Teachers' guidelines

Title of the toolkit: Why is thawing permafrost dangerous for the Earth's climate?

Information about the package:

Brief Description: Permafrost is permanently frozen ground. It is soil, rock, or organic material that remains at 0°C or below for at least two consecutive years. We will check whether permafrost changes as a result of climate change and how it can affect the dynamics of climate change. How many greenhouse gases can be released into the atmosphere as a result of the warming permafrost, and why is thawing of permafrost dangerous for the Earth's climate?

How does the package relate to STEAM education: The thematic scope of the package is science-centered and includes inquiry activities. The package is interdisciplinary as it uses physical and geographic concepts. It can be used mainly in Geography classes.

Keywords: permafrost, climate, climate change, greenhouse gases, methane, melting and thawing

Age Range: 14-18

Didactical Hours: 2-3 hours + time for a demonstration

Learning objectives:

The student will:

- explains the meaning of the term permafrost and describes how it was formed;
- describes the difference between melting and thawing;
- explains how climate change can affect the rate of permafrost thawing;
- analyzes plots of vertical temperature distribution for selected boreholes in the Arctic;
- explains, using the example of permafrost, what is a positive feedback loop;
- calculates the approximate amount of CO2 that will be released into the atmosphere as a result of the thawing of permafrost and compares it with the anthropogenic emissions;
- explains what sub-sea permafrost is and why its thawing is dangerous for the Earth's climate.

Content of the package and guidelines for teachers:

Link to the package: https://graasp.eu/s/h9noc8

We encourage teachers to copy the graasp package to their own graasp space in order to become "owner" and be able to modify the content, hide or unhide some materials, add quizzes etc. Moreover, teachers may share the package with their students and check the progress of each student.

A short video tutorial on how to do it is available at:
https://view.genial.ly/5f7ef81f1b2b330d2efa3411/video-presentation-tutorial-graasp

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EDU-ARCTIC 2: from polar research to scientific passion – innovative nature education in Poland and Norway receives a grant of ca. 240 000 EUR received from Iceland, Liechtenstein and Norway under EEA funds. The purpose of the EDU-ARCTIC 2 project is to: enhance the knowledge about nature, geography, natural resources, political specificities concerning polar regions and increase awareness of environmental issues and climate change, increase of interest in pursuing STEM education and careers due to enhancement of knowledge about scientific research, and their place in the modern world, familiarizing young people with scientific career opportunities; introduce innovative tools by way of an e-learning portal and effective methods of teaching science in schools.

If you don’t have access to the graasp package, contact us: edukacja@igf.edu.pl

The package consists of 8 sections described in detail below:

1. **Let’s guess what permafrost is**

First, students try to give a definition of permafrost. They will find out where it occurs, what areas it covers, how long ago it was created and what thickness it may have. They will analyze the vertical section.

Suggested resources:

- Permafrost ppt presentation (slides 1-8) or “Let’s guess what permafrost is” graasp section
- Worksheet for students – task 1.

Estimated time: 10 minutes

2. **Permafrost demonstration**

What happens when the temperature rises above 0 degrees Celsius? Ice is melting. But what happens to the frozen ground? We check it in a simple demonstration. Note: access to the freezer is needed and time for samples to freeze and thaw.

If you do not have enough time during the lesson, photos of the individual steps of the demonstration can be shown. It is also worth encouraging students to put an ice cube inside the form - this way they will simulate ice wedges.

Suggested resources:

- Permafrost ppt presentation (slides 9-15) or “Permafrost demonstration” graasp section
- Hidden section “For teachers” on graasp contains photos from the demonstration
- Worksheet for students – task 2.

Estimated time: 10 minutes for discussion on the demonstration - 3 hours (including time for freezing and thawing)

3. **Thawing permafrost**

In this section, students will learn what happens when permafrost thaws. Is it dangerous? They will also recall information about greenhouse gases and a positive feedback loop - which will be useful in further tasks. First, students watch a video about thawing permafrost. The video is in English, so you can use the transcription. Ask students if they know examples of positive feedback loops. They can give examples from various fields (e.g. physiology, biology). A good example to cite is the melting of the sea ice in the Arctic, which is changing the albedo. Water absorbs much more Sun radiation, which increases the temperature and accelerates the melting of sea ice.

Suggested resources:

- Permafrost ppt presentation (slides 16-18) or “Thawing permafrost” graasp section
- Video (6:47): https://youtu.be/yN4OdKPy9rM
- Video’s transcription
- Worksheet for students – task 3.

