THE OCEAN SENSES ACTIVITIES BOOK

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INTRODUCTION

Giuliana Panieri and Mathew Stiller-Reeve

Welcome to AKMA Ocean Senses!

This booklet consists of 16 interdisciplinary lesson plans and ideas that inspire to learn about the ocean and connect to it via their senses. Teachers from kindergarten to high school- are the primary audience, but this is not only for teachers. We hope people of all ages can be inspired. Parents can try some of the ideas out with their children at home. Some ideas could be tried out in older adults' homes or local youth groups. For example, some of the lessons can be used by older pupils as guides for younger pupils at school or science fairs. All the lesson plans were developed within a research project called Advancing Knowledge about Methane in the Arctic (AKMA Project number 287869). The AKMA project was funded by Norwegian Research Council and led by the UiT - The Arctic University of Norway in Tromsø in collaboration with Woods Hole Oceanographic Institute in the USA.

The AKMA project aimed to advance collective knowledge about methane activity in the seabed, on the seafloor and in the ocean in Arctic regions. The Arctic regions are particularly vulnerable to the effects of climate change, and methane is a highly effective climate gas when it reaches the atmosphere. The project started as a collaboration between UiT and the Woods Hole Oceanographic Institute. As things progressed, we also expanded to include scientists and educators across the world, from South America, Central Asia, Africa, and Europe. One of the flagship activities of the project was the research expedition in May 2022, which we called AKMA2 Ocean Senses (you can find the cruise report here: https://doi.org/10.7557/cage.6755

The AKMA Ocean Senses Research Expedition took place aboard the research vessel Kronprins Håkon to the Barents Sea and the Arctic Ocean between May 11-22 2022, and was endorsed by the UN Decade of Ocean Science for Sustainable Development. The expedition had some important overarching aims. Firstly, we investigated and collected data from extreme environments such as cold seep sites. These sites are areas on the ocean floor where methane, hydrogen sulfide and other hydrocarbons naturally occur and bubble up in the water column. They are also sites where environmental stressors affect biological communities

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and produce peculiar seafloor features. Secondly, we wanted to develop a platform for interdisciplinary collaboration to bring AKMA science into the classroom. We aimed to develop different lesson plans to encourage discussion on the ocean and climate change among school pupils and learners of any age. We wanted to spread awareness about the Arctic environment and the potential impact of climate change on the biological communities that live there.

The lesson plans we developed were inspired by an idea to connect the ocean and the ocean floor to students and schools via the "senses". We wanted to encourage a sense of human-connectedness to this place that most people think of as dark, abstract, and sometimes scary. Encouraging pupils to feel more connected to a place, we hope they will feel encouraged to learn more about it and, hopefully, protect it through their choices. To achieve these ideas, we needed to open the door to influences from people in different disciplines and, most importantly, from people who work as teachers.

During the AKMA2 Ocean Senses expedition, different groups of us co-created different lesson plans. These smaller groups comprised people from very different backgrounds. There were teachers, natural scientists, social scientists, humanities scholars, education practitioners, and artists. The diversity within and between these smaller working groups is reflected in the variety of the resulting lesson plans. Some lesson plans are shorter, inspirational texts, whereas others are much longer and more detailed.

The lesson plans are meant as inspiration. It will be up to you, the teacher, to see how you can adapt these ideas to your class and curriculum. You will find lesson plans that inspire pupils to feel and think about the different aspects of the ocean and ocean floor. Some lesson plans involve artistic activities, whilst others encourage pupils to get outside and experience the world in different ways. Some lesson plans bring the ocean floor to life through smell and sound, whilst others will inspire through activities that involve maps and detective work. The activities can be used as they are for younger children, or they can be used to encourage discussion about more complex issues for older pupils. Some of the lesson plans have been tested in classrooms in Norway, Italy, and Brazil, but not all of them. If you test out some of them, we would love to hear from you.

This booklet results from the exciting and rewarding interdisciplinary collaboration during the AKMA project. We hope that you will find the lesson plans useful, and we hope they will help to inspire learners of all ages to have a closer relationship to the environments on the ocean floor and far beyond. The vision of the UN Decade of Ocean Science for Sustainable Development is to develop the "science we need for the ocean we want".

We can all be inspired to protect the natural world for future generations.

LESSON CONTENTS

Here is an overview of the contents of each lesson plan, along with some information about common elements in all the lessons.

Each lesson plan begins with specific information about the following:

- Focus
- Learning objectives
- Keywords
- In short (for the teachers)
- Materials needed
- Teaching time
- Classroom organization

We then follow up with background information and specifics about the learning procedure. Most lessons can be adapted to suit your class or the group of people you work with.

Some lesson plans have additional audio-visual resources that you can find via the AKMA website: https://akma-project.com or https://en.uit.no/project/akma from summer 2023.

Besides the specific information in each of the lesson plan, some important elements are applicable to almost all the plans in this booklet, as follows.

Ages	5-105 People of all ages deserve to feel connected to the ocean. Our lesson plans can be used as described for all ages or they can be used as supplements to more advanced science lessons in high school or university.
Subjects involved	All the lesson plans combine ideas about science and the natural world with art, social studies, music, and physical education.
Inclusion	Since the lessons are inspired by using one's senses, then some may not be appropriate for people with certain disabilities. If this is the case, then we hope that other lessons in the booklet will help folks connect to the ocean using their other senses.
Prerequisites	We have tried to develop lessons that can be used in kindergarten but can equally be used as a supplement to science or art lessons at high school or beyond. Therefore, it should be possible to apply most lessons without much or any background knowledge or vocabulary. The key words in each lesson should give a good idea about the overarching issues which may come up. The one exception is lesson XX about paired teaching. This lesson is aimed at middle- and high-school pupils.
Methods	All lessons are immersive. Some of the lessons also have elements kinesthetic learning, but also problem-solving and inquiry-based learning (like lesson XX about paired teaching).
Final wrap-up	The lessons have different outcomes, but they all attempt to create a connection to the ocean and ocean floor via the senses. We recommend rounding off each lesson with a discussion about how the experience made the pupils feel.

FUNCTIONS OF SENSES IN LEARNING

Zeynep Sancak Sert and Giuliana Panieri

Using various senses to process and store new information is a powerful way of exploring the natural environment for children, but also adults. Using senses through the sensory organs (the eyes, ears, nose, tongue, and skin) makes the learning experience effective, meaningful and unforgettable. This is the most natural method that children use to learn each detail in their environment since they were born.

The world comprises various objects that stimulate our senses in multiple ways. We connect the outer world through our senses so that we perceive the environment around us and make interactions (Ranu, 2022). Therefore, it is advantageous for children to integrate all their senses into their learning environment. Children learn best by being actively involved in the action. One can forget the theoretical description of how to ride a bicycle or bake a cake. Still, it is an everlasting experience/information when such actions are done actively by integrating the senses and body movements. After receiving such information, brain networks stimulate the senses, but learning from this unique experience is only possible by using memory networks.

Tang (2017) explains the brain network involved in learning and teaching using memory systems. The information we receive from our environment is stored in our sensory memory, and this first step forms short-term memory. Short-term memory is temporary storage for small amounts of information. After processing the information in short-term memory, long-term memory is created to store the information over long periods and to communicate this information with the outer world. The memory process includes three stages: Encoding, storage and retrieval. Each of these stages recruits different brain networks. For example, sensory memory activates three different systems to encode the information, which is visual, acoustic and semantic systems. Moreover, encoding the information requires interaction between attention and memory networks. This interaction can be different in each individual´s brain; each brain creates its unique way of learning.

“Sensory Theory” by Laird (1985) suggests that effective learning occurs only when the senses of sight, hearing, touch, smell and taste are stimulated. Using the five senses simultaneously in

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processing the information helps us to learn. The theory also suggests that there is a greater chance for learning to happen if multi-senses are stimulated. Therefore, it is crucial to adapt the sources and methodologies used in teaching according to the sensory system.

In an era where we are so close to the digital screens in our daily lives, children need to be presented such materials that encourage them to grab, shake, smell, listen, taste and write, therefore designing and implementing multi-sensory materials leads to re-shape the educational approaches (Ponticorvo et al., 2019).

Katai (2011) and Sheyesteh et al. (2019) suggest that a combination of senses connects individuals with the outer world and offers them the opportunity for inclusive learning. Sensory experience alerts the emotions evoked through the senses according to the frequency of sensory experience (Pishgadam et al., 2013). The emotions and sensory inputs received from the environment also influence individuals´ understanding of reality and perception of the future (Pishgadam et al., 2016). Accordingly, all the activities that involve the combination of multiple senses in this book would not only be beneficial to get a closer experience of the ocean but also leads to exploring one´s senses and emotions. Furthermore, the book offers active learning with engaged activities that invite children and adults to do things and think about the actions they are involved. Active learning help to integrate the diversity of children when used in the classroom. This allows engaging all the populations in a classroom, such as underrepresented groups, which helps to improve the classroom atmosphere (Haak et al., 2011). Active learning explains the reason why the atmosphere in the classroom is better enhanced with constructivism. Constructivism describes the different types of practice that are influential for underprepared groups in the classroom, such as the exercises that involve students explaining their thoughts and those that challenge their previous conception towards that topic (Vygotsky, 1978). The constructivist approach is crucial, especially for introductory courses, so there would be no missing minds in the classroom. A classroom can include various types of intelligence, such as natural, kinesthetic, interpersonal, intrapersonal, visual-spatial, verbal, logical (Multiple Intelligence Theory, Gardner, 1993) and neurodivergent brains, such as autistic and attention deficit individuals. With that said, the Ocean Senses book, a multi-sensory learning tool that supports active learning using senses, can be an overarching agent for all types of students in the classroom environment.

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SIGHT

EXPLORING THE ARCTIC DEEP-SEA BY COLOR FILTERS

Focus:

To get to know some of the creatures in the deep-sea that use color and the lack of light to camouflage themselves.

Learning objectives:

With these TWO activities, we use vision to explore life forms in the deep sea which have adapted to extreme conditions. Through the activities, the pupils will also become familiar with some organisms well-hidden at the bottom of the ocean.

Key words:

Camouflage strategies, Deep sea ocean, Physical effects of light, Characteristics of sea lifeforms

This specific lesson plan was developed in a close collaboration with:
Vibeke Os, Heike Jane Zimmermann and Giuliana Panieri.

Edited by: *Giuliana Panieri and Mathew Stiller-Reeve*
Layout and Graphics: *Heike Jane Zimmermann*

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IN SHORT (FOR THE TEACHER):

The pupils will learn how animals in the deep sea use the lack of light and colour to camouflage themselves and also learn about some of these creatures.

Activity 1

DISCOVER HOW FILTRATION OF THE LIGHT AFFECTS YOUR VISION:

Materials:

- Each group (3-4 pupils) gets three transparent sheets in blue, green, and red, A4 size.
- A pair of scissors to cut the transparent sheets so each pupil has a piece to hold in front of their eyes.
- A4 (or A3) size print outs for each group of:

a) "Lifeforms of the Deep Ocean" illustration (see page 16)
b) "List of Different Lifeforms" (see page 17)
(This could also be projected on a wall or screen for everyone to see)
c) Activity Sheet (see page 18) to record observations.

Activity 2

FINDING THE FISHES:

Materials:

- Each pupil makes a pair of paper goggles. Please use slightly thicker white A4 paper to cut out the paper goggles. (see `Paper Goggles Template` page 20).
- Scissors to cut out the goggles.
- Blue transparent foils to be cut in small pieces and mounted over the eyeholes in the paper goggles.
- A4 (or A3) size red paper to cut out deep-sea animal shapes. (see "Cut-out example" page 21 or get inspired by the creatures on page 17).
- Tape to mount the pieces of transparent foil on the goggles.
- Elastic band to fit the goggles on the pupils' heads.

Classroom organization (suggestion):

a) Groups of 3-4 pupils for activity 1.
b) For activity 2, one-half of the class will hide the creatures they have cut out. The other half will find the creatures in groups of 2 or 3.

BACKGROUND STORY:

These exercises explore the color filtration of light in the deep ocean, and some of the fascinating animals and lifeforms that have adapted to life at these depths. We will find many different life forms, like fish, anemones, jellyfish, shrimp, etc., in different water depths where they have evolved to deal with what we humans consider extreme conditions. These conditions include cold temperatures, intense water pressure and darkness.

Images of life in the deep-sea (Image left to right: brittles stars, octopus and anemones by Michal Adamczyk/Mostphotos; Right: Jaap) Bleienberg/Mostphotos)

As light passes down through the ocean, the water acts as a filter and allows only specific colors to pass through while it absorbs other colors in the top few meters. Violet and the orange-red wavelengths are the first to be absorbed, with greens and blues being the last before complete darkness. In clear water the blue light can reach 100 meters. Once a color has been absorbed in the ocean, it is no longer possible to see that color. At depths of 100 meters, blue fish start to appear colorless and are more difficult to see. Some deep-sea animals have taken advantage of these optical properties of water and developed very interesting features to camouflage. This camouflage helps animals hide from their predators and sometimes also helps predators hide from their prey before they attack.

Many fishes and other animals have a red color on their skin, making it easier to hide from a predator's eye. However, the deep sea is dark, so some animals make their own light via a process called bioluminescence.

Today we will explore how sea animals adapt to the light filtrating down in the deep ocean.

