Climate change – effects and adaptation

Responsible Research and Innovation www.irresistible-project.eu

Colophon

IRRESISTIBLE is a project on teacher training, combining formal and informal learning focused on Responsible Research and Innovation. It is a coordination and support action under FP7-SCIENCE-IN-SOCIETY-2013-1, ACTIVITY 5.2.2. Young people and science: Topic SiS.2013.2.2.1-1 Raising youth awareness to Responsible Research and Innovation through Inquiry Based Science Education. The project IRRESISTIBLE is funded by the EU as FP-7 project number 612367

www.irresistitle-project.eu

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The learning materials and the teaching period were designed by the teacher trainers and teacher trainees of the University of Jyväskylä as a part of the trainees' studies in 2014 and 2015.

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The learning materials have been modified on the basis of experiences gathered during teacher training programmes in other European universities (Boğaziçi University and Lisbon University).

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Structure of the teaching period

General description of the materials

Several teaching periods that encourage pupils to think about new technologies and scientific achievements as well as to examine them in an ethical way have been compiled in the IRRESISTIBLE project.

The teaching period developed in Finland familiarized pupils with climate change as a phenomenon. The period examines the functions of the greenhouse effect and reflects widely upon the consequences of climate change on Earth.

Inquiry-based learning plays a key role in all the learning materials of the project. The pupils familiarize themselves with the topics, practise planning and carrying out research as well as learn about data gathering and source criticism.

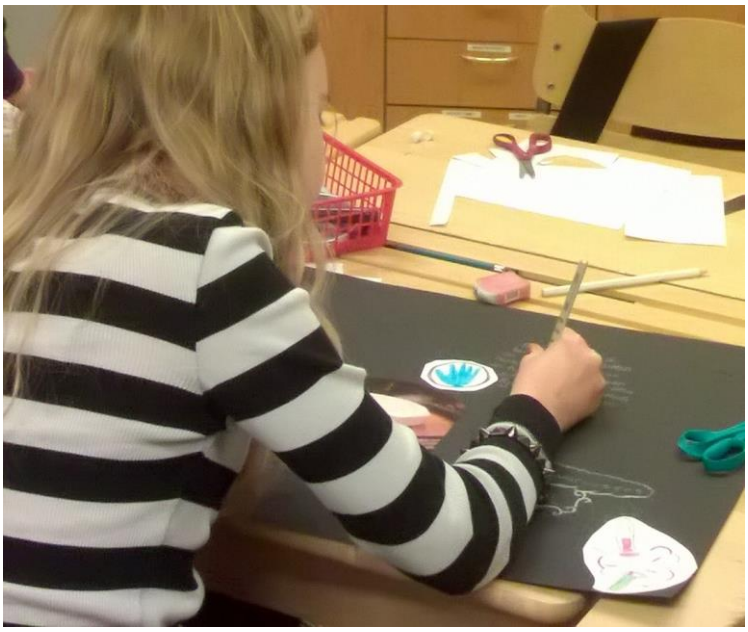

Fig. 1. A pupil working on a poster about the visit to the Nanoscience Center of the University of Jyväskylä

Sharing information is another important aspect of the teaching periods of the project. The pupils share with others the important results that they've found, and by increasing awareness they help people to act more sensibly for the part of the climate. Sharing can be carried out in the school community or in a wider scale via the web or a shared event, for example.

Content of the teaching period

Pupils' preliminary knowledge

At the start of the teaching period, the pupils should be aware that

- substances can be categorised based on their chemical components
- different species have adapted into certain habitats
- the atmosphere is vital for maintaining life
- the steps included in the production of food can be described as a production chain

Learning goals

The learning goals of the teaching period include topics from several different subjects. The goals have been categorised by subject below.

Environment and nature studies, classes 4 - 6

During the teaching period, the pupil will

- learn to conduct simple natural scientific experiments
- learn to present information on the environment and its phenomena in various ways
- get used to using the concepts with which the environment and relevant phenomena and objects are described and explained
- identify ways of protecting the nature and conserving energy resources
- learn about species, their structure as well as how species adapt to their habitats
- interpret maps and use statistics, diagrams, images and electronic communication devices as sources for geographical information

Social studies, classes 7 - 9

During the teaching period, the pupil will

- learn to understand the effects of societal decisions on citizens' lives
- become interested in societal participation and impacting
- examine and develop his/her skills as a responsible consumer and societal agent
- identify the two sides of the climate change debate

Chemistry, classes 7 - 9

During the teaching period, the pupil will

- make observations and measurements, gather information on the topic of the study and reflect on the reliability of information
- recognize the composition of air and the chemical symbols of the atmosphere's gases

Physics, classes 7 -9

During the teaching period, the pupil will

- make observations and measurements, gather information on the topic of the study and reflect on the reliability of information
- understand the importance of the atmosphere in maintaining life

Structure of the teaching period

The teaching period along with the related materials and studies has been designed to encompass eight lessons. The materials can be used in the way depicted on the following page.

Should the pupils prepare an exhibition for the other classes in their school building, it's a good idea to arrange a grand opening and invite the other classes to visit the exhibition, in addition to carrying out the tasks mentioned above.

The proposed structure serves as an example of how the teaching period can be arranged. It's based on teaching sequences in 2014 and 2015 in the primary schools of Jyväskylä and the experiences gained during them.

- Getting familiar with climate change
- Drawing about climate change

Lesson 1.
Preconceptions

- The melting of sea ice and glaciers
- Droughts and floods

Lesson 2.
Experiments

- The effect of acidification on corals

Lesson 3.
Experiments

- Different habitats
- The effects of climate change on humans and animals

Lesson 4.
Gathering
information

- The production chain of food and carbon footprint
- Viewpoint: joint responsibility

Lesson 5.
Elaboration

- Designing an exhibition / sharing information

Lesson 6.
Designing an
exhibition

- Preparing one's own work
- Holding the exhibition / sharing information

Lesson 7.
Designing an
exhibition

- Reviewing feedback
- Assessing one's own and the community's work

Lesson 8.
Summarising the
project

2

Teaching methods

Teaching methods

This teaching period employs the inquiry-based 6E instructional model. You may be more familiar with the so-called 5E model (Bybee, 1997). The main features of all inquiry-based instructional models are similar, and they depict research work.

Components of the 6E model

Engage – Explore – Explain – Elaborate – Exchange - Evaluate

The following table illustrates an example pairing of working methods with the 6E phases.

table 1

Working methods in the module related to the 6E model

	Working methods
Engage	Initial videos and drawings Discussions
Explore	Letter activities with pupils' replies Gather information for exhibition pieces Design research questions in pupil activities
Explain	Pupils' inquiry-based experiment activities Carbon footprint calculator, related activities and reflection
Elaborate	Set the pupil activities in the context of climate change Reflect on the effect of one's own actions Make learning videos (during optional museum visit)
Exchange	Design the exhibition
Evaluate	Summary discussion View learning videos (filmed during optional museum visit)

Responsible Research and Innovation

All teaching periods developed in the IRRESISTIBLE project include themes of Responsible Research and Innovation, i.e. RRI.

These RRI themes define the participants in the interaction between natural sciences and the rest of the society, one of the participants being teachers. On the other hand, they are topics which teachers should include in teaching and other activities in the school community. Numerous learning goals for primary schools can be achieved by adding RRI perspectives to the teaching periods defined in the syllabus (Finnish National Board of Education, 2014) and to different phases of inquiry-based learning.

The name RRI is used by the EU to describe the good interaction between natural sciences and society. In good interaction, all participants can see new research and products from multiple perspectives.

