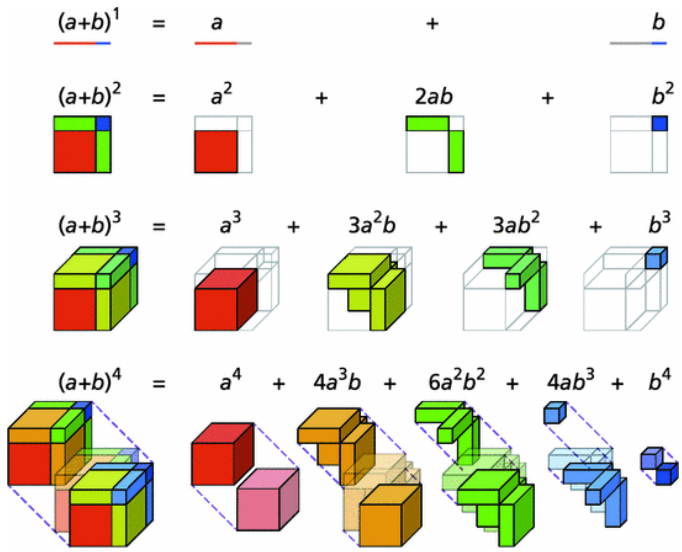
Option 2: Practical work by learners

Instead of a demonstration, you can also let learners work in groups to make the squares and rectangles to explore the different algebraic expressions (See figures below).
More detailed instructions can be found at:
https://www.youtube.com/watch?v=Ygkzh4sJOQE (for $(a + b)^2$)
https://www.youtube.com/watch?v=TsaH0GR15V4 (for $(a – b)^2$)
https://www.youtube.com/watch?v=XlcYreirNxU (for (a+b) (a-b))
https://www.youtube.com/watch?v=pK5NBIkLXa4 (for $(a + b)^3$)






(a – b)² = a² – 2ab + b²
a
a – b
b
(a – b)²
ab
b(a – b)
a – b
b
a


(a+b)¹ = a + b
(a+b)² = a² + 2ab + b²
(a+b)³ = a³ + 3a²b + 3ab² + b³
(a+b)⁴ = a⁴ + 4a³b + 6a²b² + 4ab³ + b⁴

M.6 Example Practical Work on Pascal's Triangle

The Pascal's triangle will help to find binomial coefficients of the expression:

$$(a+b)^n = \sum_{m=0}^{n} \binom{n}{m} a^m b^{n-m}$$

Pascal's triangle has many properties and links with binomial distributions, normal distribution, Central Limit Theorem, Probability, Fibonacci Sequence, Sequence of Coefficients in binomial powers (see Figure 23).