Estimated time: 15 minutes (or more, if you need to stop the video several times)

4. **What would happen if…**

After watching the video and reminding the feedback concept, students will make a mind map using predefined concepts and relationships, or suggest their own. The main task is to describe the relationship between the processes occurring as a result of thawing of permafrost and the Earth's climate.

Then ask students to create a hypothesis for permafrost and climate change.

Suggested resources:

- Permafrost ppt presentation (slides 19-20) or “What would happen if” graasp section
- Worksheet for students – task 4 and 5.

Estimated time: 10-15 minutes

5. **Trip to Alaska, trip to the future!**

In this section, students will explore how climate change affects permafrost, how its temperature is changing, and how fast the changes are. Students receive charts with data from boreholes in 3 locations. First, they should find these places on Google Earth and see what the landscape looks like in places with permafrost. Then they choose one of the locations and check the temperature at 4 different depths: 5 m, 10 m, 20 m and 40 m for the years: 1996, 1997, 1998, 1999, 2006, 2008, 2009, 2010. Then, they calculate the average over the periods: 1996-1999 and 2006-2010. Note that in order to observe trends, it is necessary to analyze periods longer than one year.

By analyzing the graphs and data collected in the table, students answer 3 questions, and then summarize their observations about whether permafrost has recently been thawing more or less.

Suggested resources:

- Permafrost ppt presentation (slides 21-22) or “Trip to Alaska, trip to the future” graasp section
- Worksheet for students – task 6.

Estimated time: 20 minutes

6. **Release of methane and CO2 from permafrost**

Students learn that permafrost may contain organic matter that didn’t decay previously because of the cold. Permafrost acts like a lid, locking frozen carbon deposits deep below ground. As the organic matter thaws, microbes degrade it – a process that releases carbon dioxide and methane starts.

Students learn also that methane is ca. 80 times more potent than CO2 in the short term. In the longer term it is oxidized and forms CO2, which remains in the atmosphere for much longer.

Next, students will use various scenarios of release of carbon from thawing permafrost by 2100. They compare the estimated amount of greenhouse gases from thawing permafrost and compare it to anthropogenic emissions of a chosen country.

In order to check the emissions for a particular country use the website: https://ourworldindata.org/co2-emissions. Click on “Map” and choose the country. Students should calculate the estimated amount of anthropogenic emissions assuming that the emissions will be constant till 2100.

In the calculations they also assume that from 1 kg of carbon, ca. 3 kg of CO2 are produced. In the calculations they need to change units: 1GT = 1 billion tons = 10^9 tons = 1 PG (petagram).

Suggested resources:

- Permafrost ppt presentation (slides 23-29) or “Release of methane and CO2 from permafrost” graasp section
- Video: https://youtu.be/awNnw_e9KL8
- Website https://ourworldindata.org/co2-emissions
- Worksheet for students – task 7.

Estimated time: 20 minutes

7. Want to know more?

In this section, students will learn about sub-sea permafrost: how it was formed and why it is a "cork of champagne". They can also read the article - an interview with Dr. Shakhova, who studies the East Siberian Arctic Shelf's sub-sea permafrost. Finally, students can be informed that scientists still do not know how much methane will be released as a result of the thawing of sub-sea permafrost. Therefore, most climate models do not take this methane into account at all. And since we know that positive feedback will accelerate this process, we can expect that even the worst-case scientific scenarios may be underestimated.

Suggested resources:

- Permafrost ppt presentation (slides 30-36) or “Want to know more?” graasp section
- Video: https://youtu.be/0vhPBlEnUsc
- Article: https://envisionation.co.uk/index.php/nick-breeze/203-subsea-permafrost-on-east-siberian-arctic-shelf-now-in-accelerated-decline

Estimated time: 10 minutes

8. Show off your findings

Ask your students to prepare presentations or videos presenting problem of thawing permafrost to their peers from other classes, who didn't participate in this activity. They have 10 minutes for their presentation. They may prepare it as a homework or an extra work.

In their presentations they should answer the questions given below.

1. What is permafrost and how it formed?
2. Is permafrost getting warmer?
3. What happens when permafrost thaws?
4. How much carbon is there in permafrost? do scientists know it exactly?
5. How long does methane stay in the atmosphere?
6. Why is it called „positive feedback loop”?

Suggested resources:

- Permafrost ppt presentation (slide 37) or “Show off your findings” graasp section

Estimated time: 10-45 minutes (depending on how many students will present their work). In addition, time for students' own work - e.g. homework, additional work.