Products and applications that have been found to be challenging serve as the backdrop for this kind of thinking:

Examples of challenging inventions

- iron – immensely practical and durable but dangerous
- gunpowder – promoted the effects of warfare on civilians in an unpredictable way
- asbestos – was a safe building material thanks to being fireproof, but caused extensive health problems for builders and demolishers
- CFC and DDT – helped solve problems related to hygiene (cold storage, pests and parasites), but released harmful gases into the atmosphere

In hindsight, it's difficult to say whether a product has been beneficial or detrimental. As such, it's fair that participants reflect on possible future effects together and make their views known already in the product development phase. The goal is that different

actors (schools, consumers, enterprises, researchers, policymakers etc.) work together for economically, socially and ecologically sustainable development.

Examples of such products, disadvantages and advantages, surprising discoveries and other related themes have been compiled in the blog http://irresistiblesuomi.tumblr.com since 2015. Reflection questions and news articles in the blog can be freely used by teachers.

Themes of Responsible Research and Innovation (RRI)

- Engagement: researchers, pupils, teachers, parents, science museums, policymakers etc. familiarise themselves with the topic from their own perspective and identify each other's roles in the work.
- Equality: the topic is studied to find out possible aspects of equality. Equality can be generational, economic, cultural, geographical etc.
- Ethics: the topic is studied to find out possible ethical aspects related to e.g. health, environment and safety that should be opened for debate.
- Open Access: everyone shall share his/her research with others for evaluation and use. For example, one's financial situation or customer must not prevent the data and its method of gathering from spreading.
- Science Education: help citizens understand the topic better.
- Governance: Policymakers take all perspectives into account, as they have the great responsibility of making decisions that affect all the above actors.

Whenever such themes are discussed in the materials, they are noted as RRI ideas or considerations. Pupils don't have to recognize the RRI abbreviation or memorize the above list: instead, these are used to remind the teacher of good occasions to discuss these topics and to help guide the pupils towards a big picture of RRI themes.

Assessment

The pupils work on the project as a group, and assessment should emphasize the changes that have occurred in the whole class rather than a single pupil. This will encourage pupils to take responsibility for learning as a group and not ignore other members of the group or focus on their own performance. This will also promote the development of responsibility, which is one of the key themes of the module.

Formative assessment

- Teacher feedback on written or drawn work
  - *The teacher evaluates if the pupil has written the text on his/her own or copied it from an online source. 'How would you describe in your own words…?'*
  - *'How could you elaborate the drawing?' Oral description of the drawing as a pupil aid.*

- Immediate teacher feedback during inquiry-based learning assignments
  - *Topics: formulating questions, working, sensibility of experiment arrangements*

- Pair feedback during inquiry-based learning assignments
  - *Pairs compare each other's research questions or experiment arrangements.*

- The pupils film a video on what they learned during an optional museum visit
  - *The videos illustrate the use of different media as information sources, the use of appropriate concepts and various representations of information.*

- Concluding discussion of the project in the classroom
  - *The teacher evaluates the atmosphere of the class. The teacher or the pupils identify any misunderstandings of the topic and try to correct them. The pupils reflect on the reliability of the information produced by them, and the teacher encourages them also to identify issues that hamper the reliability of the information.*

Summative assessment

This guide doesn't include tools of summative assessment (test questions etc.). We feel that the pupils' project constitutes such a large amount of work that the teacher need not design a test as well. The teacher can come up with questions on the topic or score the works created during the project. In such cases the assessment criteria must be told to the class before starting the work.

3

Materials for the teaching period

Getting familiar with the topic

Preconceptions

The period can be started by having the pupils reflect on what they already know about climate change. Younger pupils might find it easier to draw their ideas about climate change (see Fig. 2), whereas older pupils can devise concept maps on the topic or discuss in pairs or small groups.

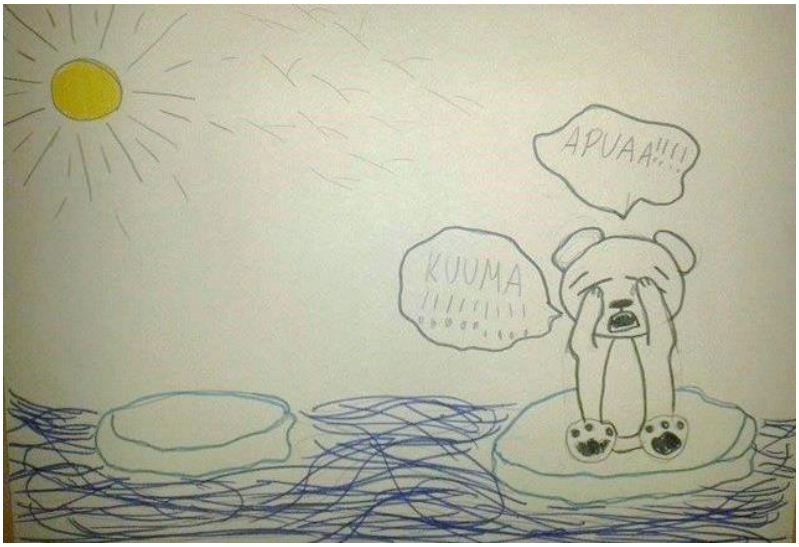

Figure 2. Pictures on climate change drawn by fift-graders

After drawing or small group discussions, the class will summarise their thoughts on climate change. The teacher can summarise the thoughts on the blackboard or via

an electronic platform. (S)he can use concept maps for revealing the pupils' understanding of climate change. Drawings can be captured with an iPad or a mobile phone camera for sharing with the class.

Concept maps: http://popplet.com/

An app for building concepts maps with iPads or in the browser. It can be used in this task by the students or the teacher.

RRI Ideas for Preconceptions

In the beginning of studying climate change there is a good opportunity to discuss students' early ideas of the causes of climate change. The teacher may direct the talk towards human and individual actors' impacts on climate. The class can compare how they perceive different actors' possibilities to minimize our negative effect on climate.

Anatomy of climate change

Depending on the preliminary knowledge of the pupils, the first class or even more can be used to discuss the functions and basic concepts of climate change.

High-quality teaching materials on the topic can be located easily on the web (see select examples in Table 2). Both government offices and non-commercial organisations typically adopt restraining climate change as their agenda and provide materials for educators. You will find more materials in your own language.

Both the research based on which climate change can be detected and the long-term effects of climate change on the Earth can be discussed by using the Climate Guide's IPCC infographics on the physical background of climate change and visualisations of the Earth's climate history, for example.

Pupils can also work independently on a couple of provided sources and test their knowledge by taking a climate quiz or by trying simulations with a specific goal. The purpose could be, for instance, to find out the year in which one of the target levels of carbon dioxide (several depending on the source: 350 ppm, 450 ppm) will be exceeded.

table 2

Online resources for studying climate change

	producer	contents	language
http://www.eea.europa.eu/fi/themes/climate	EEA	articles on the effects of climate change	several
https://ilmastoopas.fi/fi/ilmastonmuutos/ilmio	Climate Guide	articles, illustrative pictures	Finnish, Swedish, English
https://ilmastoopas.fi/fi/ilmastonmuutos/videot-ja-visualisoinnit	Climate Guide	videos, visualisations, infographics	Finnish, Swedish, English
http://www.wmo.int/pages/themes/climate/index_en.php	WMO	articles, calculations	English
http://www.ipcc.ch/	IPCC	report, infographics, presentations	several
https://www.climateinteractive.org/tools/	Climate Interactive	games and simulations	English

Experimental work

General notes

The experiments have been designed in such a way that they can be applied both in primary school classes 5 and 6 and in secondary school. The work emphasizes inquiry-based learning, or getting familiar with it if the pupils aren't already aware of it.