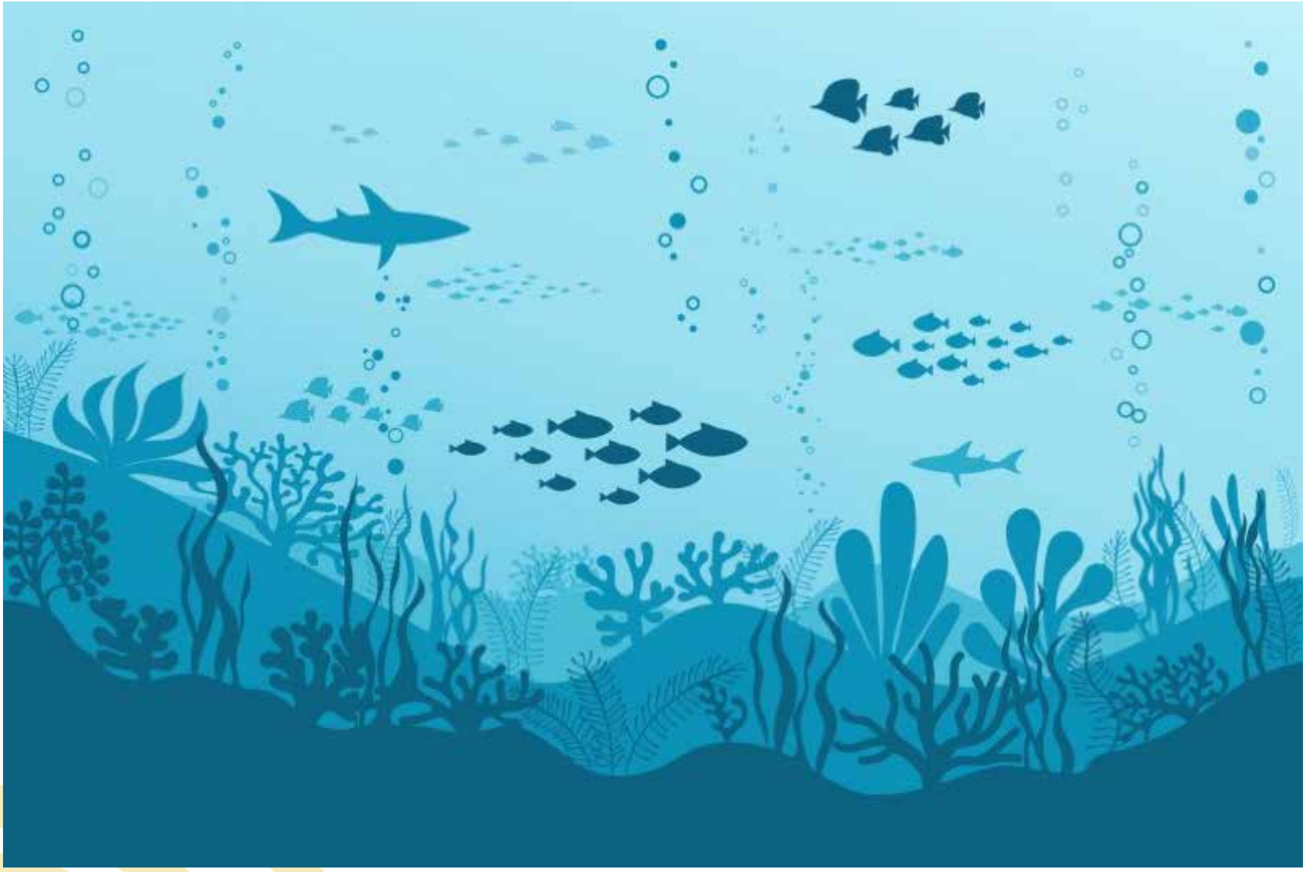


Illustration of the ocean depths (Andrii Malysh/Mostphotos)

Activity 1:

DISCOVER HOW FILTRATION OF THE LIGHT AFFECTS YOUR VISION

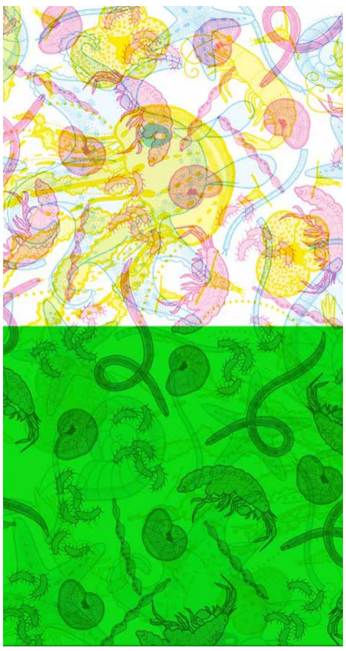
Print the illustration "Lifeforms of the Deep Ocean" (see page 7) in color. The illustration shows different deep sea lifeforms in three colors (yellow, cyan and magenta) printed on top of each other. The drawings represent diverse lifeforms from the arctic ocean described on page 8.

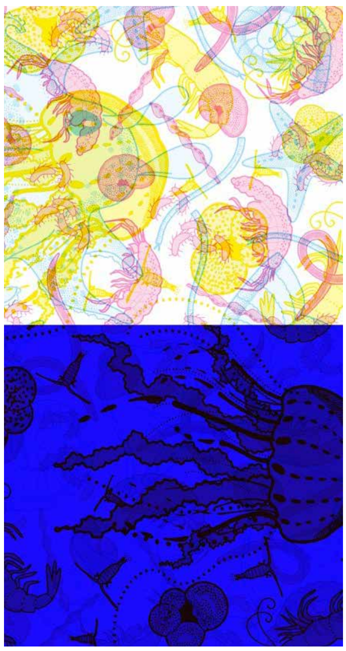
1. Place the print in front of the pupils (as print out) and let them describe what they see.
2. Then let them see through the different colored transparent foils and let them describe the differences they see.

By looking through the colored transparent foils (blue, red, and green), the color will filter out some of the printed figures, so some sea animals almost disappear while others will appear more clearly. (`Example of Filter Effect` see page 6)

The pupils can use the "List of Different Lifeforms" (see page 8) to describe which ones appear using the different color filters and fill in the activity sheet on page 9.

Effect using the a) **red** transparent foil, b) **green** transparent foil c) **blue** transparent foil





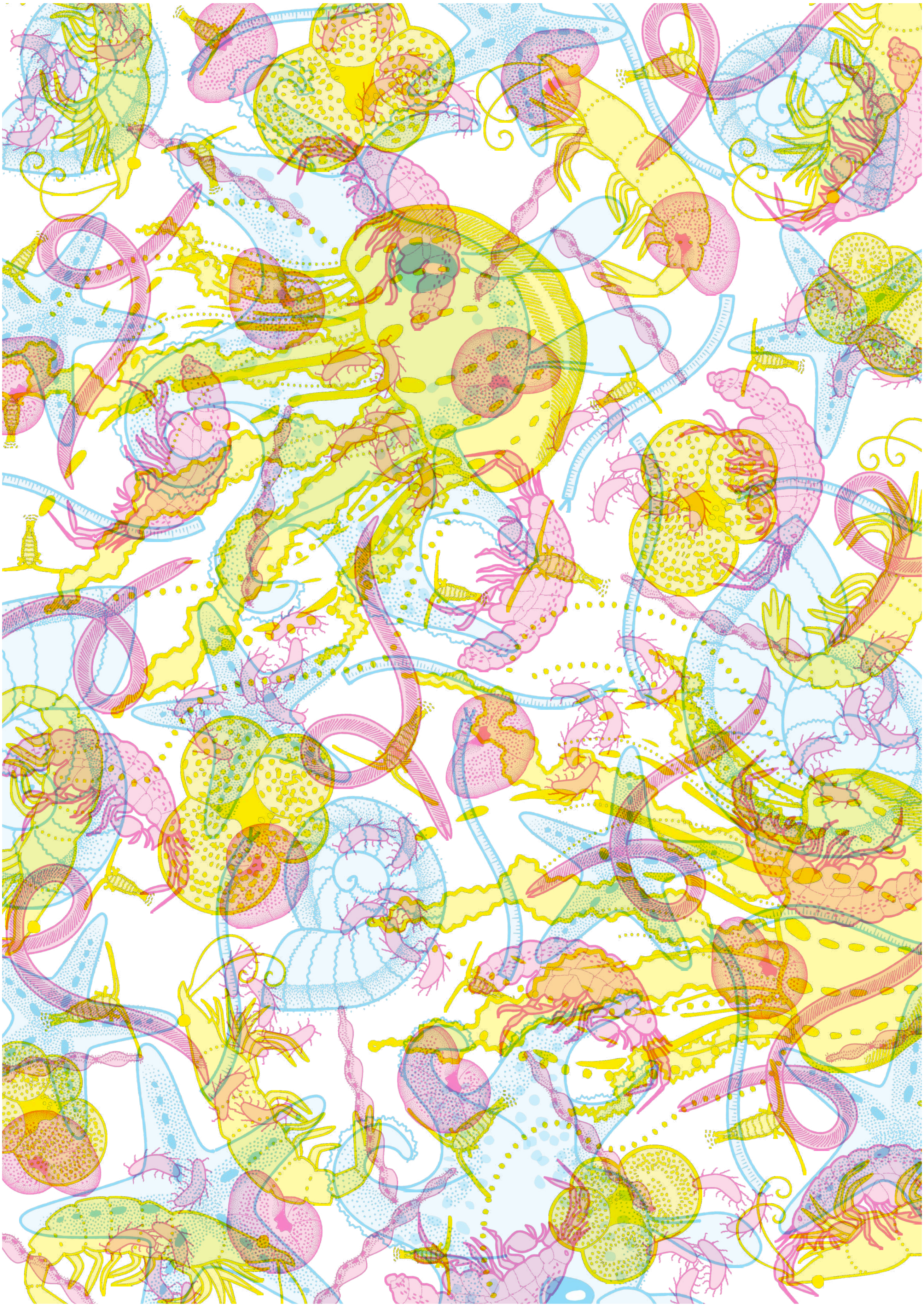
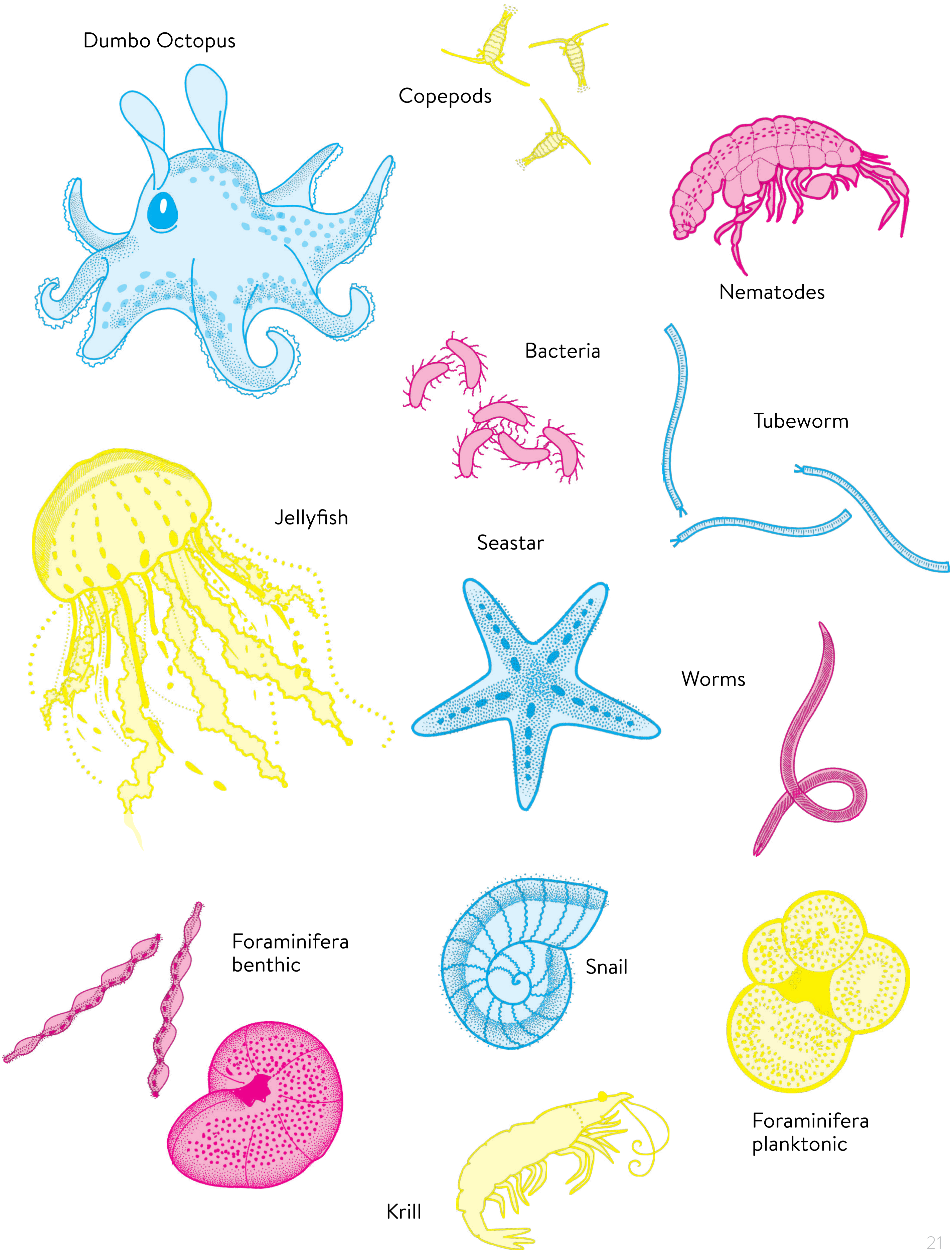


Illustration of marine organisms as explained in the text of this activity. By Heike Jane Zimmermann www.miucreative.com


Dumbo Octopus
Copepods
Nematodes
Bacteria
Tubeworm
Jellyfish
Seastar
Worms
Foraminifera
benthic
Snail
Foraminifera
planktonic
Krill

Activity Sheet

List the names of the lifeforms you see when you hold the different colored transparent foils in front of your eyes.

Use the “List of different lifeforms” (on page 8) to help.

Using red filter	Using green filter	Using blue filter

Activity 2:

FINDING THE FISHES

The pupils start by making goggles using the blue transparent foil. Then they can draw (on red paper) their own deep-sea animal shapes, for instance, fish, crabs, octopus, or shrimp. Simple animal shapes are likely best since you want as many as possible. Once the shapes are cut out, then you can place them all over the classroom including on the walls and the floor. **You might divide the class into two groups,** where one group places their animals around while the other group waits outside. Turn off the light and close any curtains, so the room is dimly lit (not completely dark, leave enough light to walk around safely). The effect of color filtration works best if the figures are posted on dark/non-white areas within the room.

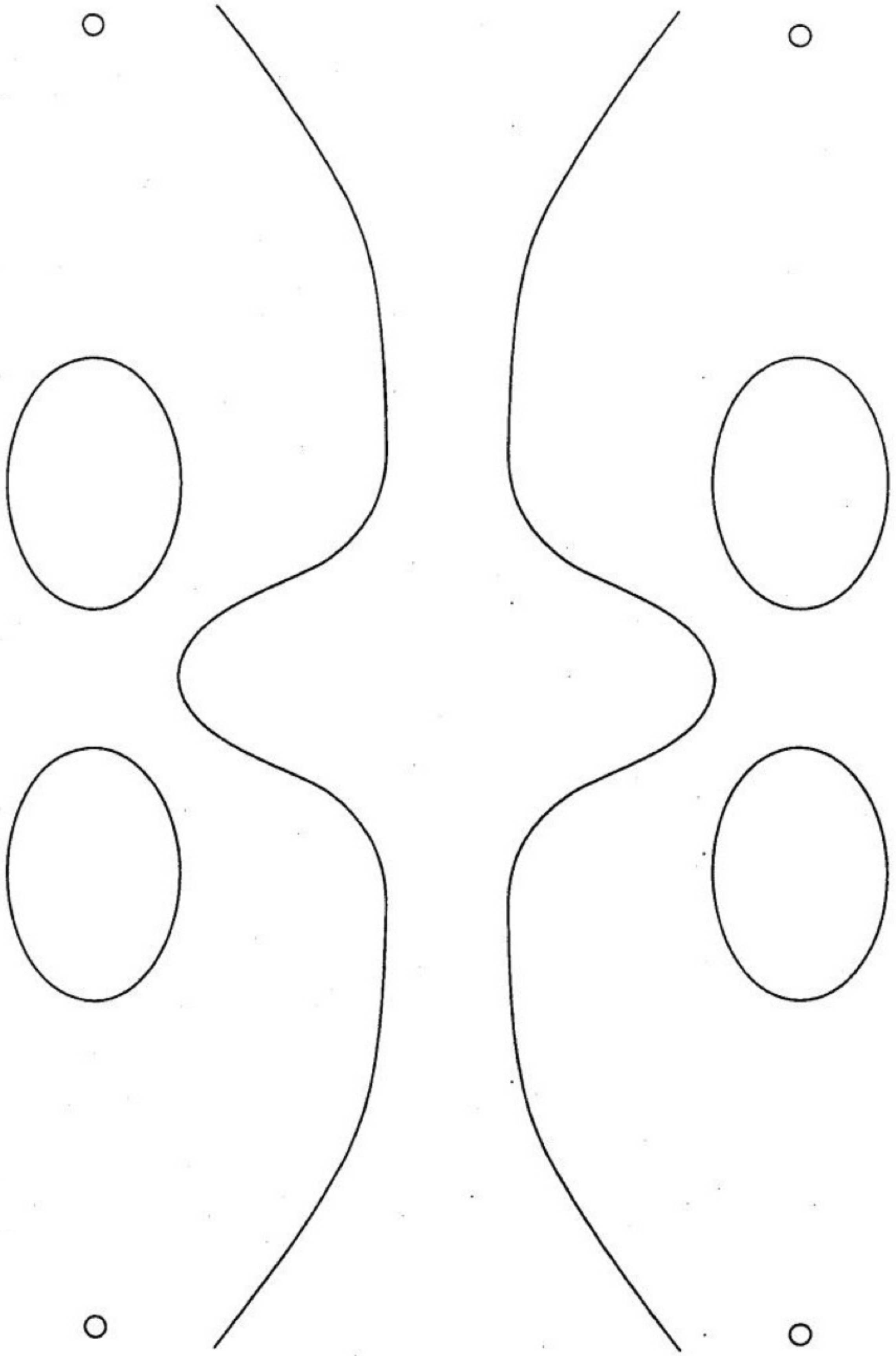
The group of pupils outside can put on the blue filter goggles, and then they enter the room to search for the fishes and creatures in an orderly manner (for example, all walk in a circle around the room).