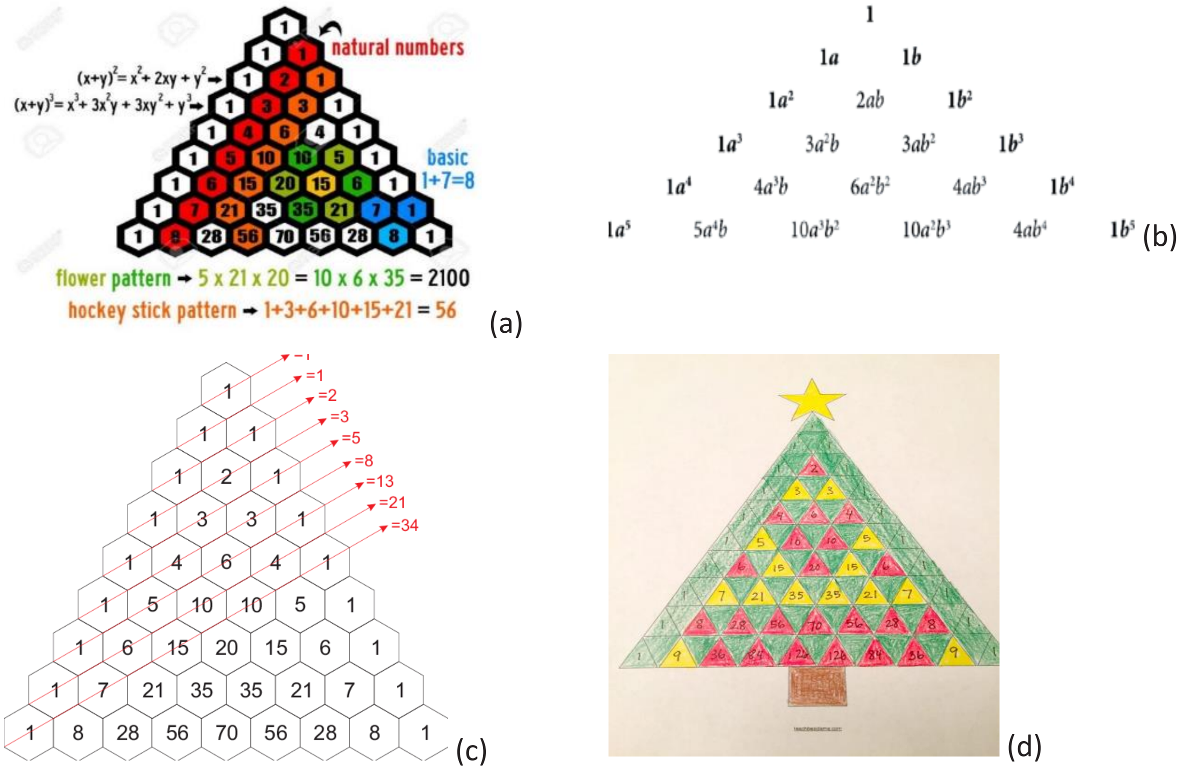


Figure 23: Characteristics and applications of Pascal's Triangle

Explore activity

You can challenge learners to find some of the patterns themselves. An example of a questioning sequence using figure 23 (d):

- What do you see in the picture above? many small triangles, Christmas tree, numbers.
- At each row, how many geometrical shapes do you have? Consider the ones in red and yellow.
- On the first row, there is one triangle. On the second, there are two triangles. On the third, there are three triangles, etc.
- How are the numbers along the first inner diagonal related? What about numbers along the second diagonals?
- The numbers along the inner diagonal are consecutive numbers.
- The numbers along the second diagonal are triangular numbers. Those are numbers obtained by continued summation of the natural numbers 1, 2, 3, 4, 5,6,7,8,9,10, etc.

- What do you think could be the next row? Explain your answer.

Instructions for the teacher:

- Build Pascal's triangle with your learners. Let them work in groups and ask them to find as many patterns as possible in the triangle.
- Give them some hints like Fibonacci, prime numbers, powers of two, algebraic terms etc., or give them access to resources (pictures, videos) to explore.
- Use the ideas from the videos below to develop a worksheet for learners with questions to help them explore the properties of the triangle.

Interesting movie about Pascal's triangle: https://www.youtube.com/watch?v=0iMtlus-afo

Links with Fibonacci, prime numbers, powers of two…
Pascal's Triangle can also be used to introduce chance and the normal distribution. A good **explanation** is found:
https://www.youtube.com/watch?v=UCmPmkHqHXk

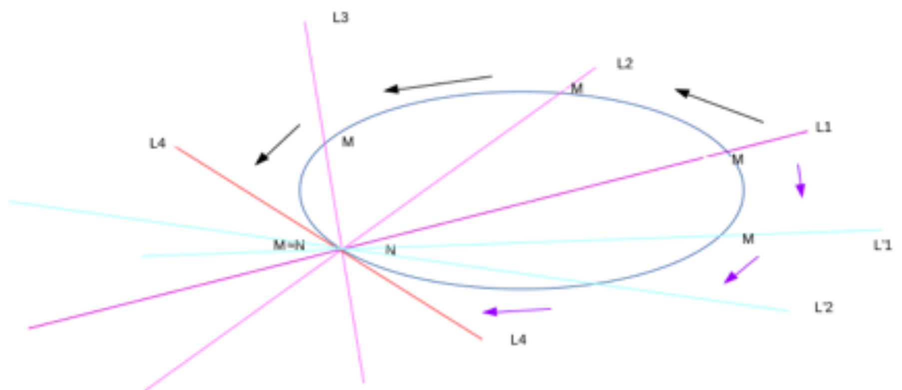
M.7 Example Practical Work on Geometric interpretation of a limit (S4 Unit 8: Limits)

This is an interesting, but challenging activity (only for strong groups). This idea is also relevant in the context of derivatives.