The teacher also has the option of doing experiments as teacher demonstrations or planning the teaching based on the following classification:

Levels of inquiry-based learning

- **Confirmation:** the pupils confirm previously learned ideas and/or practice data gathering and saving.
- **Structured inquiry**: the pupils analyze the gathered data via the method described for them and formulate answers to the teacher's questions.
- **Guided inquiry**: the pupils design and observe their own data-gathering methods and formulate conclusions in such a way that they are able to answer the teacher's questions.
- **Open inquiry**: the pupils formulate their own research questions, design and carry out data-gathering with their self-developed method as well as discuss the observations and results.

Please note that the printable student instruction sheets are found in the Appendix of this document. The student instructions here are provided within text for teachers' convenience.

All experimental work should be done with teacher supervision and necessary safety precautions.

Melting glaciers

Relating the experiment to climate change

The melting of glaciers situated on continents causes the sea level to rise. The melting of sea ice doesn't cause the sea level to rise. As the climate warms up, the seas warm up as well, and the resulting thermal expansion causes the sea level to rise.

Purpose of the experiment

The purpose of the experiment is to study how the melting of sea ice and glaciers affects the sea levels.

Required time

The experiment takes about 20 minutes.

Assessment

The assessment is directed at assessing the pupils' process skills. As such, the assessment focuses on formulating the pupils' questions, carrying out the experiment, as well as analyzing and interpreting the results.

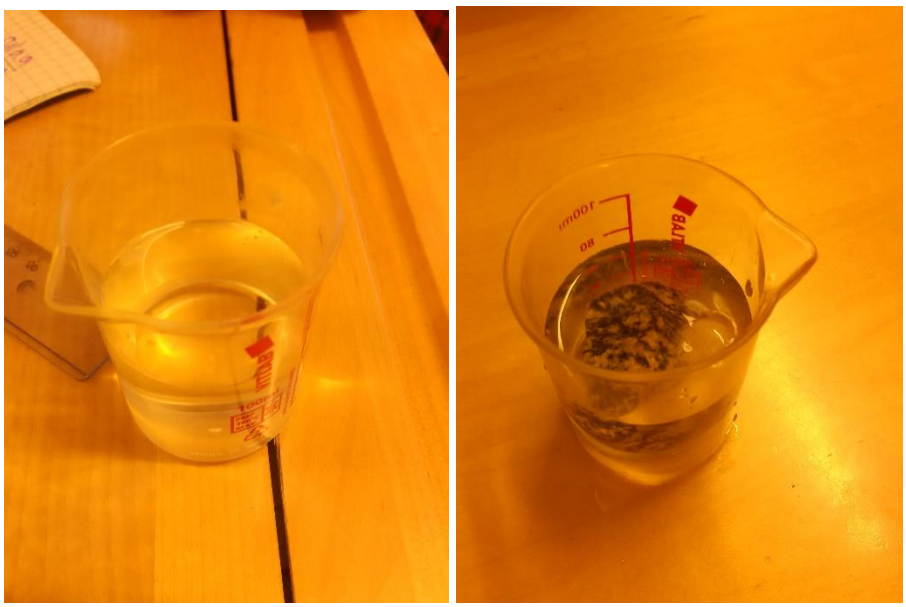

Figure 3. Sea ice and glacier experiments nearly finished

Doing the experiment

Divide the class into groups of four. All groups get one measuring glass and are designated as either a glacier group or sea ice group. Each glacier group is accompanied by a sea ice group with which the hypotheses are compared with. They can write their predictions and hypotheses down in post-it notes and stick them on the blackboard or a separate stand.

The glacier and sea ice groups follow separate instructions. Give the pupils a chance to make proper research notes and guide the pupils in making the notes if necessary. The notes are also used for assessing students' process skills.

In the end, the glacier and sea ice groups come together and share hypotheses and results. At the end of the demo, reflect with the students on the connection of the experiment with climate change. Let the students express themselves and emphasize the observations and results of the experiment.

Student difficulties

Students may be confused as per why it matters whether the ice cube is suspended in water or not. This is an opportunity to consult the basic principles of buoyancy and the differences in density of liquid and frozen water. Buoyancy can be explored e.g. with the PhET simulation: https://phet.colorado.edu/en/simulation/buoyancy

Student instructions: Melting Glaciers

Materials

- ice cubes
- small stones
- two beakers or equivalent
- water

Glacier group instructions

A glacier is ice that covers a part of a continent. Glaciers are found in Greenland and Antarctica. It's said that the melting of glaciers has become faster due to global warming. Now, you get a chance to study the effect of melting on the rising of sea levels. The stone represents a continent, the ice cube acts as glacier and the water depicts sea water.

1. Decide with your group if glacier ice melting affects the sea level. If yes, how? Share your hypothesis with another group.
2. Put a stone in the measuring glass and add hot water so that the surface reaches 40ml. Place an ice cube on the stone. It represents the ice that is on top of the continent, meaning that it's not in direct contact with sea water and doesn't float in it.
3. When the ice has melted partly or completely, discuss
    a. What happened to the melted ice?
    b. How would the melting of glaciers affect seas?
4. Compare your results with the group opposite to you and reflect together on what caused the results.

Sea ice group instructions

Sea ice is ice that is formed on top of the sea level when the temperature is cold enough. It grows and melts according to seasons. Now, you get a chance to study how the melting of sea ice affects the rising of sea levels. The ice cube represents sea ice and the water depicts sea water.

1. Decide with your group if sea ice melting affects the sea level. If yes, how? Share your hypothesis with another group.
2. Place the ice cube in the measuring glass and add hot water so that the surface reaches 40ml.
3. When the ice has melted partly or completely, discuss:
    a. What happened to the melted ice?
    b. How would the melting of sea ice affect seas?
4. Compare your results with the group opposite to you and reflect together on what caused the results.

Droughts and floods

This activity examines two phenomena caused by climate change: droughts and floods, which have interesting connections with climate change. During this task it is helpful to discuss with students what can kind of soil prevent floods. They should, after this experiment, understand that the moist soil (in most soil types) can infiltrate more water.

RRI Ideas for Droughts and Floods

During the experiment it is fruitful to discuss about what causes soil to become dry in large regions – why are there droughts in the first place? The teacher can lead the discussion towards actions of people and how that loss can be reduced.

Relating the activity to climate change

When examined globally, the increased drying up of areas with low levels of rain is one effect of climate change. On the other hand, climate change makes weather harder to forecast, meaning that even dry areas might experience heavy rain. When the ground shrinks and cracks due to drought, its ability to absorb water weakens. As such, heavy rain can often cause floods in dry areas. The sparse vegetation of dry areas also increases flood peaks as sparse vegetation doesn't bind water well.

Purpose of the activity

The purpose of the activity is to study how dry or moist ground affects the absorption and run-off of water. This activity employs the model of open inquiry-based learning. Its other big purpose is that the pupils get to plan the experiment setup by themselves.

Required time

Designing and doing the experiment takes around 45-60 minutes.

Assessment

The teacher offers guidance during the experiment but doesn't take part in it. By asking questions, the teacher helps the pupils reflect on the results of the experiment, its success and the error factors of the results. It's important to help pupils make research notes and give feedback on their work.

Assessment is directed at pupils' process skills. It focuses on formulating questions, designing a measurement setup, and analyzing and interpreting the results.

Doing the experiment

Teacher divides the class into groups of 3-4 and introduces the available materials and task. If necessary, the teacher aids the pupils' reflection with open and person-centric questions. The teacher guides the pupils in making research questions for which they can obtain data with the materials at hand.

If several groups are formed, the results can be compiled into a shared graphical model. The teacher helps the pupils think about the significance of parallel measurements in carrying out research.

As an ending discussion the groups can show their different setups and share their results with the class. The teacher should pick from students' explanations parts that connect with climate change and the bigger picture.