As the classroom now simulates the ocean floor, it must be QUIET. The pupils can for instance get points based on the number of fish/shellfish they find. If pupils are wearing goggles, we could say they are scuba divers. Scuba divers work in pairs, so pupils work with their "dive buddies" to spot animals. Also, scuba divers cannot speak to each other since they are underwater. [EXTRA: you might consider extending this activity to learn the different hand signals that scuba divers use to communicate:
https://blog.padi.com/marine-life-hand-signals-for-underwater-communication/

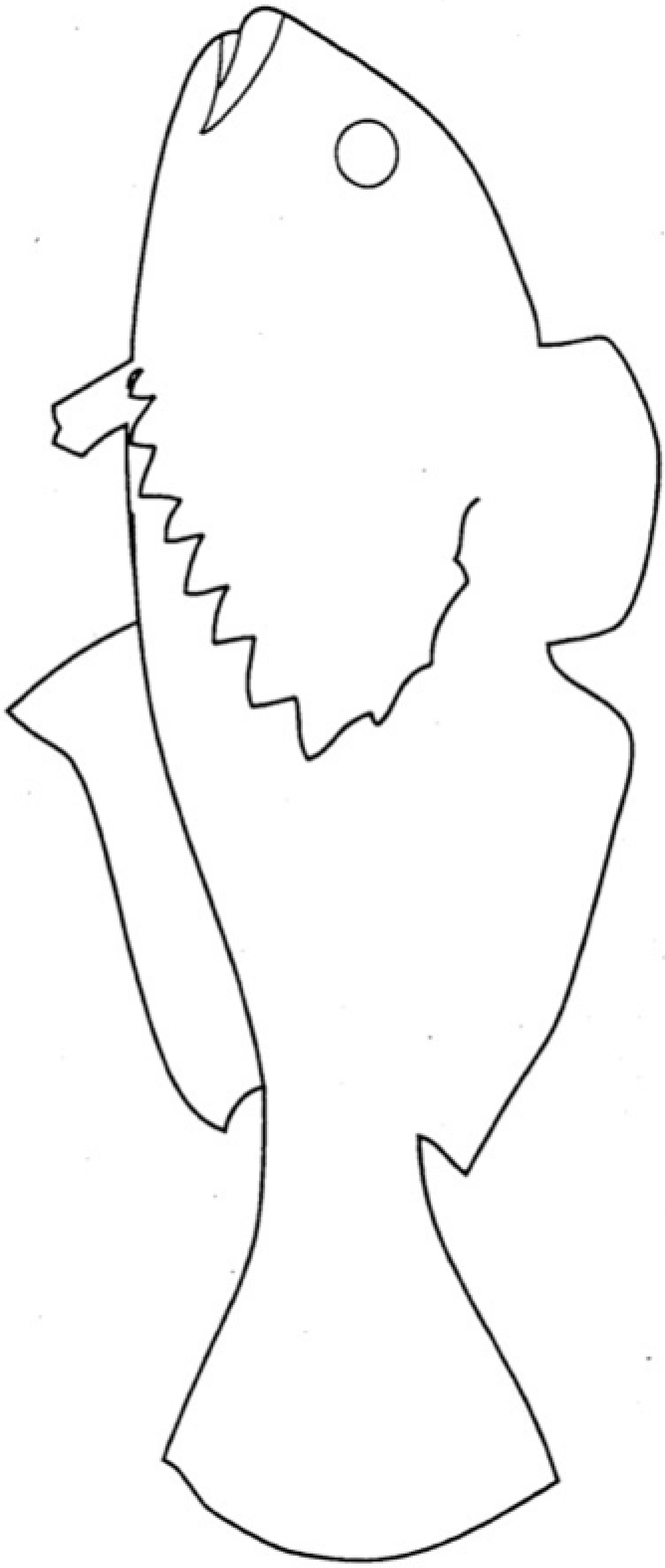
After the "dive", let the pupils count their findings and write them down. They can discuss which of the animals were the easiest and hardest to find and have fun identifying what type of animals the different cut-outs represent.

As light travels down through the ocean, the red light is filtered out first. Blue light travels deepest in the ocean. Even in the deep sea, where it is completely dark, some animals make their own light. Many deep-sea animals have red colors on their skin to be invisible to predators, or sometimes also because they are predators themselves.

This activity also simulates the darkness of the deep sea. How many animals can your pupils find?



Template for the googles to be cut



Template of a fish to be cut

SMELL

LIFE FROM BAD SMELLS

Focus:

To understand that hydrogen sulphide indicates that there is life at the bottom of the deep-sea.

Learning objectives:

With this activity, we create a nasty smell similar to hydrogen sulphide from rotting organic matter. We use that smell as a foundation for a discussion/lesson on interesting life, animals and food webs from the deep sea floor.

Key words:

Deep-sea, hydrogen sulphide, chemosynthesis, nematodes, tube worms, food webs.

This specific lesson plan was developed in a close collaboration with:
Mathew Stiller-Reeve, Erling Rosnes, Mari Eiliertsen, Sofia Ramalho, Victor Poddevin and Giuliana Panieri.

Edited by: *Giuliana Panieri and Mathew Stiller-Reeve*
Layout and Graphics: *Heike Jane Zimmermann*

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IN SHORT (FOR THE TEACHER):

The class will produce a smell like a hydrogen sulphide by rotting some organic matter in a bottle (basically like making compost), which will take a couple of weeks. They will smell the resulting odor. You can use the experience of this smell to frame a lesson/discussion about creatures at the bottom of the sea using the background information and the photo resources below.

Materials:

The total amount of materials will depend on whether pupils will work individually, in pairs or larger groups. Each group should have:

- A large plastic soda bottle.
- Leaves or grass cuttings (or other organic waste)
- Soil and sand.
- A large balloon.
- The teacher will have one bottle as a control with nothing inside and a balloon on top.

Audio/visual materials:

PowerPoint slides from AKMA to help tell the story of the animals introduced in the background story below.

Teaching Time:

- 30 minutes for the pupils to fill their bottles (if they go outside and look in nature/parks/fields themselves).

- 30-45 minutes (1-2 weeks later) for the pupils to smell the gas (OUTSIDE!) and then to tell the story of the animal communities that are dependent on hydrogen sulphide. The teacher can use much more time if there are other elements of the curriculum that connect to this story.

Classroom organization:

One suggestion is to have groups of 2-3 to fill the bottles. Normal discussion format for the follow-up lesson/discussion.

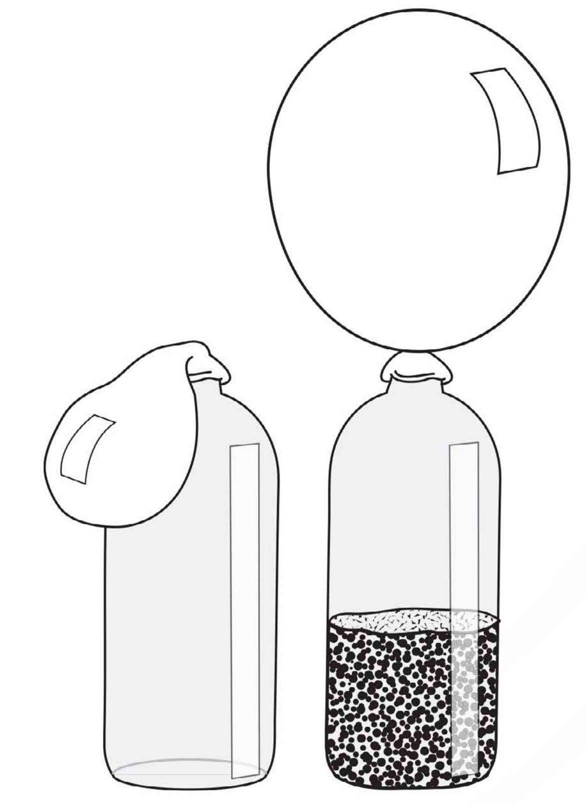
Practical:

Cover the top of one empty bottle with a balloon. This container will be the "control" of the experiment.

Fill second bottle 1/3 with plant pieces (torn into pieces). Drop sand and soil on top of plant pieces to create a thin layer. Cover top with balloon. You can also get the pupils to fill more bottles with different organic and food waste, but make sure you label the bottles clearly. It can be interesting to compare the different amounts of gas that are emitted from the different decomposition processes. Place the bottles in a warm sunny location for 1 week or more. Have pupils observe and compare any gas collection in balloons. Discuss their observations and ideas. Do all the balloons fill up, or do some deflate further?

With the filled balloons, go outside. Make sure the pupils let out a small amount of gas at a time and smell lightly. Ask your pupils what the smell reminds them of.

Tell them that the chemical in the smell is an important part of processes that support life in some extreme locations on the planet: at the bottom of the deep-sea!



BACKGROUND STORY:

This background story gives you, the teacher, interesting information to link the deep-sea to the smell your pupils have made in the bottles. Most of the information comes from Dr. Sofia Ramalho (University of Aveiro) and Dr. Mari Eilertsen (University of Bergen) whilst on board the AKMA Ocean Senses expedition.

Life on Earth is most often dependent on the energy from the sun. This energy is first captured via photosynthesis, and then distributed to others in the ecosystem via food webs. In the deep ocean, where light does not penetrate, life is built on different sources of energy.

At the bottom of the deep sea, there are many places where methane gas bubbles up into the sea water. This methane does not smell of anything. However, we can find bacteria on the sea floor which eat this methane.

When the bacteria eat the methane, a chemical reaction happens, and the methane is converted into ENERGY and hydrogen sulphide (and a couple of other chemicals). This process is like photosynthesis, but it is called

CHEMOSYNTHESIS, since the energy comes from a chemical rather than the sun light. The bacteria use the energy to live and grow, and the hydrogen sulphide (H2S) is a waste product.

Just like waste products we are used to on land, hydrogen sulphide (H2S) smells of sewers and rotting organic matter. It's stinky, but this stink means that life is being supported!

Even though H2S is poisonous for most animals, bacteria can carry out chemosynthesis and live in areas where the H2S builds up. The bacteria are often whitish or blueish and can gather to create what we call "bacterial mats" on the sea- floor.

Example of bacterial mats found at the sea floor in the Arctic Ocean. (Image: AKMA)

The bacteria grow and are what we call organic. This means that other things can eat them. Most of the time they are quite safe since they live in patches that are poisonous to other animals (because of the H_2S). However, some small animals manage to roam around on the bacterial mats and feed off the bacteria that live there.

One such animal is a Halomonhystera which is a type of roundworm known as NEMATODE. This nematode can eat the bacteria and is not affected by the poisonous H_2S. But its babies are not safe. They are not hardened to cope with the poison, and if they were on the bacterial mat they would die. To protect the babies, the mother Halomonhystera hatches the eggs inside her, and let's the babies grow until they are old enough and tough enough. Then the mother dies and the young Halomonhystera that are left escape and continue to live safely on the bacterial mats.

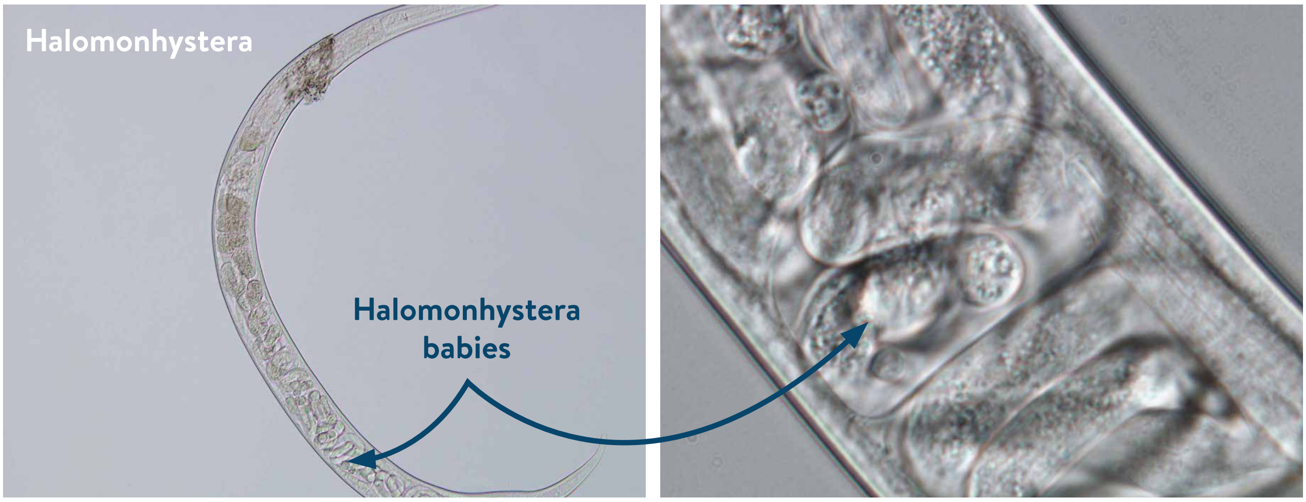


Image left: A Halomonhystera worm with babies nestled inside. Image right: A close of the baby Halomonhystera babies.

There are many other animals that live on or close to the bacterial mats and near to the smell of H2S. Very often, we find “forests” of worms close to the bacterial mats. These “forests” look like bushy coverings and are full of tube worms. Usually, they cannot stand the poisonous H2S, but they need to live nearby to find food. One such tube worm is a Oligobrachia who has an interesting collaboration with bacteria.