Geometric interpretation of a limit of Tangent and Secant $\lim_{N \to \infty} S_{MN} = T_N$ where S_{MN}- Secant and T_N is tangent to circle at N.

This app can help to visualize the idea:
http://danaernst.com/CalculusApplets/SecantTangent/

Practical work: Ask learners to draw a circle, and to label any two points M, and N on that circle. Ask them to draw a line passing through points M and N (secant to the circle). Then, considering the fixed-point N, move the point M clockwise and anticlockwise to obtain a family of secant lines. When, M is close to N in whatever direction, the family of secants will leads to a single line called tangent, TM= $2 \times \frac{7}{7} = 2$ or $10 \times \frac{22}{7} = \frac{220}{7}$



The above graph shows how the point M of L1 is moving toward Point N in either senses while N is fixed with a family of lines . We finally found that the point M is coinciding with point N. And then the line L1 which was secant to the Circle is becoming tangent to the circle at the point N .

A possible questioning sequence:

- T: What is the name of the line? (Kq)
- L: The secant line to the circle.
- T: What will happen if you move the point M along the circle towards N while N is fixed? (Oq)
- L: The points N and M will finally coincide.
- T: What will happen to the original line NM if N and M coincide?
- L: The line will touch to the circle at a single point.
- T: Will the line change the position if the point M is moved toward N clockwise or anticlockwise? (Tq)
- L: The line will still be the same.
- T: What is the name of that line? (Tq)
- L: The tangent line to the circle.

M.8 Example Simulations and Questioning on Statistics

The simulation provides learners with an illustration of scatter diagrams, regression lines, the strength, weakness, or lack of correlation between the two variables.
https://phet.colorado.edu/sims/html/least-squares-regression/latest/least-squares-regression_en.html

(S5 Unit 9: Bivariate Statistics)
Questions you can ask learners:

- T: What does it mean when the slope of the line is positive? (Tq)
- L: The line is increasing and the correlation is positive
- T: What is the effect of a negative slope on the correlation? (Tq)
- L: The line is decreasing and the correlation is negative
- T. How are the variables changing when the correlation is negative? (Oq)
- L: Two variables are moving in opposite directions (one is increasing another is decreasing)
- T. How are the variables changing when the correlation is positive? (Oq)
- L: The two variables are in the same direction (either increasing or decreasing)
- T. What does it mean for a dataset if the correlation is zero? (Tq)

Guidelines for practical activity:

1. Provide learners with data for two variables (X and Y)
2. Ask learners to present the data in a cartesian plane
3. Ask learners to determine whether there is any relation between variables X and Y.
4. Ask learners to draw a line of best fit.
5. Ask learners to have a look at other datasets and to predict the sign of the correlation coefficient

M.9 Practical application of 5Es and key aspects of STEM instruction in a Mathematics Lesson

In this video, https://youtu.be/Rmd_GFDdcRo , teacher Clementine facilitated a mathematics lesson titled: "Image of geometric shape under parallel projection". In the lesson, she used the 5E's model and applied various aspects of STEM instruction. As you watch the video, reflect on the questions below:

1. Explain to what extent the introduction is exciting and engaging learners.
2. Are learners engaged in practical activities? Are the activities related to the lesson concepts to address the key question? Explain your answer
3. Have the learners got an opportunity to elaborate on new challenges or application of learned concepts in real life experience?
4. What key aspects of STEM instruction were mostly used in the watched lesson? Are they relevant to the lesson?
5. What does the physics teacher need to do to make his physics lesson more inquiry based?

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