Student instructions: Droughts and Floods

Materials

- two flat dishes per group
- a sieve
- moist clay or soil
- dry clay or soil
- a measuring cylinder
- water

Doing the experiment

In your group, think about which places around the world have been reported to experience droughts or sudden floods. Think also about the reasons why these events happen on Earth.

Plan a setup for an experiment in which you can test how the moisture of the ground affects its ability to absorb water and the amount of non-absorbed water.

As a group, make a prediction on what will happen in the experiment.

Carry out the experiment you designed. Write down the results of the experiment. Think about how the results of your experiment are related to climate change.

Acidification and corals

Relating the experiment to climate change

Seas store carbon dioxide. The increase of carbon dioxide in the air causes it to be absorbed in the seas even more. This phenomenon is called the acidification of seas. The increased amount of carbon dioxide in seas starts to lower the basicity that is natural to seas and necessary for the habitats of marine species, making seas more acidic.

Purpose of the experiment

The purpose of the experiment is to study how the acidification of seas affects corals. Seashells are used instead of corals, as an acidic solution affects them in the same way.

Required time

Seeing some differences in the shells takes around 15 minutes. The seashells can be left in the solutions for a longer time, if more drastic results are hoped for. Students may work on something else in the meantime.

Assessment

The assessment is directed at assessing the pupils' process skills. As such, the assessment focuses on formulating the pupils' questions, doing the activity as well as analyzing and interpreting the results.

Safety

The hydrochloric acid used in this experiment is diluted down to a 10% (2.8 mol/L or 2.8M) solution in water. It is still hazardous to skin or eye contact (irritant and corrosive). Contact may cause itching and redness and minor burns. In case of skin contact, the area should be rinsed with water for several minutes. Check for further information from a laboratory safety sheet.

Have the students wear lab coats, safety glasses, and gloves, as they handle the hydrochloric solution.

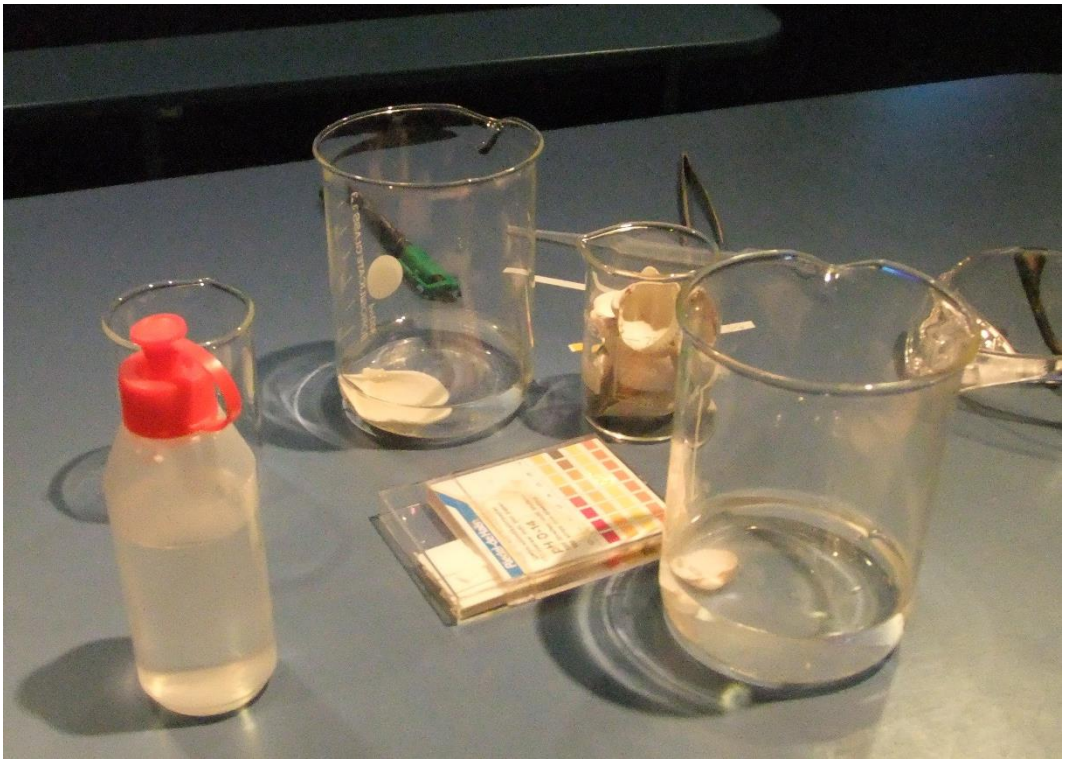

Figure 4. Seashells experiment at the Natural History museum of Central Finland

Doing the experiment

Clam shells represent the calcium carbonate exoskeleton of the corals. Calcium carbonate is the same material clam shells and limestone is made of. You can ask guiding questions from the students: What do clams and corals have in common? Have you heard about stony corals? Do you know how limestone is formed? It's a sedimentary rock. It is composed of the skeletons of corals and other marine creatures with a calcium carbonate shell.

The fresh tap water in the bowl is more neutral than seawater. Seawater's pH value on the scale would be a bit more basic. However, the value on the pH strip should be around seven, i.e., neutral.

The sizzling happens where the acidic solution begins to decompose the calcium carbonate $CaCO_3$, in the shell. It releases carbon dioxide – the same gas as in gassy water of fizzy drinks – in the process:

$$CaCO_3(s) + 2\ HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

Further questions for students: What is the harm to corals? Their building material, the calcium carbonate, is decomposed. Can corals grow under these conditions?

If the students check the pH values at intermediate times, they should see acidity neutralized somewhat as the calcium salts $CaCl_2$ dissolve evenly in the solution.

In the end, the pH values will be more acidic in the hydrochloric acid beaker than the plain beaker. The hydrochloric acid depicts carbon dioxide, which acidifies the sea.
The value taken right after adding hydrochloric acid is lower pH than in the end.

Student instructions: Acidification and corals

Materials

- seashells
- two beakers
- diluted hydrochloric acid (10%)
- a pipette
- pH strips
- water
- optional camera / mobile phone camera

The students must wear lab coats, gloves, and protective glasses. Hydrochloric acid is irritating. It mustn't come into contact with skin.

Doing the activity

1. Choose one seashell for each bowl. What could the seashells represent in this experiment?
2. Add around 2 centilitres of water to the bowls so that the seashells are covered. Take photos of the seashells.
3. Measure the water's pH by soaking the strips. Compare the strips with the table on the side of the strip case. Which value does the pH strip indicate?
4. Add 20 drops of hydrochloric acid in one bowl. What does it sound like? What causes the sound?
5. Measure the pH values again. What do you see when comparing the values with the results from the previous measurement? What does the hydrochloric acid depict in the experiment?
6. The seashells can now be left in the bowls for c. 15 minutes.
7. At the end of the lesson, check on the seashells again. Compare the seashells' appearance with the photos you took earlier. You can also measure if there's any change in the solutions now that the calcium salt has dissolved into the water.

Different habitats

Letter activities

An activity type which brings the consequences of climate change closer to the pupil's everyday life is well suited for young pupils. The idea is to link the consequences of climate change concretely to the lives of (fictional) people and animals. The appendix to this teacher guide contains several ready-made letters, and the teacher can design ones by him/herself as well.

The pupils' task is to write a reply to the letter and search for information in suitable data sources on the Internet in order to be able to answer the questions in the letter. Inspiring characters make the effects of climate change more concrete for the pupils.

Written answers to the letters are done in small groups. After that, the groups will present the problem and the answer to the class.

During the summary, the teacher can ask the class to make general observations: what did the writers' experiences have in common? What did the proposed reasons for the changes have in common?