A «worm forest» of Oligobrachia at the bottom of the Arctic Sea near Svalbard. The white strands are the tubes that the worms have built that
they live inside (Image: AKMA, University of Tromsø, Havforskningsinstituttet)

Oligobrachia are a type of worm called a tube worm. An Oligobrachia lives in a hard tube the sticks up from the sea floor which it makes itself using a hard substance called chitin. We do not fully know what Oligobrachia eats. But we do know that bacteria live inside them. These bacteria eat the hydrogen sulphide that other bacteria have excreted, so they can grow. It is likely the Oligobrachia “eats” what the bacteria excrete, then they eat the bacteria themselves. All-in-all the bacteria need a tube worm to survive, and the tube worm need the bacteria to survive. A collaboration like this is what we call SYMBIOSIS.

Discussion:

We know a lot about the food webs on the Earth’s surface, but we still have much to discover about food webs at the bottom of the deep-sea (over 1500m deep). When researchers like Mari and Sofia don’t know for sure, they make hypotheses and test them. Maybe you and your class can make some hypotheses for the following questions:

- What other animals do you think are part of this “food web”?
- How do you think this “food web” can influence what we eat at the surface? Think about fish moving up and down in the water column....

The animals/organisms we have discussed on this lesson are small and can differ from sea to sea. We still have a lot to learn about these organisms and how they behave. However, we know one thing for sure. The lives of these creatures are intrinsically connected to chemicals that smell really bad for us humans on the Earth’s surface. Life from bad smells!

SOUND

LISTEN TO THE WORLD AROUND US

Focus:

To take time to identify and recognize the sounds in the spaces around us.

Learning objectives:

With this activity, we will draw attention to our surrounding environment through listening. This can function as a stand-alone activity. However, you can also use it as a starting point before transferring the experience to deep- sea environments in the activity called "Cold Seeps Symphony".

Key words:

Spatial awareness, listening, sound walk, noise pollution.

This specific lesson plan was developed in a close collaboration with:
Lisa Katrin Losleben, Monica Clerici, Villads Dyrved Holm and Giuliana Panieri.

Edited by: *Giuliana Panieri and Mathew Stiller-Reeve*
Layout and Graphics: *Heike Jane Zimmermann*

Losleben, L. K., Clerici, M., Holm, V. D., & Panieri, G. (2023). Listen to the world around us. In G. Panieri & M. Stiller-Reeve (Eds.), The Ocean Senses Activity Book (pp. 35-39). Septentrio Educational, 2023(1). https://doi.org/10.7557/8.7050

IN SHORT (FOR THE TEACHER):

This is an activity to make pupils more aware of the environments around them through active listening. The pupils can work alone or in pairs. They will spend time in an area and write notes on what they hear.

You will need to investigate and plan which areas the pupils should spend time in before. You can also prepare the pupils by talking about sound and issues like noise pollution. This activity will act as a foundation before the pupils can progress to other activities with sounds and narratives from the deep-sea (see Activity: Cold Seeps Symphony).

Materials:

Each pupil needs:
- A pen/pencil.
- Paper/notebook or the worksheet provided on page 5.

Teaching Time:

90 minutes (estimated) depending on the location where the pupils will listen.

Classroom organization:

Let the pupils work individually or in pairs for the listening exercise. Standard discussion format for the follow-up lesson/discussion in the classroom.

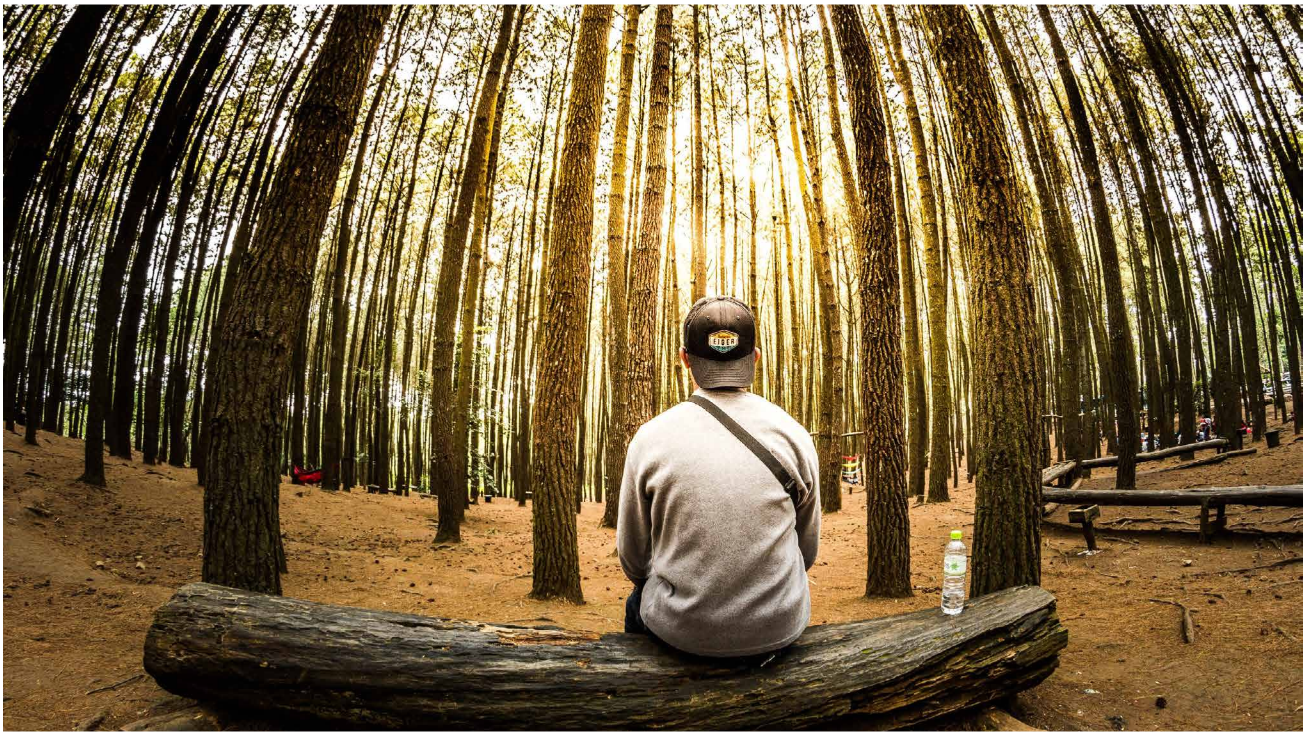
Location:

Somewhere outdoors. This could be near the school or further afield. The activity could be carried out in different locations and the pupils could discuss the differences in what they hear.

BACKGROUND STORY:

Actively listening to the world around you can sometimes be called a “soundwalk”. A soundwalk is an “embodied method of personally connecting with the soundscape through focused listening while physically moving through space” (Polli 2021).

This method was developed by Hildegard Westerkamp and has inspired further adaptions (such as “sound sittings”). These activities can be done in any environment, both on school property and in other locations around the school or further afield.



A person sitting on a log, contemplating the forest in front. Illustration to inspire listening outdoors in a forest if you have one nearby (Rangga Aditya Armien/Pexels)

Learning procedure:

Pupils will start by exploring the chosen area. They will find a place to sit down undistracted by other pupils or groups. They will then spend much time quietly listening to all the sounds they hear. The area could be one of the following:

- The school playground
- A woodland
- A town park
- A bus station
- A beach
- A shopping mall

The pupils should work alone or in pairs. Once they have sat and listened, they should make notes and answer some of these questions (see worksheet on next page, which could be printed for them to use):

- What sounds do you hear?
- What is the loudest sound?
- What sound is closest to you?
- What non-human sounds do you hear?
- What sounds are human-made?
- Which sounds are moving and not moving?

Discussion:

Use these questions to structure the classroom discussion afterwards. With the whole class, map all the sounds everyone has heard in each environment/area. Were there sounds that only some pupils heard? Were there sounds that were difficult to identify? Did the pupils hear more than they may have previously realised?

Another way to round off this activity is for the pupils to write a short essay describing the experience, what they heard and whether they considered some of the sounds as noise pollution.

Reference:
Polli, A. (2021). Witnessing Space. In The Oxford Handbook of Sound Art, ed. by Jane Grant, John Matthias, and David Prior.
DOI: 10.1093/oxfordhb/9780190274054.013.1

Describe the area you are in:

What sounds do you hear?

What is the loudest sound?

What sound is closest to you?

What sound is furthest away?

What non-human sounds do you hear?

What sounds are human-made?

Which sounds are moving and not moving?

COLD SEEPS SYMPHONY

Focus:

To listen to the Arctic Ocean's sounds and to learn about the Arctic Ocean's biodiversity, particularly near cold seeps. We will experiment with creating new sound expressions inspired by the Ocean. For pupils with hearing impairment, pupils can create a bodily expression of this and/or use instruments they are comfortable with.

Learning objectives:

With this activity pupils will start to understand:

- the multitude of sounds audible in the Ocean and near to cold seeps at the sea-bed.
- That the oceans, including the Arctic Ocean, harbors great biodiversity.
- What an oceanographic ship is, and the anthropic sounds related to it.

Key words:

Ocean research, exploration, human/non-human relationship within ocean, sounds, place, noise.

This specific lesson plan was developed in a close collaboration with:
Lisa Katrin Losleben, Monica Clerici, Villads Dyrved Holm and Giuliana Panieri. All the sounds in the narrative (except the wave sound) were recorded on board the MS Kronprins Håkon in May 2022; The ship's horn was simulated with an instrument by Flavio Fulchi.

Edited by: *Giuliana Panieri and Mathew Stiller-Reeve*
Layout and Graphics: *Heike Jane Zimmermann*

Losleben, L.K., Clerici, M., Holm, V.D., & Panieri, G. (2023). Cold seeps symphony. In G. Panieri & M. Stiller-Reeve (Eds.), The Ocean Senses Activity Book (pp. 40-46). Septentrio Educational, 2023(1). https://doi.org/10.7557/8.7051

IN SHORT (FOR THE TEACHER):

This is an activity in which pupils will construct their own instruments and use them to mimic the sounds they hear in the accompanying sound and narrative recordings from the Arctic Ocean.

The aim is for the pupils to better understand ocean research, but also human and non-human sounds and relationships within the ocean. Through the discussion afterwards, you should focus on what the pupils feel when hearing (and recreating) the sounds from the bottom of the Arctic Ocean. They can also discuss the importance of preserving the biodiversity we find there.

Materials:

For teachers:

- Background Information about fauna on the sea floor and near cold seeps https://akma-project.com or find on https://en.uit.no/project/akma from summer 2023)
- The sound file of the narrative to accompany the activity (see accompanying sound file).
- Instructions on how to build the recycled instruments that the pupils will play as they follow the sound file of the narrative.

For pupils (SEE PAGES 5-7):

- Instructions on how to build recycled instruments able to follow the narrative. For the instruments, you will need the following (exact quantities depend on the number of children in the class):
  - Shaker/wave sound: cardboard cylinder, rice, plastic, or aluminium cover.
  - Empty water bottle/ship's signal horn: empty glass water bottle or a metal flask.
  - Castanets/clicking signals: cardboard, metal bottle caps.
  - In general, for building and decor: glue, tape, scissors, paint, pencils, and brushes.

Teaching Time (estimated):

60 min. Instrument building, although more time can be spent drawing, designing, and decorating the instruments.
60 min. Listening and playing instruments + discussion with the teacher.

Class organization:

The class should be split into 3 groups corresponding to the three different instruments. The teacher can decide how to arrange the activity if other instruments or modes of expression are included in the activity.

BACKGROUND STORY:

The Arctic Ocean is among the most remote and least known environments on our planet, yet. Like most environments, the Arctic Ocean is already threatened by human activities, such as litter deposition, increased CO2 emissions, and noise pollution from marine traffic and natural resource exploitation. Through sound and music, we can develop a closer connection to and greater respect for these oceanic environments.

A vast variety of species live in and around the Arctic Ocean. Seabirds and marine mammals like polar bears, seals and whales are usually the first that come to mind. However, under the surface of this magnificent ocean, we find the homes of thousands of different species. Also, the seafloor is chemically active, and we find methane bubbling up in the Arctic Ocean (cold seeps). Bacteria that can process methane and related substances, allow the formation of carbonate crusts. These solid structures also support great biodiversity.

Learning procedure:

The sound file provided with this activity is a soundscape that was created on the actual AKMA scientific expedition through the Arctic Ocean in May 2022. Your pupils will first get the opportunity to construct self-made instruments. These instruments can mimic sounds in the soundscape.

You will first divide the class into different groups. In each group, each participant will create a certain type of instrument, although pupils can also work in pairs. You can print out the instructions on the following pages to help the pupils through the process. You, the teacher, will guide the pupils in building the instruments while giving them information about what sound they will mimic. Or ask them what sounds they think their instrument will make. And get them to think about what sounds like their instruments in nature and the ocean.

Once the instruments are complete, you can play the sound- file/soundscape. you can choose whether to read the narrative themselves (script starts on page 8) or to use the soundtrack with the narrative already incorporated. The script is a guide highlighting when the pupils should play their instruments.

Once the "symphony" is over, you and your pupils can discuss what they experienced, their emotions and what they understood from the soundscape. The main topic discussed should be the importance of understanding and preserving this biodiversity, and how sounds can be heard even at the bottom of the Arctic Ocean.

Use the following questions to structure the classroom discussion afterwards

- How can you hear when you are below water?
- Do you think that animals can hear the same as us?
- How do you think scientists' study what's on the seafloor?
- How is it possible to record sounds under the sea?

Instrument 1: SHAKER/WAVE SOUNDS MATERIALS:

Example of cardbord cylinders (e.g., empty chips can)

- Cardboard cylinder (e.g., empty chips can)
- Plastic lid or baking paper and an elastic to close the end of the tube
- Rice or beans
- Paint, brushes, pencils, glue, and marine themed decors

Building the instrument:

- Take an empty Pringles container, or a cardboard cylinder, and cover the outer surface with paper or masking tape. On this, you can paint or draw ocean motifs. You can also attach marine themed decorations;
- Insert a handful of rice or dried beans into the container, and seal it;
- Ensure the cap fits tightly and securely. If not, you can substitute the lid with some baking paper attached to the top with an elastic band and/or tape;
- Different beans, rice, and pulses make different sounds, so experiment with different contents!

Instrument 2:

EMPTY WATER BOTTLE/SHIP'S SIGNAL HORN MATERIALS:

- Empty glass water bottle or flask. NB: Make sure the opening at the top is not too big so that it makes a sound when you blow across the top. Bottles with larger openings can be gently hit with a piece of foam to make a sound.
- Glass paints,
- Paint brushes,
- Pen (permanent markers to draw on the glass bottle),
- Glue, and
- Marine themed decors to decorate your bottle.
- Water to fill your bottle to various levels.
- Pieces of foam to gently hit the top of the bottle if necessary.

A child holding an empty transparent bottle

Building the instrument:

- Decorate your bottle with paint and marine themed decorations;
- Depending on how full the bottle is, the instrument will play a different sound, when you blow across the opening, or gently hit the top with a piece of foam;
- You can leave the bottle empty for a very deep and strong sound, or you can experiment with different water levels in your bottle to make a different pitch.

Instrument 3:

CASTANETS/CLICKING SOUNDS MATERIALS:

For each castanet, you will need:

- Cardboard to cut into a strip the width of a bottle top.
- 2 metal bottle tops. These need to be slightly flattened so they stick to the cardboard (see the image below). Ask your teacher if you are allowed to flatten them yourselves.
- Glue
- Paint, brushes, pencils and marine themed decors to decorate the castanet.

Building the instrument:

- Cut out a rectangular piece of cardboard as wide as the bottle tops and long enough to be folded in two like a duck's beak;
- Stick two bottle tops at the end of "beak" with the glue, so that they hit each other when the cardboard is squeezed;
- Decorate the castanets with paint, pencils, and marine themed elements!

Example of castanets madewith bottle tops and cardbord

FOR THE TEACHER:

It's up to you, the teacher, to choose either the soundtrack/ soundscape with an already integrated voiceover of the narrative, or to read the narrative yourself. Either way, we suggest that you previously listen to the soundtrack in its entirety to have a better picture of the task for the pupils.

The following narrative also indicates when the pupils can/should play their instruments. Feel free to add musical intervention from pupils at other times too.

THE NARRATIVE (SPOKEN WORDS IN THE SOUND FILE):

As you see the Ocean from above, what you may perceive is a vast blue spot covered in waves. But is it really only that? Come with us on a journey to discover the beauty of one of the most alien elements on our planet.

We start our adventure leaving the seashore of Longyearbyen, from the Svalbard archipelago, the last human-populated frontier before the north pole. The ship we are onboard now is an oceanographic ship, fundamental transportation for marine scientists. The ship is filled with advanced instruments capable of doing unimaginable things, and to take us on an adventure. What you can hear is the sound of waves gently breaking on the shore (PUPILS MAY USE INSTRUMENT 1). Once left behind us the snowy coasts of Svalbard we rapidly take the open sea in search of the wonders of the marine environment.

Can you hear it? (PUPILS MAY USE INSTRUMENT 1 and 2) the sound of the waves still keeps us company, but something more is coming... (PUPILS MAY USE INSTRUMENT 2) We are welcoming ourselves into this blue blanket that is going to carry us for the next days.

Reference:
https://zinginstruments.com/homemade-musical-instruments

We let the sound of the ship prevail in our sleep while we are rocked by the waves (PUPILS MAY USE INSTRUMENT 1). But in the middle of the night something strange happens, (PUPILS MAY USE INSTRUMENT 1 MORE VIGOROUSLY) you hear an increasing crackling sound... something strange that you've never listened before. We jump down the bed and run to the porthole of our cabin, look! Ice! We are surrounded by a breath- taking white expanse of snow and ice! You can hear the boat crackling, scratching, and cutting through meter-thick, teal ice floes.

Once we reach a solid spot, we decide to explore more the unknown corners of this incredible environment. We can hear our footsteps get caught in the snow, the iced wind blowing through our ears and something else... an incredible whiteness all around us. You may think that this place resembles some iced planet lost in an unknown galaxy. But in reality, it has had its hands in life much more than you might think...

We deploy our hydrophone, an instrument marine scientists use to record sounds meandering from the ocean. While the microphone enters the water you can start hearing the muffled sounds of the ship and our voices getting more and more distant. And suddenly (PUPILS MAY USE INSTRUMENT 2 & 3) the magic happens, you hear whistling, giggling, and clicking cetacean sounds. These could be dolphins, whales, belugas and much more!
What a wonderful surprise!

While we continue our journey into the heart of the abyss, the environment becomes darker and darker until no glimpse of the light can be found. But this darkness isn't scary or intimidating, because if you can listen closely, you get more familiar with the sounds meter after meter (PUPILS MAY USE INSTRUMENTS 1, 2 & 3). We might even encounter the sound of popping bubbles from methane sources. Bacteria that can process this substance allow the formation of carbonate crusts, a hard surface that allows the presence of a wonderful biodiversity: from tubeworms, snails, microbes, shrimp that rely on processes able to transform these substances in nutrients for themselves instead of using the sun. Anemones whose tentacles vibrate in water streams, starfishes that follow the same flow, and octopuses that want to participate in this joyful dance. You may also hear Skates gently caressing the seafloor and fishes darting in these magical waters. Can you imagine what this symphony of ocean life might sound like?

What a wonderful ride has been this concert of ocean sounds! We slowly come back to the surface more conscious of the beauty and biodiversity of the ocean, how something that was just a blanket has become a place of life, width and sounds? (FROM HERE THE TEACHER WILL OPEN THE DISCUSSION WITH THE PUPILS)

FORAMINIFERA BOOGIE

Focus:

To learn about foraminifera through practicing and presenting the song "The Foraminifera Boogie". Pupils and teachers can also decide to play instruments along with the recorded soundtrack.

Learning objectives:

In this activity, pupils will practice listening to one another and the music. They will learn lyrics and use their voices to sing the song. This can be combined with playing actual musical instruments or using instruments the pupils have made themselves (for example see the activity "Cold Seeps Symphony"). This activity brings together music with the scientific story of the Foraminifera.

Key words:

Ocean, researchers, little known beings in the Arctic Ocean, co-living of humans and non-human beings, planetary time.

This specific lesson plan was developed in a close collaboration with:
Villads Dyrved Holm, Lisa Katrin Losleben, Heike Jane Zimmermann, Monica Clerici, Giuliana Panieri. and many others in the AKMA Ocean Senses team, and not least the wonderful childrens choir.

Edited by: Giuliana Panieri and Mathew Stiller-Reeve
Layout and Graphics: Heike Jane Zimmermann

Holm, V.D., Losleben, L.K., Zimmermann, H.J., Clerici, M., & Panieri, G. (2023). Foraminifera boogie. In G. Panieri & M. Stiller-Reeve (Eds.), The Ocean Senses Activity Book (pp. 47-51). Septentrio Educational, 2023(1). https://doi.org/10.7557/8.7052

IN SHORT (FOR THE TEACHER):

In this activity, you and your class will listen to and learn a song about foraminifera. The song is fun to learn and contains fun characters and interesting information. The goal is to learn the song and then perform it (possibly also with other instruments if you decide).

Materials:

- Song texts (see page 5) printed for each of your pupils.
- A reasonable sound system to play the music recordings through.
- Other instruments, if possible. One can also use the instruments pupils may have made in the activity “Cold Seeps Symphony”.

Teaching Time (estimated):

Recordings of the song are available via the AKMA website (https://akma-project.com/fauna-catalogue or find on https://en.uit.no/project/akma from summer 2023). One version is with a children’s choir, and the other version is instrumental.

Class organization:

One suggestion is to get your pupils to work in pairs to learn the song text and then bring the whole class together to perform.

EXTRA:
A performance of the song by children from the international school in Tromsø can be viewed at the following link:
https://www.youtube.com/watch?v=XSiAQFrjbTo
A karaoke version is available at the following link:
https://www.youtube.com/watch?v=ltyfL2XaNXA

BACKGROUND STORY:

Foraminifera are single-celled organisms living on the ocean floor. Their history reaches back approximately 500 million years. They build their shells from the minerals in the oceans. By analyzing these shells, we can get information about the climate of the past.

This song may help your pupils imagine themselves as a researcher who dives deep in the ocean to learn more about foraminifera and the climate of the past. Your pupils may also consider new perspectives about planetary time. In the song, we get to know two foraminifera, called Nina and Berry, who understand humankind as a rather new phenomenon on Earth.

Foraminifera are not only fascinating subjects to learn about, but they are a useful starting point for discussions on planetary time and ocean literacy. The learning activity also increases awareness about ocean creatures that are small, manifold, and beautiful.

Example of foraminifera shells. (Image: Smithsonian https://ocean.si.edu/ocean- life/plankton/foraminifera)

Learning procedure:

Although this activity can work as a stand-alone activity, we recommend you first look at “Cold Seeps Symphony”. That activity will give the pupils some nice background information and handmade instruments they can also use here.

For this activity, let your pupils listen to the song’s recording first. You can print out the song lyrics (see next page) for them to read and learn. They can then try singing the song with the recording of the children’s choir.

The final goal is to perform the song with the instrumental backing track and maybe with other instruments the pupils play or have made in other activities.

Discussion points:

Foraminifera are ancient species which have persisted through time, but few people know about them. They not only captivate our imagination through their beauty and fragility, but they can also tell us concrete details about how the climate was in the past.

After practising and performing the “Foraminifera Boogie”, consider discussing the following questions:

- What are the main things we learnt about foraminifera in this song?
- What more would you like to know about foraminifera?
- Use your imagination: What might foraminifera in the oceans today think about humans?

FORAMINIFERA BOOGIE

Berry keeps its feet on the bottom of the sea
Nina is planktonic, floating and free
Use a microscope or squint your eyes
They're very very small, and look very nice

Foraminifera can teach us a lot
If the ocean was cold, salty or hot
Listen very carefully, hear what they say
Learn how the past is connected to today

They're older than the dinosaurs, older than us
You can find them in the oceans, the beach and the rocks
forams carry history, unveiling lots of mystery
chemistry, biology, micropaleontology!

Foraminifera can teach us a lot
If the ocean was cold, salty or hot
Listen very carefully, hear what they say
Learn how the past is connected to today

If you want adventure curiosity is key
Swim along the currents to the Arctic sea
dive down deeper to the coldest seep
look at all the secrets these environments keep

Foraminifera can teach us a lot
If the ocean was cold, salty or hot
Listen very carefully, hear what they say
Learn how the past is connected to today

Illustrations by Heike Jane Zimmermann (www.pixiepencil.com)

TASTE

OCEAN SENSES
– TASTE –

A JOURNEY TO A COLD SEEP

How scientists study methane in the arctic ocean: A paired teaching lesson plan

Focus:
Where are and what happens at cold seeps and how scientists study them.

Learning objectives:
After this lesson, students should be able to:

1. Relate different datasets by observing and describing scientific maps
2. Differentiate between carbon dioxide and methane gas
3. Clarify misconceptions about greenhouse gas
4. Explain what cold seeps are and why most gas/methane hydrates occur at continental margins
5. Describe some of the methods scientists use to locate and study methane/gas hydrates

Prerequisites:
Prior to this lesson, students should be familiar with understanding maps, molecular structure and bonding, and the greenhouse effect and gases.

Key words:
Arctic Ocean, Methane, Carbon Dioxide, Gas Hydrate, Cold Seep, Greenhouse Gases.

This specific lesson plan was developed in a close collaboration with:
Solmaz Mohadjer, Vibeke Aune, Giuliana Panieri and Davide Oddone.

Edited by: *Giuliana Panieri and Mathew Stiller-Reeve*
Layout and Graphics: *Heike Jane Zimmermann*

Mohadjer, S., Aune, V., Panieri, G., & Oddone, D. (2023). A journey to a cold seep. In G. Panieri & M. Stiller-Reeve (Eds.), The Ocean Senses Activity Book (pp. 53-69). Septentrio Educational, 2023(1). https://doi.org/10.7557/8.7053

IN SHORT (FOR THE TEACHER):

This video lesson contains 4 video segments and 3 classroom activities in between the segments. During the classroom activities, students will

1. Discuss the differences and similarities between two greenhouse gases (methane and carbon dioxide).
2. Use scientific maps to observe and describe what they see.
3. Explain their scientific map to others and relate different maps to answer questions about where most gas hydrates locate and why.

The teacher can play the video segments and extra footage and photographs provided in the supplemental material to engage and prepare the students for the classroom activities, and to introduce them to some of the tool's scientists use to study cold seeps in the ocean.

Materials:

3 Maps for Activity #2 and #3. Print maps in colour, preferably of the size 60x90 cm. The maps should be printed at the same scale with legends clearly shown. Uniformity of the map scale makes it easy for students to compare data from map to map. The PDFs of these maps are included at the end of the lesson package (pages 15-17). You can also find them here:

Map 1: https://plateboundary.rice.edu/DPB_map_gifs/topo.grad.50percent.gif

Map 2: https://doi.org/10.1016/j.dsr.2004.06.014

Map 3: https://www.usgs.gov/media/images/map-gas-hydrates

Optional: Molecular modeling kit for Activity 1 (alternatively use modeling clay and straws to construct the methane and carbon dioxide models).

Extra imagery and video footage of the seafloor and the Remotely Operated Vehicle (ROV) sampling – These files are included in the lesson package, and available at: https://akma- project.com or from summer 2023 at https://en.uit.no/project/akma

Visual/audio materials:

This is a video lesson. You will need audio-visual equipment (and internet connection if you plan to stream the video). About 20 minutes of the class time is covered by the video-scientist and teacher. At the end of the last segment, we have included a teacher's guide to the classroom activities. We encourage teachers watching this segment prior to using this video lesson. The teacher's guide is about 7 minutes. In addition, there are extra video footage including videos of the seafloor and an ROV (a remotely operated underwater vehicle) sampling available at: https://akma- project.com or from summer 2023 at https://en.uit.no/project/akma

Teaching time:

The video lesson takes about 60 minutes. This includes 20 minutes of video segments taught by the video- scientist and teacher plus 40 minutes of classroom activities facilitated by the in-class teacher.

VIDEO accompanying this lesson plan: https://youtu.be/k0awmdQQITA

BACKGROUND STORY:

This section is intended to be read by those interested in using this video lesson in their classrooms.

1. What are cold seeps and why do they matter?

Cold seeps or cold vents are areas of the ocean floor where methane (CH4) and other gases escape and are released into the water. You might have heard of hydrothermal vents (or hot springs) where seawater circulates through hot volcanic rocks. Cold seeps are different from hydrothermal vents because they occur under cold temperatures. Where we have cold seeps, we have carbonate rocks. These form because of reactions between methane and seawater. There are also lots of microbial activity at cold seeps. These microbes oxidize (or eat) methane anaerobically (in the absence of oxygen). Cold seeps are easily recognizable because of the white bacterial mats that mark their locations on the seabed.

Cold seeps are an essential part of deep-sea ecosystems. As mentioned above, they feed communities that rely on bacteria that convert chemicals (e.g., methane) to food. Some of these bacteria form white mats that can be detected on the seafloor (see below image), and some live in symbiosis with animals such as tube worms or mussels. The animals provide a safe home to the bacteria, and in return, the bacteria make food for the animal. This makes cold seeps oases in the deep sea! Cold seeps could also be important contributors to climate change because they emit methane into the ocean. In addition, since cold seeps generally indicate large amounts of hydrocarbons below the seabed, they can be considered as new sources of hydrocarbons for addressing our increasing energy demands.

Example of bacterial mats found at the sea floor in the Arctic Ocean. (Image: AKMA)

2. How do scientists study cold seeps?

Scientists use underwater technology such as remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs) to study cold seeps. These machineries have several cameras and powerful lights to take photos of cold seep sites deep in the ocean. They are also equipped with devices that can sample sediments, rocks, biological communities, gas, and water, and help with bathymetric mapping of the ocean floor.