Pupils' replies

The pupils' replies can be naive, but they offer a good chance for the teacher to carry out formative assessment and to correct possible misconceptions. Below are shown an example of a letter activity and the reply written by a group of fifth graders.

Example letter text

GROWL!

I'm Pete Polar Bear from Greenland. I live on glaciers and feel that my home has become smaller. I received a letter from my buddy, Polly Penguin from Antarctica, and she's got similar problems there. Are glaciers really growing smaller? What makes it happen?

Thanks for your help,
Pete Polar Bear

Example pupil answer to letter

"Climate change affects especially polar bears, their food and homes. When oil and gases leak into water, fish get less food and suffer. When oils leak into the seas, it's very harmful for birds, such as the penguins of South Africa. If the Saimaa ringed seals vanish from Saimaa, they'll vanish from the whole country and become extinct. A bird named dodo became extinct because of humans in the 1600s. People also think that it's not harmful for themselves if hundreds of animals become extinct. But it's really harmful for animals, they'll get less food. So don't throw gases into water or litter the nature!"

Carbon footprint

Studying one's carbon footprint provides various possibilities for studying climate change with the pupils. Research related to one's own everyday choices, a quiz which develops product awareness and guiding the discussion towards social responsibility are presented here.

Connection between the carbon footprint and climate change

In principle, all human activities affect the amount of greenhouse gases in the atmosphere, as nearly all human actions use carbon-based fossil resources either directly or indirectly. In this activity, the effects of human actions on the climate are defined via a carbon footprint. A carbon dioxide equivalent (CO_2e) is used to measure the effect. The carbon dioxide equivalent means the total effect on climate change proportioned to carbon dioxide.

Carbon footprint on the web

Purpose of the activity

The purpose of the activity is to study how personal everyday choices influence one's carbon footprint.

Materials

- tablets or computers

Choosing between activities

There are two alternatives for doing the activity: either figuring out the carbon footprint of one's breakfast or figuring out the broader carbon footprint of one's "lifestyle". The breakfast activity is better suited for younger pupils, as it's more concrete and doesn't require as much mathematical skill.

In order to find out the carbon footprints of a person or a household, the pupils must do preliminary research at home and know how to calculate monthly or personal shares, for example.

Breakfast carbon footprint (younger pupils)

The pupils can do the activity independently. However, it's essential to reflect together on the carbon footprint of breakfast and which foodstuffs have the biggest effect on the formation of the carbon footprint.

1. Go to http://www.eatlowcarbon.org/food-scores/ or another suitable calculator available in the pupils' language.
2. Move the cursor over the foods that you had for breakfast to see their CO_2e value and write it down.
3. Sum all the foods you ate for breakfast to get your breakfast's carbon footprint.

RRI Ideas for Breakfast Carbon Footprint activity

Milk and meat products grow one's carbon footprint quickly. Discuss with the pupils why these products cause the most significant food-based greenhouse gas emissions. Alternatively, you can sum the pupils' carbon footprints and discuss the thoughts that arise from them.

Personal carbon footprint (older students)

The pupils will do preliminary homework with a worksheet in the appendix in which information about the electricity consumption and travel in one's household is gathered.

Notice that the pupils should fill in only those sections relevant to their consumption. The teacher can remove the sections concerning car and plane travel, for example, and ask the pupils to ignore them in the counter as well.

The counter can be used in several languages, such as in English, French, German, Spanish, Italian, Czech, Slovakian, Polish, Hungarian, Lithuanian and Russian.

Count your own carbon footprint

1. Go to http://www.carbonfootprint.com/calculator.aspx.
2. Fill out the counter with the information you gathered in your homework, or convert it into the requested format unless already done.
3. Write down your carbon footprint and the global average.
4. Test how different choices change your carbon footprint. Which of the choices could you make in real life?

Discuss in your group or with the whole class

- How could you make your carbon footprint smaller?
- How could you make others' carbon footprint smaller?
- How does the state try to direct people's consumption? What kinds of new ways could be used?
- What kinds of ways are unacceptable? Why?

RRI

Ideas for personal carbon footprint activity

Travel and warming grow the carbon footprint quickly. Have the pupils notice how living in your country compares with the global average carbon footprint. Reflect on the reasons for this, such as the climate or geographical location.

What kinds of small changes would be easy to make, and would they affect the carbon footprint? Ask the pupils to give evidence with the counter.

What kinds of ways would be effective but would generate much opposition? Think about the options in a large scale: not only forbidding or illegalizing but also raising prices, removing benefits, tax deductions etc.

Ask the pupils also to think who should participate in the decision-making for the implementation of such measures.

Guessing the size of products' carbon footprint

Purpose of the activity

The purpose of the work is to reflect on the size of different products' carbon footprint. The Climate Guide's article on climate-friendly food serves as suitable background reading.

Climate-friendly Food

Find the article in English at https://ilmasto-opas.fi/en/ilmastonmuutos/hillinta/-/artikkeli/ab196e68-c632-4bef-86f3-18b5ce91d655/ilmastomyotainen-ruoka.html.

Materials

- Matchboxes or other small boxes
- Small wooden cubes or other small and identical objects, 100+ pcs
- Carbon footprint estimates for different products

Teacher preparation

Print or write the names of products that the pupils are familiar with on the matchboxes, e.g. “tuna, frozen, 300g”.

Print or write the carbon footprint of that same product, i.e. the emissions that are generated during the whole lifespan of the product, calculated as a carbon dioxide equivalent. Glue a piece of paper inside the matchbox, e.g. “900g CO_2e”.

The Bamco counter serves as a suitable source (http://www.eatlowcarbon.org/food-scores/).

Make sure that there are enough wooden cubes for assessing the carbon footprint of each product. Each cube corresponds to 100g CO_2e.

Activity steps

Video: Carbon dioxide equivalent

To clarify the concept of carbon dioxide equivalent, you can use the video (Campbell, 2010): https://www.youtube.com/watch?v=niotf0oHvQY

It’s advisable for the teacher to ask open questions in order to help the pupils reflect on the size of different products’ carbon footprint. For example, when discussing meat, the pupils can be helped by asking open questions that examine the course of matter and energy in an ecosystem.

“Guess the footprint” game

1. Receive matchboxes and wooden cubes from the teacher.
2. Your task is to estimate the carbon footprint of the products in the matchboxes. You’ll find the correct answer inside.
3. Use the cubes to help concretize the size of the carbon footprint. One cube represents 100g CO_2e.

Alternatively, you can arrange this as a competition in small groups in such a manner that each group can have at least 30 cubes. A score sheet for playing is in the Appendix.

3-Materials for the teaching period

Reflecting on the results of the activity is important so that the pupils will form a correct understanding of the relationship between the carbon footprint and climate change.

Elaboration and application: societal effects

On their own, the pupils can start thinking about the effects of different products on the climate throughout the products' lifespan. The teacher can spark discussion also on the size of products' carbon footprint and the reasons for their differences.

A good example of an opening question is bottled water: what does its carbon footprint consist of, since water doesn't have to be manufactured?

RRI

Ideas: consumption habits

It can be sufficiently challenging for younger pupils to reflect on their own consumption choices, on which they can have a direct impact. For instance, they could think about if it would be possible to discuss at home whether bananas, oranges or carrots should be bought as snacks and the different justifications for the choice (taste, climate effect, availability etc.). They can also think about whether they should travel by car, bus or on foot and the justifications for the choice.

RRI

Ideas: decision-making in society

Older pupils can approach the subject first by reflecting on the origin of emissions, leading discussions most often to start from one's own environmental effects. If so, the teacher should guide the discussion towards a larger scale, such as traffic (Fig. 5), and have the pupils think about the effects of a private person's choice, legislation, incentives, sanctions and punishments.