Other tools used to study the seafloor include multi-corer, gravity corer, heat flow probe, and seismic datasets, which are used for imaging the subsurface fluid and gas flows. To learn more about some of these techniques, we suggest watching the scientific videos on the website of the AKMA project: https://akma- project.com or from summer 2023 at https://en.uit.no/project/akma

ÆGIR 6000 is a remotely operated vehicle (ROV) designed to be used by scientists to access and study the sea floor. It is suitable for depths of up to 6000 meters. ÆGIR is operated by the Norwegian Marine Robotics Laboratory at the University of Bergen (UiB).
Image credit: Solmaz Mohadjer.

3. What is methane and how is it produced?

As mentioned above, methane and other gases are released into water at cold seeps. But what is methane and how is it produced? Methane (CH4) is a hydrocarbon (made of a single carbon atom with four arms of hydrogen atoms) and the main component of natural gas.

Methane occurs in nature both below the ground and under the seafloor due to biological and geological processes. Under the seafloor, methane is produced by microorganisms that live in the sediment layers. These organisms slowly convert organic materials into methane. The organic materials are the remains of other organisms that once lived in the ocean, sank to the ocean floor when they died, and finally became a part of the sea sediments.

The methane released from natural sources only makes up a small percent of the total methane emissions in the atmosphere. More than half of the methane in the atmosphere, in fact, comes from certain human activities such as oil and gas production, agricultural activities and waste management. In fact, methane levels in the atmosphere are mainly driven by emissions from the fossil fuel and agriculture/livestock sectors.

You might have heard of cows and other grazing animals, for example, as methane producers. They have microbes in their stomachs to help with digestion. These microbes produce methane as they break down the food. The methane can then be released into the atmosphere when animals burp or pass air.

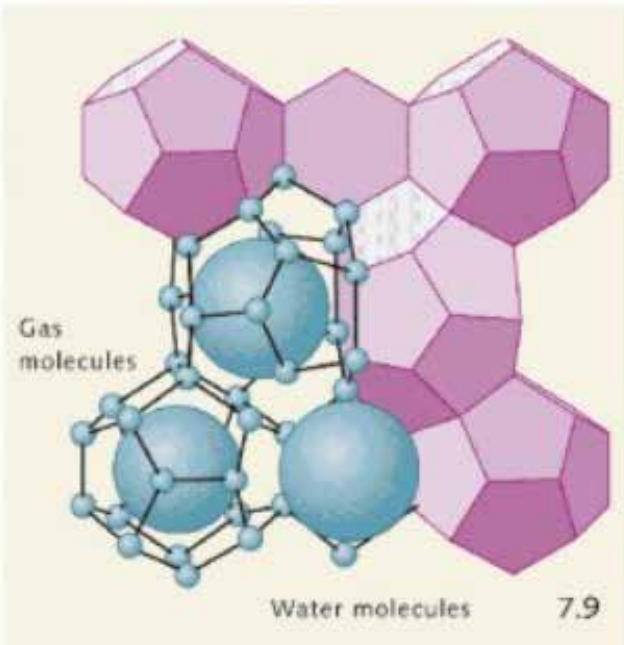
Even their manure is a place for microbes to hang out and produce more methane. Similarly, rice paddies when flooded, create a perfect home (calm water and low oxygen) for methane-producing bacteria. Microbes also hang out and produce methane at landfills and sewage treatment facilities.

Methane can also be intentionally or unintentionally released from oil and gas wells during drilling and production, and even after a well has ceased production. This can happen when wells are not plugged properly, emitting large volumes of methane into the atmosphere.

4. What are natural methane gas hydrates (burning ice)?

Natural methane gas hydrates (also known as burning ice) are an ice-like solid (not gas) composed of water and methane gas. The gas is locked up in water molecules, and if you dig out a chunk of this if you put a match to it, you'll notice that it won't melt. Instead, it will make a fizzing sensation, and if you put a match to it, it catches on fire. Natural gas hydrates are made from living organisms and carbon in decayed and partially decayed plant and animal tissues and natural organic matter like those that form in soil when plant and animal matter decays. Gas hydrates are found where we have deposits of organic matter consumed by microbes, typically along margins of continent where temperature is low, and pressure is high. In the ocean, we find them in cold seeps.

A vast amount of methane gas hydrates exists at the deep sea though the exact amounts and locations are not entirely known. These hydrates are generally stable unless something like warm water disturbs them. When destabilized, these hydrates can release methane from the seafloor into the atmosphere and warming it up by trapping heat in the atmosphere.



(Image left) methane hydrates with its honeycomb structure, (Image right) structure of gas hydrates: methane gas molecules (large spheres) trapped in cages made of water molecules (smaller spheres), if the cages break (due to increasing temperature, for instance), the methane gas escapes and can enter the water column/atmosphere. Image source: https://worldoceanreview.com/en/wor-1/energy/methane-hydrates/

5. Why do methane emissions matter? How can they be reduced?

Methane emissions matter because methane is a powerful greenhouse gas, with a warming effect 40 times that of carbon dioxide. This means that methane is more potent than carbon dioxide at trapping heat in the atmosphere, so its presence in the atmosphere affects the Earth's temperature and climate system. Most of the methane in the atmosphere are from man- made (anthropogenic) sources, not the cold seeps where methane gas enters the water column.

Carbon dioxide gets a lot of attention in climate change discussions. This is because there is a lot of it in the atmosphere and its concentration is increasing. Carbon dioxide can also last for centuries in the atmosphere. Methane, however, is much less abundant in the atmosphere and lasts there for only about a decade on average. This means that methane has a large effect over a relatively short period. Therefore, reducing methane emission can have a rapid and significant effect on atmospheric warming potential.

Learning procedure:

Follow the process in the accompanying paired teaching video:
https://youtu.be/k0awmdQQITA

Group work:

Activity 1 (mystery bottle) is discussion-based and can be done either in small groups or as a whole group.

For Activity 2, students form three groups with each group standing near where their assigned map is displayed. Group 1 is assigned Map 1 (Bathymetry), Group 2 is assigned Map 2 (Organic carbon content in marine sediments), and Group 3 is assigned Map 3 (methane/gas hydrates locations). To divide students into groups, have them count off by 3 to determine their group number. This ensures random selection of students per group. One of the benefits of this random selection is to have students work with others outside their usual social groupings.

For Activity 3, students form three new groups (Group A, B, and C). This will be a different group of students than they worked with during Activity 2. Each new group should have at least one person from previously formed groups in Activity 2. For example, Group A should have at least one person from Group 1, 2 and 3. Each group needs to sequentially visit each of the maps to become familiar with all the maps.

Practical:

In addition to the instruction provided below, please check out the 'Teacher Segment' of this video lesson for more detailed instructions.

Activity 1

MYSTERY BOTTLE, 5 MINUTES:

This is a discussion-based activity where students are asked to discuss how to identify a bottle with methane gas from a bottle containing carbon dioxide.

1. **Start the video lesson** by playing the first video segment. The video-scientist and teacher will provide some background information and introduce Activity 1. Pause the video at the end of the segment.
2. Divide your students into small groups or have a whole class discussion.
3. Ask students how they'd identify which bottle contains methane and which one contains carbon dioxide. Allow students to freely explore ideas and explain their reasoning to support each idea. Consider writing down their ideas on the board.
4. After they are done with the discussion (5 minutes), return to the video lesson to play the next segment during which the video-scientist and teacher explain the similarities and differences between the two gases, and introduce Activity 2.

Activity 2

OBSERVING MAPS, 5 MINUTES:

[Video segment 5:40 - 8:30]

This is an exercise based on observing and describing maps. You will use 3 maps: Map 1 (Bathymetry), Map 2 (Organic carbon content in sea sediments) and Map 3 (Location of methane/gas hydrates). Each map is described below:

a. Map 1 shows the topography and bathymetry of the Earth. This is the elevation of the land surface and the depth of the oceans. The map uses color to indicate varying elevations and depth and simulates sun shading to add a sense of 3D to the map. The scale bar on the right shows colors on the map correspond to elevation in meters.

b. Map 2 shows the global distribution pattern of the total organic carbon content (in wt%) in the ocean sediments found at <5 cm sediment depth.

c. Map 3 shows the location of gas hydrates (recovered, inferred, and drilling sites).

1. Before students arrive in the class, print the 3 maps, and attach them to the walls of your classroom, far enough apart that groups of 8-10 students can stand around a map and not interfere with a group standing around and discussion another map. You may choose to print the maps large and laminate them. Students may discuss the maps more readily if they are standing rather than sitting, but if you are limited by space, feel free to tape the maps on a table (e.g., lab table) and have students sit around the table. Keep in mind that these maps are reusable, especially if you laminate them.
2. After students are in the class, divide them into three groups. Each group stands around their assigned map (e.g., Group 1 stands around Map 1).
3. Ask students to become familiar with their maps. They should read the side label to see what is being displayed and how it is displayed. They should work as a group to find out what they are looking at. Once they have studied their maps, they can start to describe what they see. Their description should include words like deep or shallow, high organic carbon or low organic carbon, etc. While students are doing this, circulate among the groups listening and clarifying misconceptions.
4. Once students are done with studying their maps (10 minutes), return to the video lesson and play the next segment. The video-scientist and teacher will discuss the maps and introduce Activity 3.

Activity 3

RELATING MAPS, 15 MINUTES:

[Video segment 8:45 – 9:50]

1. Divide students into new groups (Group A, B and C). This will be a different group of students than they worked with during Activity 2. Each new group should have at least one person from previously formed groups in Activity 2. For example, Group A should have at least one person from Group 1, 2 and 3. This ensures that each group has members familiar with each of the three maps.

2. Remind students of the three questions they are asked to discuss:

    a. At what depth do most gas hydrates locate?
    b. Where do you see high amounts of organic carbon in sea sediments?
    c. Where do you expect to find gas hydrates and why?

To answer these questions, students need to relate the three maps to one another. Consider writing these questions on the board.

3. Ask each group to visit each of the maps to become familiar with all the maps. During each visit, the expert(s) of that map from Activity 2 will brief the group. For example, when Group A visits Map 1, those already familiar with Map 1 brief the rest of the group, and together they try to answer the questions. Students can choose to write down their answers in a notebook or on the board. As students do this, feel free to circulate among the groups listening and clarifying misconceptions.

4. Once students are done (15 minutes), return to the video lesson and play the last segment. The video-scientist and teacher will discuss the three questions and show some of the tool's scientists use to study cold seeps. This is the last video segment and the end of the lesson.

Further discussion

Now that you have learned about natural and man-made methane emissions, as well as cold seeps and how scientists find and study them, we encourage you to use the extra material (under resources) to discuss the following questions:

1. What kind of information can be obtained from using a gravity corer? How do cores obtained using this method differ from other coring methods (e.g., multi-corer, push cores using an ROV)?

2. What can you (as an individual) do to reduce methane emission? Give 2-3 examples.

3. How do scientists use seismic data to document methane emissions deep in the ocean?

4. Is there methane in the atmosphere of the Mars? How about its subsurface? What could the existence of methane on Mars potentially mean?

Resources

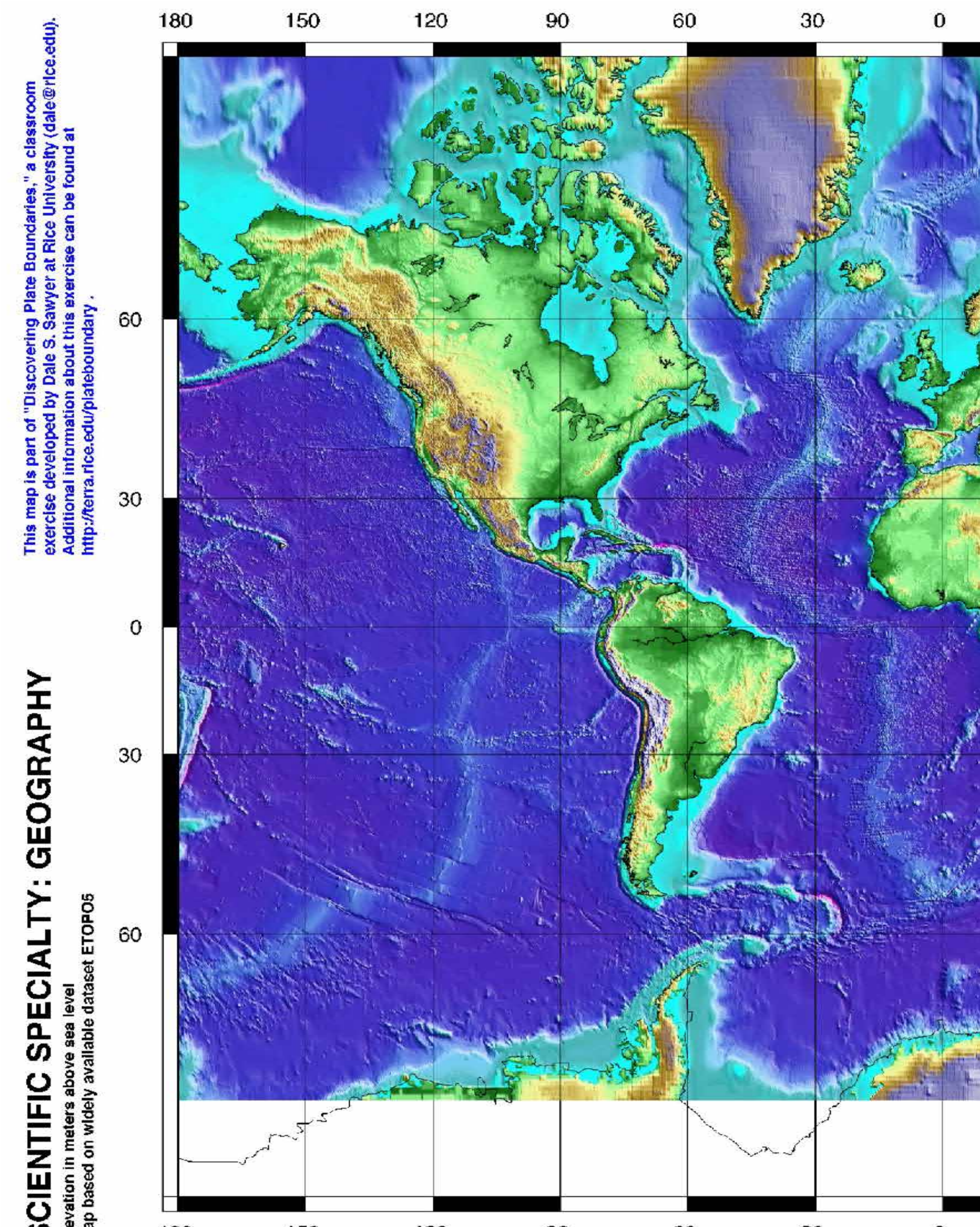
AKMA science videos:
https://akma- project.com or from summer 2023 at https://en.uit.no/project/akma

Cold seeps:
https://oceanexplorer.noaa.gov/edu/themes/cold-seeps/

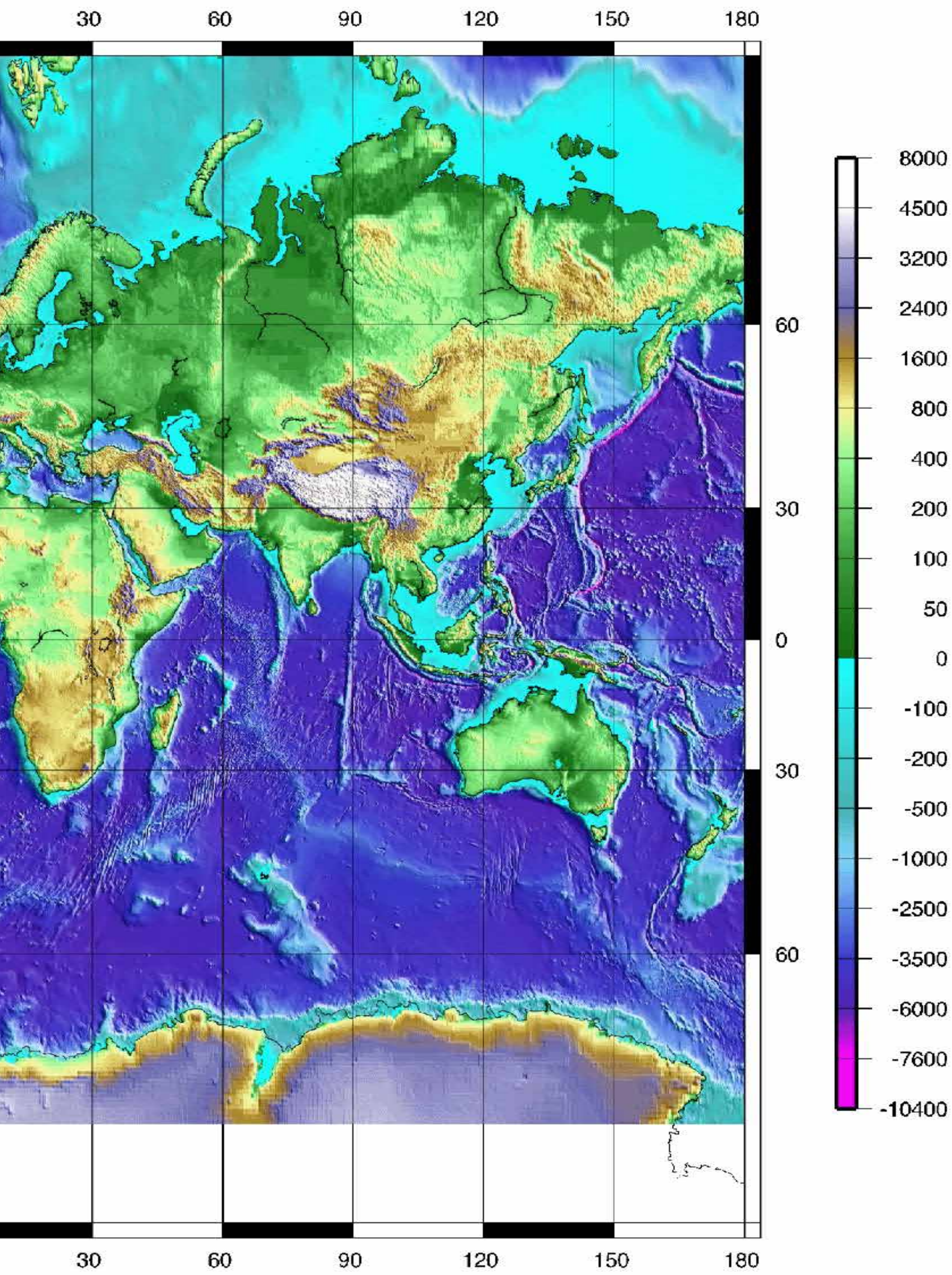
Reducing methane emissions:
https://eos.org/editors-vox/menthanes-rising-what-can-we-do- to-bring-it-down

Microbial consumption of methane on the seafloor:
https://eos.org/research-spotlights/investigating-rates-of- microbial-methane-munching-in-the-ocean

Martian methane:
https://eos.org/articles/how-scientists-search-for-martian- methane



Topography/Bathymetry map: https://plateboundary.rice.edu/downloads.html (last access: 24.11.2022)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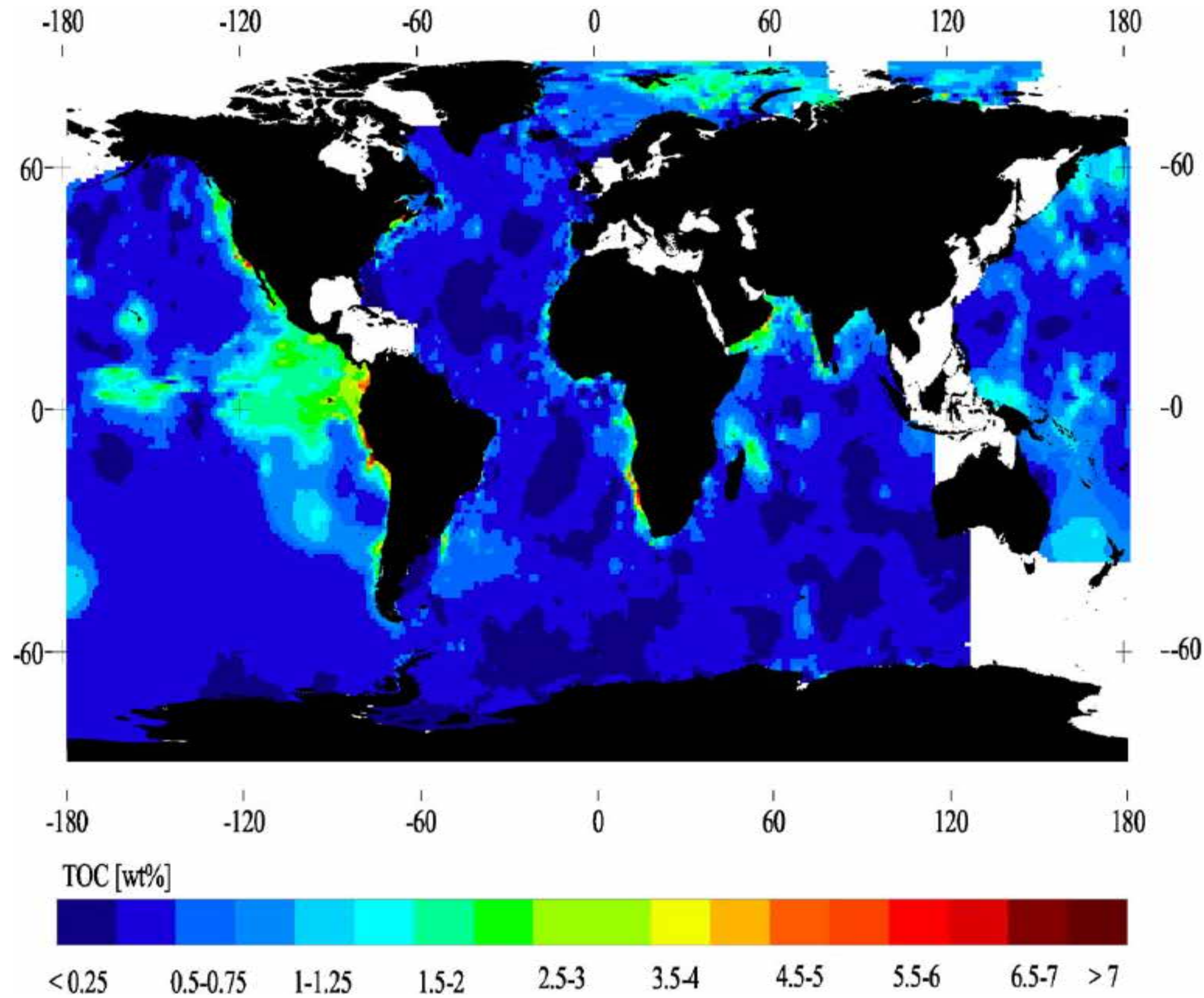
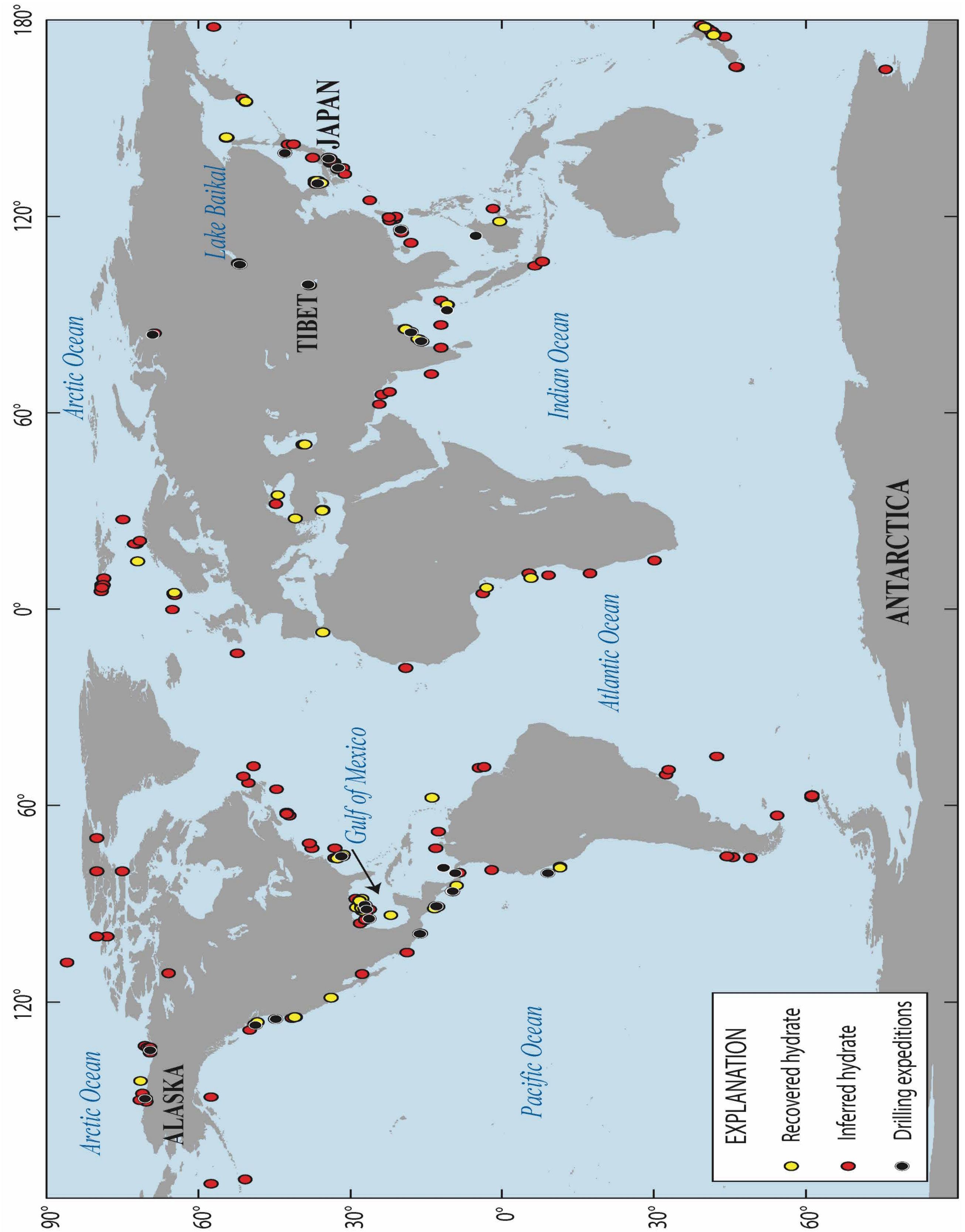


Fig. 11. Global distribution pattern of the TOC content in surface sediments (o5 cm sediment depth).

Seiter, Katherina, et al. “Organic carbon content in surface sediments—defining regional provinces.” Deep Sea Research Part I: Oceanographic Research Papers 51.12 (2004): 2001-2026.



Map of Gas Hydrates: US Geological Survey: https://www.usgs.gov/media/images/map-gas-hydrates (last access: 24.11.2022)

TOUCH

WHERE IS THE (ANCIENT) OCEAN FLOOR?

Focus:

To understand that that the ocean floor is dynamic and changes through time. Sometimes it's far away, and sometimes much closer than we think. But where is the ocean floor?

Learning objectives:

In this activity, pupils will understand that we can find ancient ocean floors on land because of tectonic activity. NB: This will require prior planning and may not be possible if your school is too far from such tectonic formations.

Key words:

Sedimentation, sedimentary rocks, tectonics, Earth history.

This specific lesson plan was developed in a close collaboration with:
Filip Maric, Margherita Paola Poto and Giuliana Panieri.

Edited by: *Giuliana Panieri and Mathew Stiller-Reeve*
Layout and Graphics: *Heike Jane Zimmermann*

Maric, F., Poto, M.P., & Panieri, G. (2023). Where is the (ancient) ocean floor? In G. Panieri & M. Stiller-Reeve (Eds.), The Ocean Senses Activity Book (pp. 71-73). Septentrio Educational, 2023(1). https://doi.org/10.7557/8.7054

IN SHORT (FOR THE TEACHER):

The idea is to find some examples of sedimentary rocks near your school and use these as a location for a class outing. The pupils will be able to touch and stand on or near an ancient ocean floor. You will need to investigate whether such formations are observable near your school. This experience provides the stage for you to give more information about geology and how sedimentary rocks form.

Materials:

Ideally, this is a geologic excursion activity where pupils go to an area where sedimentary rocks appear at the surface.

Teaching Time:

The amount of time will depend on the distance to the chosen location and how much time you spend investigating and discussing.

Examples of sedimentary rocks. Are there examples of sedimentary rocks near your school? The examples near your school may not be as big as mountains (Image left: Michael Dziedzic via Unsplash.com. Image right: Gary Yost via Unsplash.com)

BACKGROUND STORY:

Half of the exposed land on the earth surface is sedimentary rock. This rock is ancient ocean floor that has been uplifted through millions of years of tectonic activity.

Famous areas of land that consist of sedimentary rock that has been uplifted from the ancient ocean floor include the Dolomites, many parts of the Alpine regions, the Grand Canyon, the White Cliffs of Dover, and in the Arctic Circle, also the entire Svalbard archipelago.

Learning procedure:

Pupils are meant to move through an area with exposed sedimentary rock. You might consider challenging older pupils to investigate and find a location themselves.

They are then asked where they think the ocean floor is, and whether they think they will ever go to the ocean floor themselves.

You can include breaks and discussions during the excursion when you give information about the origin of this sedimentary rock. This can include information about processes of sedimentation, tectonic activity, and how tectonic activity has uplifted the ancient ocean floor over millions of years to shape some of the most well-known landscapes of the earth.

While pupils continue to move through the landscape, they are meant to reflect on how the ancient ocean floor supports their bodies and gait. By touching sedimentary rock, you can further encourage them to reflect on how and why the (ancient) ocean floor is in such close reach.

More information:

Geology: Introduction to Geology: Chapter 9:
https://gotbooks.miracosta.edu/geology/chapter9.html

HOW DEEP IS THE OCEAN?