The pupils can gather examples of different levels of legislation (global, state, municipality) that influence the restraining of climate change. This can be done as an information gathering activity independently or with a pair.

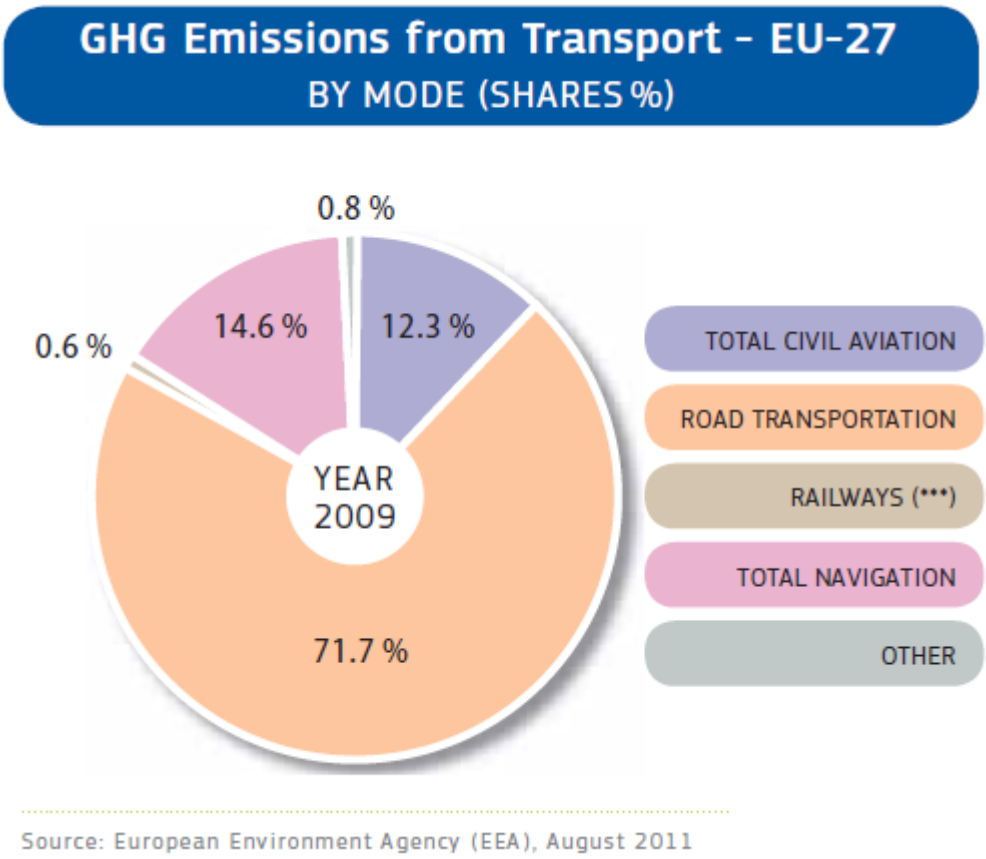

Figure 5. The distribution of CO_2 emissions in European traffic in 2009. European Commission: EU transport in figures 2012.

Carbon footprint summary discussion

The summary discussion provides a chance to raise different RRI themes equally. In order to understand these themes, the discussion can be allowed to divert into recent news stories as well, provided that the news is related to the topic (e.g. initiatives as a way of impacting).

For example:

- Who passes laws? Are they based on scientific research? Why or why not?
- What information sources are available to policymakers? What about citizens?
- Can climate change increase inequality? Come up with examples.
    - If the pupils are unable to come up with examples, they can be directed to think about issues of equality between geographical areas.
- How can an ordinary citizen influence municipality policymakers or legislators?

Different ways of sharing the pupils' conclusions

Organising an exhibition

This choice is explained in more detail in the Irresistible Exhibition Development Guide.

IRRESISTIBLE Exhibition Development Guide

Find it online at https://issuu.com/institutodeeducacao-universidadedel/docs/development_guide_-_v2.2_web

Figure 6. Putting up a poster exhibition in the school lobby on ways of restraining climate change.

Creating a blog

Teacher preparation

Some of the advantages of a blog are that the pupils' faces don't have to be shown in the finished piece and that it's easily presentable to a wide audience via the web. The blog can be maintained together with a parallel class or another school.

It's advisable to arrange the adding of content to the blog through a teacher. As such, no blog accounts are necessary for the pupils, and the teacher doesn't have to worry about the possible appearance of inappropriate content, the disappearance of old content, vandalism etc.

Blog platforms online

Examples of free blog platforms are https://www.tumblr.com, http://www.padlet.com and https://www.blogger.com/.

Content writing for the blog

The pupils themselves decide the topics that they discuss in the blog.

Examples:

- The pupils present the experimental activities done during the teaching period as blog posts and explain how the results are connected to climate change.
- The pupils post the pictures on climate change that are drawn at the beginning and the end of the period in the blog and use it as an art platform as well.
- The pupils gather information on the effects of climate change on different geographical areas / species / other narrowed-down topics and publish concise facts in the blog.
- The pupils collect media articles which discuss climate change and comment on them in the blog.

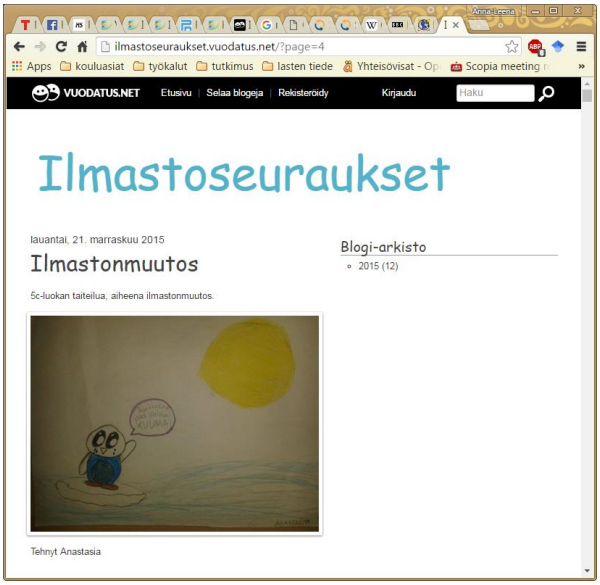

Figure 6. The 'Ilmastoseuraukset' blog (Climate consequences) into which fifth-graders posted pictures and facts, at http://ilmastoseuraukset.vuodatus.net/

Filming a video piece

Teacher preparation

Pupils are familiar with filming videos with mobile phones or iPads. Pupils will need little guidance in filming, and classrooms are often abundant with helpers for those in need. The teacher is advised to learn the basics of the applications to be used. iPads have become more common in schools, and so we recommend the iMovie application, for which there are ample general instructions online.

iMovie for Beginners

The following instruction video 'iMovie for Beginners' by Eric Timmer is suited for basic use: https://www.youtube.com/watch?v=OuNdGKnxrEY

It may be that the pupils have not previously encountered copyrights and don't understand which materials can (or cannot) be used in videos and how. The teacher can find websites with appropriate pictures or background music for the videos in advance, or the pupils can create all content by themselves - depending on the type of the project.

Free content for video making

Free music with a Creative Commons license:

- (available for use, author must be credited on the video): http://in-competech.com/music/

Free pictures with a Creative Commons license:

- photos: https://www.flickr.com/creativecommons/
- photos and drawings: https://pixabay.com/
- photos and drawings: http://www.stockvault.net/

In addition, the Climate Guide website contains several infographics and visualisations that can be used in the videos if the sources are credited.

Permissions: appearing on video

If the pupils wish to present the video to others outside the class, the teacher must ask the guardians' permission for the appearance of all pupils on the video beforehand.

Video project with pupils

Video projects in schools trying out the module have so far consisted of climate news (future prospects as climate change accelerates), a catastrophe movie, clay animations, facts about the effects of climate change on different animals and videos on visits to an exhibition about climate change.

For example, the video project might proceed as follows:

The pupils are divided into small groups and plan topics on which they wish to gather more information and make a video.

The class chooses the topics for video pieces together and decides whether all groups will make a similar piece (news, animation, PowerPoint presentation etc.) and whether each group will make one video or the whole class will work on the same piece.

Younger pupils will need teacher's help in creating a list of tasks to be followed, or the teacher can supply a list depending on the type of video the pupils are making. The tasks will be quite different for a clay animation or a newscast! Older pupils should write a task list be themselves.

Finally, the groups will work independently by e.g. gathering information, preparing the shoot, acquiring equipment and finally shooting the video, editing, and presenting it.

Summarizing the project

Reflecting on learning

The class may watch all learning videos, if filmed, together. A list of things that the whole class has learned during the teaching period can be written.

Quiz platforms

The pupils can answer quiz questions, such as quizzes customized by the teacher or other pupils on platforms like Kahoot!, Socrative, etc.

RRI Sharing and impacting

The pupils will design a follow-up for the project: how could the class work together to slow down climate change? The pupils are divided into small groups to think about how to take advantage of the project. Examples:

- Sharing the exhibition or blog further. To whom and how?
- Writing a letter to the editor. On which topic?
- A nature awareness campaign, such as cleaning streets
- Visiting an environment-friendly company and asking how the pupils can impact or help
- Inviting a local politician or politicians to the classroom to listen to the pupils' research results

The class will discuss the proposals together. One or more proposals will be selected to be done together.

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A

Activity worksheets

Melting of Glaciers

Materials

- ice cubes
- small stones
- two beakers or equivalent
- water

The melting of glaciers situated on continents causes the sea level to rise. The melting of sea ice doesn't cause the sea level to rise. As the climate warms up, the seas warm up as well, and the resulting thermal expansion causes the sea level to rise.

Purpose of the experiment

The purpose of the experiment is to study how the melting of sea ice and glaciers affects the sea levels.

Assessment

The assessment is directed at process skills. It focuses on formulating questions, carrying out the experiment, and analyzing and interpreting results.

Glacier group instructions

A glacier is ice that covers a part of a continent. Glaciers are found in Greenland and Antarctica. It's said that the melting of glaciers has become faster due to global warming. Now, you get a chance to study the effect of melting on the rising of sea levels. The stone represents a continent, the ice cube acts as glacier and the water depicts sea water.

1. Decide with your group if glacier ice melting affects the sea level. If yes, how? Share your hypothesis with another group.
2. Put a stone in the measuring glass and add hot water so that the surface reaches 40ml. Place an ice cube on the stone. It represents the ice that is on top of the continent, meaning that it's not in direct contact with sea water and doesn't float in it.
3. When the ice has melted partly or completely, discuss
    a. What happened to the melted ice?
    b. How would the melting of glaciers affect seas?
4. Compare your results with the group opposite to you and reflect together on what caused the results.

Melting of Glaciers

Materials

- ice cubes
- small stones
- two beakers or equivalent
- water

The melting of glaciers situated on continents causes the sea level to rise. The melting of sea ice doesn't cause the sea level to rise. As the climate warms up, the seas warm up as well, and the resulting thermal expansion causes the sea level to rise.

Purpose of the experiment

The purpose of the experiment is to study how the melting of sea ice and glaciers affects the sea levels.

Assessment

The assessment is directed at process skills. It focuses on formulating questions, carrying out the experiment, and analyzing and interpreting results.

Sea ice group instructions

Sea ice is ice that is formed on top of the sea level when the temperature is cold enough. It grows and melts according to seasons. Now, you get a chance to study how the melting of sea ice affects the rising of sea levels. The ice cube represents sea ice and the water depicts sea water.

1. Decide with your group if sea ice melting affects the sea level. If yes, how? Share your hypothesis with another group.
2. Place the ice cube in the measuring glass and add hot water so that the surface reaches 40ml.
3. When the ice has melted partly or completely, discuss:
    a. What happened to the melted ice?
    b. How would the melting of sea ice affect seas?
4. Compare your results with the group opposite to you and reflect together on what caused the results.

Droughts and Floods

Materials

- two flat dishes per group
- a sieve
- moist clay or soil
- dry clay or soil
- a measuring cylinder
- water

When examined globally, the increased drying up of areas with low levels of rain is one effect of climate change. On the other hand, climate change makes weather harder to forecast, meaning that even dry areas might experience heavy rain. When the ground shrinks and cracks due to drought, its ability to absorb water weakens. As such, heavy rain can often cause floods in dry areas. The sparse vegetation of dry areas also increases flood peaks, because sparse vegetation doesn't bind water to itself.

Purpose of the activity

The purpose of the activity is to study how dry or moist ground affects the absorption and run-off of water. Its other big purpose is that the you get to plan an experiment setup on your own.

Assessment

The assessment is directed at process skills. It focuses on formulating questions, designing and carrying out the experiment, and interpreting results.

Instructions

In your group, think about which places around the world have been reported to experience droughts or sudden floods. Think also about the reasons why these events happen on Earth.

Plan a setup for an experiment in which you can test how the moisture of the ground affects its ability to absorb water and the amount of non-absorbed water.

As a group, make a prediction on what will happen in the experiment.

Carry out the experiment you designed.

Write down the results of the experiment.

Think about how the results of your experiment are related to climate change.

Acidicity and Corals

Materials

- seashells
- two glass beakers
- diluted hydrochloric acid (10%)
- a pipette
- pH strips
- water
- optional camera / mobile phone camera

Seas store carbon dioxide. The increase of carbon dioxide in the air causes it to be absorbed in the seas even more. This phenomenon is called the acidification of seas. The increased amount of carbon dioxide in seas starts to lower the basicity that is natural to seas and necessary for the habitats of marine species, making seas more acidic.

Purpose of the experiment

The purpose of the experiment is to study how the acidification of seas affects corals. Seashells are used instead of corals, as an acidic solution affects them in the same way.

Assessment

The assessment is directed at process skills. It focuses on formulating questions, carrying out the experiment, and analyzing and interpreting results.

Instructions

Wear lab coats, gloves, and protective glasses.
Hydrochloric acid is irritating. Do not touch it!
If you spill any on yourself or a group member, alert the teacher immediately.

1. Choose one seashell for each beaker. What could the seashells represent in this experiment?

2. Add around 2 centilitres of water to the beakers so that the seashells are covered. Take photos of the seashells.

Acidicity and corals - continued

3. Measure the water's pH by soaking the strips. Compare the strips with the table on the side of the strip case. Which value does the pH strip indicate?

4. Add 20 drops of hydrochloric acid in one beaker. What does it sound like? What causes the sound?

5. Measure the pH values again. What do you see when comparing the values with the results from the previous measurement? What does the hydrochloric acid depict in the experiment?

6. The seashells can now be left in the beakers for 15 minutes.

7. At the end of the lesson, check on the seashells again. Compare the seashells' appearance with the photos you took earlier. You can also measure if there's any change in the solutions now that the calcium salt has dissolved into the water.

Guess the carbon footprint

Materials

- carbon footprint boxes
- pieces depicting carbon dioxide emissions

In principle, all human activities affect the amount of greenhouse gases in the atmosphere, as nearly all human actions use carbon-based fossil resources either directly or indirectly. In this activity, the effects of human actions on the climate are defined via a carbon footprint. A carbon dioxide equivalent (CO_2e) is used to measure the effect. The carbon dioxide equivalent means the total effect on climate change proportioned to carbon dioxide.

Purpose of the activity

The purpose of the activity is to think about the size of different products' carbon footprint. You can consider the following questions: What alternatives could we adopt? Are they more responsible - do they produce less emissions?

Instructions

1. Fetch carbon footprint boxes and pieces for your group.
2. Your task is to estimate the carbon footprint of the products that are written on top of the box. You can use the pieces to help concretise the carbon footprint's size. One piece equals 100g CO_2e.
3. Check your answer by looking inside the box.

"Guess the footprint" game

Assemble teams. Someone acts as the host and writes down the scores.

The host lifts a box from a bag without looking. He/she reads the item name and package size from the box. Each team uses the pieces to assemble what they think is the right carbon footprint for the product.

The team that got closest to the correct answer receives 2p, and the team second to closest gets 1p. The host writes down the score.

When five boxes have been guessed, the final points are counted and the winning team is congratulated.

table for carbon footprint competition

Teams	Item 1	Item 2	Item 3	Item 4	Item 5	TOTAL

Homework: personal carbon foot-print

Find out the following aspects related to consumption in your household. Some sections may not apply to you or your household, leave them blank.

Electricity consumption of the apartment:
Electricity consumption in the previous electricity bill (kWh)

_____

Calculated electricity consumption per year (kWh)

_____

Other energy consumption in the apartment:
If your household is warmed up with natural gas

Consumption in the last gas bill (kWh) _____

The amount of gas used per year (kWh) _____

If your household is warmed up with oil

Consumption in the last oil bill (litres or kWh) _____

The amount of oil used per year (kWh) _____

If your household uses coal, liquid gas, propane or burns wood (such as at a cottage, in a boat, a caravan), estimate the amount of each product used per year

coal (tonnes or 10kg sacks) _____

liquid gas (litres) _____

propane (litres) _____

wood (tonnes)_____

Homework: personal carbon footprint (continued)

School commute or other trips

Do you travel by a family car? Find out the cars' manufacturer and model. Estimate the trips you take by car per year (such as your school commute, going shopping, visiting). Don't include your parents' commuting or other trips taken without you.

Car 1: _____

trip: _____ km

Car 2: _____

trip: _____ km

Do you use public transport? Estimate how much you travel per year:

Local bus: _____ km

Long-distance bus: _____ km

Train: _____ km

Tram: _____ km

Metro: _____ km

Taxi: _____ km

Have you flown on a plane during the past year? Write down the routes, including any stopovers:

Flight 1:

_____

Flight 2:

_____

Flight 3:

_____

Homework: personal carbon footprint (continued)

Predict which section's carbon emissions form the biggest part of your climate emissions:

_____

What kinds of things that create carbon emissions are missing from the questions?

_____

_____

_____

_____

Personal Carbon Footprint

Relating the activity to climate change

In principle, all human activities affect the amount of greenhouse gases in the atmosphere, as nearly all human actions use carbon-based fossil resources either directly or indirectly. In this activity, the effects of human actions on the climate are defined via a carbon footprint. A carbon dioxide equivalent (CO_2e) is used to measure the effect. The carbon dioxide equivalent means the total effect on climate change proportioned to carbon dioxide.

Purpose of the activity

The purpose of the activity is study how lifestyle affects the carbon footprint.

Doing the activity

The activity includes homework done in advance. In the homework, you gathered information about electricity consumption and travel in your household. Find the information you gathered before moving on to use the calculator on a computer.

Only fill out the sections that concern your own consumption!

Mark the counter with the number of people living in your household, so that you can find out your share of the consumption. Mark only the trips that you took part in, and not e.g. commuting by other members of the household.

Calculate your carbon footprint

1. Go to http://www.carbonfootprint.com/calculator.aspx
2. Fill out the counter with the information you gathered in your homework, or convert it into the requested format unless already done.
3. Write down your own carbon footprint and the global average.
4. Test how different choices change your carbon footprint. Which of the choices could you make in real life?

Personal Carbon Footprint (continued)

Discuss in a group or with the whole class

How could you make your carbon footprint smaller?

How could you make others' carbon footprint smaller?

How does the state try to direct people's consumption? What kinds of new ways could be used?

What kinds of ways are unacceptable? Why?

Breakfast Carbon Footprint

Relating the activity to global warming

In principle, all human activities affect the amount of greenhouse gases in the atmosphere, as nearly all human actions use carbon-based fossil resources either directly or indirectly. In this activity, the effects of human actions on the climate are defined via a carbon footprint. A carbon dioxide equivalent (CO_2e) is used to measure the effect. The CO_2e of a product is the amount of CO_2 that would have the same effect on climate as all greenhouse gas emissions by the product have.

Purpose of the activity

The purpose of the activity is to study how your breakfast affects your carbon footprint. Another purpose is to think about the size of different products' carbon footprint.

Calculate the carbon footprint

1. Go to http://www.eatlowcarbon.org/food-scores/.
2. Move the cursor over the foods that you had for breakfast to see their CO_2e value and write it down.
3. Sum all the foods you ate for breakfast to get your breakfast's carbon footprint.

What kinds of foods seem to have the largest carbon footprint? What do they have in common?

A letter from China

Respond to the letter below:

Hello!

My name is Mei-Hua. I'm an eleven-year-old Chinese girl. My home is called Hong Kong. I live by the sea with my parents. I don't have any brothers or sisters. I heard my parents talk about if they should find work inland, since living on the shore may not be safe in the future. What did my parents mean by that? What could happen to the sea and my home in the future? Why?

I also would love to study this issues, I would like to be a scientist perhaps, to better understand what could cause this situation. But my grandparents don't agree, they say it not a woman's job to work in Science. Do you agree? What should I say to them the next time they come up with this issue?

Regards,

Mei-Hua

A letter from Argentina

Respond to the letter below:

¡Hola!

My name is Vincent. I live in Argentina, and my hobby is studying frogs. I've been horrified to notice that different kinds of frogs have become rarer everywhere in the tropical areas of South America, and some species of frogs are trying to move to another habitat. Also, many species of frogs are becoming extinct. Horrible! What causes this? Why?

Are there same kinds of problems elsewhere in the world? What about back there where you live: are some species changing or about to disappear entirely?

I'm sorry to bother you with these questions, but whenever I try to search on scientific journals online on these issues, the vast majority is not for free. It's not fair not having access to what scientists are doing and discovering! I think this information should be available for all the population of the world – don't you agree with that? Why? What could we do about that?

Regards,

Vincent

A letter from United States

Respond to the letter below:

Hello!

I'm Samantha. I live in the United States, in the state of Louisiana near a city called New Orleans. Lately, really strong weather has become more common. The risk of hurricanes is said to be bigger than before. Yesterday they said in the news that a hurricane struck nearby. Also, my friend told me that the wind tore bricks from the roof of her grandpa's farmhouse. I'm scared.

Why's the weather around here so scary and unpredictable these days? Are there changes in the weather around the rest of the world? I have heard about a climate change, but my aunt tells me it is not for real. She says it was only invented by some quarreling scientists to get more attention. I don't know how I could tell who is right!

Could you guys perhaps help?

Regards,

Samantha

A letter from Austria

Respond to the letter below:

Servus!

My name's Felix. I live in Central Europe, in a small Austrian village by the Danube to be more exact. Last week I couldn't get to school, since the roads were blocked by floods and mud slides.

Also, my granddad's worried because it's probably not possible anymore to go skiing on all glaciers in the Alps around the year. He says he will have to shut down his holiday resort, because there are less and less tourists coming. He still pays debt on the resort. What do you think he should do? Who could help him?

What's happening here? What causes the floods and warming?

Regards,

Felix