Focus:
To gain an appreciation of ocean depth using ideas of scale and physical education.

Learning objectives:
With these TWO activities, pupils will begin to understand (and feel) how deep the ocean can be in relation to their own size and height. They will get a feeling of the difference between height (above ground) and depth (in relation to water).

Key words:
Height, (ocean) depth.

This specific lesson plan was developed in a close collaboration with:
Filip Maric, Margherita Paola Poto and Giuliana Panieri.

Edited by: *Giuliana Panieri and Mathew Stiller-Reeve*
Layout and Graphics: *Heike Jane Zimmermann*

Maric, F., Poto, M.P., & Panieri, G. (2023). How deep is the ocean? In G. Panieri & M. Stiller-Reeve (Eds.), The Ocean Senses Activity Book (pp. 74-77). Septentrio Educational, 2023(1). https://doi.org/10.7557/8.7055

IN SHORT (FOR THE TEACHER):

These TWO lesson activities combine ideas of scale with physical education for the pupils to gain an understanding of how deep the ocean can be. Pupils will be asked to make human pyramids so please ensure appropriate safety precautions.

Materials:

- Open space
- Whiteboard, chalk
- A bucket ¾-full of water for your pupils to submerge their forearms in (vertically) to about elbow height.

Examples of a human pyramid the pupils could attempt to make (Image: Andy Rogers via Flickr)

More information:

https://oceanservice.noaa.gov/facts/oceandepth.htm

BACKGROUND STORY:

The highest mountain on Earth is about 8800m high. The deepest known point in the ocean is about 11000m deep. The average depth of the Arctic Ocean is about 1000m, and its deepest point is 5500m.

Appreciating the ocean's depth is essential for understanding a) the vastness of our world underwater, and b) how small we are in relation to our world and its oceans (an important insight for all humans to learn).

Activity 1:

HUMAN PYRAMID

Draw a one-meter vertical line on a whiteboard as a scale for 1000m. Write or draw a bit of ocean floor at the bottom, and a wavey ocean surface at the top.

Measure the height of one pupil standing, with their arms, stretched up above their head. Then have them draw a stick figure of themselves, to scale next to the water column on the whiteboard to compare.

In an open space, help pupils build a human pyramid, providing all necessary safety measures. Pupils could be on hands and knees for this purpose (tabletop position), maybe with 3-4-5 pupils in the bottom row, then 2-3-4 pupils in the next row, etc. Then measure the height of the pyramid and draw it next to the water column again for comparison.

Alternatively, or additionally, have one pupil stand on the shoulders of another (with all the necessary support for balance). Measure their combined height and draw next to the water column on the whiteboard for comparison.

All these practical activities could also be done before providing the ocean's depth as a comparison.

Activity 2:

BUCKET OF WATER

Draw a length scale on pupils' forearms with 0m at their longest fingertip and 1000m at their elbow. They can use the scale on their arm to compare their own height, or the height of the school, or home, or highest building on Earth, or in their city. Any of these could also be drawn on the pupils' arm, next to the scale.

Have the pupils submerge their arms in the bucket of water to measure the depth of the 'ocean in the bucket'.

Then have the pupils demonstrate the deepest point in the Arctic Ocean or Atlantic Ocean by putting their forearms next to each other in one long row.

How the depth scale might look drawn on someone's arm (Image: AKMA Project)

UNDER PRESSURE

Focus:
To understand and feel how water pressure changes with depth.

Learning objectives:
In this activity, pupils will recognize the relationship between water depth and pressure. Pupils will be able to reflect on how lifeforms in the deep sea might be affected by the high water pressures in their ecosystems.

Key words:
Depth, weight, pressure.

This specific lesson plan was developed in a close collaboration with:
Filip Maric, Margherita Paola Poto and Giuliana Panieri.

Edited by: *Giuliana Panieri and Mathew Stiller-Reeve*
Layout and Graphics: *Heike Jane Zimmermann*

Maric, F., Poto, M.P., & Panieri, G. (2023). Under pressure. In G. Panieri & M. Stiller-Reeve (Eds.), The Ocean Senses Activity Book (pp. 78-80). Septentrio Educational, 2023(1). https://doi.org/10.7557/8.7056

IN SHORT (FOR THE TEACHER):

In this lesson, the pupils will "feel" the pressure that animals feel underwater. After the activity, the pupils can discuss and try to empathize with the creatures and organisms that live in the sea. The pupils can try to extrapolate their experience and think about the immense pressures at the bottom of the Arctic Ocean. This activity might be best done outdoors since water will be used.

Materials:

Each pair of pupils will have the following:

- Plastic bag
- Water / Flour / Salt to put in the bag
- Measuring cup/jug.

Teaching Time:

20-30 minutes.

Classroom organization:

Pupils will ideally work in pairs.

There is a lot of pressure at the bottom of the sea! Comparison of styrofoam cup at normal size and after compression at 4400m depth
(Image: AKMA Project)

BACKGROUND STORY:

The Arctic Ocean is 1038m deep on average, with its deepest point, the so-called Molloy Deep being around 5500m deep.

The high pressure at the bottom of the Arctic Ocean is one of the defining features of ocean floor ecosystems. This pressure has implications for the landscapes and lifeforms living at the bottom of the Arctic Ocean. All life in the Arctic deep sea is highly adapted to these pressures.

In contrast, humans are adapted to life above the ocean surface. The deepest dive a human has ever done (without a submarine vehicle) is currently to 300m.

Learning procedure:

One pupil lies on their back. The other pupil pours one cup of water (200ml, or, alternatively 200mg flour, or sand) into a plastic bag and gently places it onto the other pupil's chest, holding onto the bag ever so slightly. The 'sensing' pupil describes how these feels.

Then the bag is gradually filled with a bit more water (possibly working up to 2 liters or 2kg).

As a group, all pupils discuss what more pressure/weight felt like. The pupils can then reflect on how lifeforms at the bottom of the sea might be affected by this pressure.

OCEAN SENSES
– TOUCH –

ARCTIC OCEAN TEMPERATURES

Focus:

To understand what water temperature is, and why it is important for life in the ocean. What factors influence water temperature (e.g., sunlight, solar radiation, heat transfer)?

Learning objectives:

In this activity, pupils will learn that temperature is an important factor influencing water, water quality, and altering the physical and chemical properties of water.

Key words:

Temperature, solar radiation, heat transfer, changes & drivers, consequences.

This specific lesson plan was developed in a close collaboration with:
Filip Maric, Margherita Paola Poto and Giuliana Panieri.

Edited by: *Giuliana Panieri and Mathew Stiller-Reeve*
Layout and Graphics: *Heike Jane Zimmermann*

Maric, F., Poto, M.P., & Panieri, G. (2023). Arctic ocean temperatures. In G. Panieri & M. Stiller-Reeve (Eds.), The Ocean Senses Activity Book (pp. 81-84). Septentrio Educational, 2023(1). https://doi.org/10.7557/8.7057

IN SHORT (FOR THE TEACHER):

In this lesson, the pupils will feel how temperature changes in water. This feeling can frame discussions on temperature, heat transfer, and possibly also large-scale changes like climate change. You can extend the activity with the pupils finding ways to change the temperature (both warmer and colder) quicker.

Materials:

Each pair of pupils will have the following:

- A basin or bucket to pour water into
- A container of cold water
- A container of water at room temperature
- A container with hot water
- Possibly also some ice cubes to add so they can further change the temperature of the water in the bucket or basin.

Teaching Time:

30-45 minutes.

Classroom organization:

Pupils will ideally work in pairs.

Example image of a glacier calving, which will happen more rapidly as seas temperatures rise
(Image: @stc2121a via Unsplash.com)

BACKGROUND STORY:

Water temperature and salinity in the Arctic Ocean are the most variable of any ocean. Water enters from the Atlantic and Pacific Oceans and ice from the surrounding continents.

Temperature ranges from −0.7°C to 3°C (30.8°F to 37.4°F).

All the world's oceans are warming due to climate change, but the Arctic Ocean, the smallest and shallowest of the world's oceans, is warming fastest of all. As the Arctic Ocean gets warmer, it causes the ice in the polar region to melt. As the ice melts, it exposes more of the ocean's surface to the sun, releasing heat and raising air temperatures.

As the Arctic continues to warm, it will melt the permafrost, which stores huge amounts of methane, a far more damaging greenhouse gas than carbon dioxide.

Learning procedure:

This water experiment will help pupils explore and feel the concept of water temperature and how it changes with different factors (sunlight, solar radiation, heat transfer). Get the pupils to pour the cold water into the bucket/basin and ask them to immerse their hands in it. Then leave the basin under the sun for ten minutes and ask the pupils to immerse their hands. Ask them what they feel and if they feel a different temperature.

Finally add some hot water and this time ask them to tell you why it is better not to immerse your hands in the water anymore. The pupils can use the ice to reduce the temperature again. Maybe they can feel that the temperature is different at the top of the bucket compared with the bottom.

A container of cold water with ice cubes. Illustration image. Maybe consider using ice in the water basin and experiment with melting and how this also impacts the temperature that the pupils feel (Image: Engin Akyurt via Unsplash.com)

More information:

https://arctic.noaa.gov/Report-Card/Report-Card- 2019/ArtMID/7916/ArticleID/840/Sea-Surface-Temperature

https://seatemperature.info/arctic-ocean-water-temperature.html

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OCEAN SENSES
– TOUCH –

OCEAN FLOOR DIORAMA

Focus:

To consolidate pupils' learning about the ocean floor in a creative and fun way. Through creating a diorama, the pupils will think about what the ocean floor looks like and what species live there.

Learning objectives:

In this activity, pupils will design, classify, and find a place for all the elements and characters that compose the ocean floor and biodiversity that they have learnt about in class.

This specific lesson plan was developed in a close collaboration with:
Filip Maric, Margherita Paola Poto, Heike Jane Zimmermann and Giuliana Panieri.

Edited by: *Giuliana Panieri and Mathew Stiller-Reeve*
Layout and Graphics: *Heike Jane Zimmermann*

Maric, F., Poto, M.P., Zimmermann, H.J., & Panieri, G. (2023). Ocean floor diorama. In G. Panieri & M. Stiller-Reeve (Eds.), The Ocean Senses Activity Book (pp. 85-87). Septentrio Educational, 2023(1). https://doi.org/10.7557/8.7058

IN SHORT (FOR THE TEACHER):

This a creative activity that can nicely round off your other lessons about the sea floor and the animals and organisms that live there. It requires that the pupils already have some knowledge about these issues. Making a diorama is an artistic approach that can help pupils to consolidate their knowledge about life on the sea floor and to inspire further discussion:.

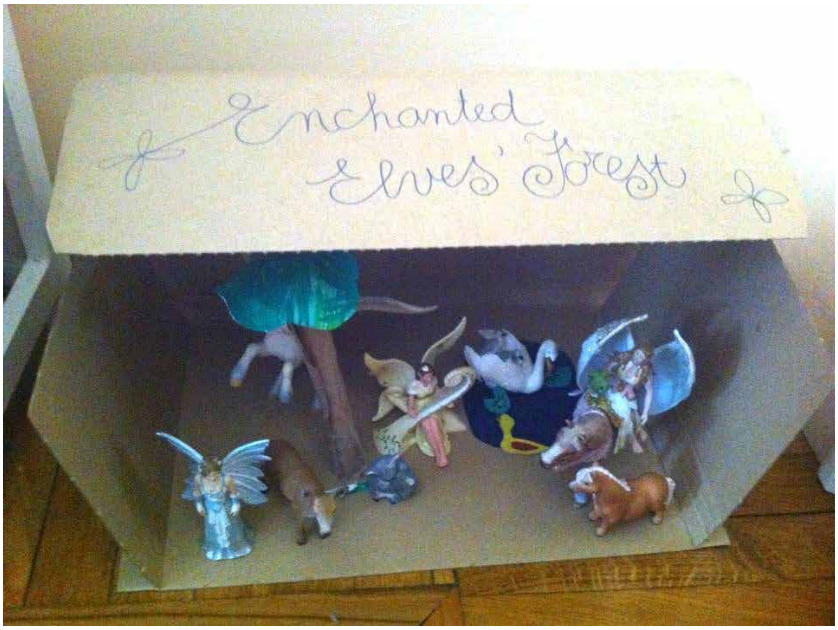
Materials:

To make a diorama, pupils should have the following at their disposal:

- Modelling clay
- Cardboard box or container (e.g., shoe box)
- Glue
- Scissors
- Paints and paintbrushes
- Markers
- Fabric scraps
- Sands and sediments to use as the seafloor
- 3D printed or sculpted sea animals and/or foraminifera (if possible) [see activities on sculpting sea animals and foraminifera]

Teaching Time:

2-3 hours or can be extended to a longer project.



Example of a diorama, here showing the "enchanted elves' forest" (Image: Margherita Poto)

Learning procedure:

The pupils can design the diorama on a sheet of paper. They can draw the elements they want to include like the ocean floor, flora, fauna etc.

Because dioramas are ideally 3D installations, they should be made in a box or frame that is several inches/cm deep. The container must have an open-faced front so that viewers can see the scene. Consider the design of the diorama when selecting the container. For instance, a diorama about deep sea will need to be tall enough to accommodate the landscapes and layers of vegetation.

Pupils can paint the outside of the box for a more finished look. Do this first and let the paint dry before starting work on the inside of the diorama.

Begin at the back of the container and work forward, adding layers of details and images to create depth to the scene. Decorate the background and inside walls first. Consider painting a basic scene or the pupils can print an underwater image and glue it on. Pupils might use images of bubbles or plankton for example.

A realistic diorama should include details on the bottom of the box as well. Pupils can use pictures, paint, modelling clay and sand to create a realistic ground or floor for the diorama. They might leave it flat or add hills and valleys as they see fit.

Pupils can sculpt their own animals (or add small toy animals) and place them on the sea floor or hang them from the roof of the box/container, so it looks like they are swimming.

Add some informative labels and exhibit the art piece!

More information:

These websites give some more ideas about how to make ocean dioramas:
https://www.thesprucecrafts.com/ocean-diorama-craft-1253799
https://www.wikihow.com/
Make-a-Diorama https://www.youtube.com/watch?v=_DJKyM3JIAI

OCEAN SENSES
– TOUCH –

SCULPTING MICRO-, MEIO-, AND MACROFAUNA

Focus:

To appreciate the biodiversity of the Arctic Ocean and ocean floor, with a particular focus on lesser-known species. What kind of micro- meio-, and macrofauna (species) live on the ocean floor and what do they look like?

Learning objectives:

In this activity, pupils will identify (one, two, or more) species living at or close to the Arctic Ocean floor and sculpt them using modelling clay. Through this activity, pupils will hopefully begin to understand differences between Arctic Ocean micro-, meio-, and macrofauna.

Key words:

Arctic ocean biodiversity, species, fauna.

This specific lesson plan was developed in a close collaboration with:
Filip Maric, Margherita Paola Poto, Heike Jane Zimmermann and Giuliana Panieri.

Edited by: *Giuliana Panieri and Mathew Stiller-Reeve*
Layout and Graphics: *Heike Jane Zimmermann*

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IN SHORT (FOR THE TEACHER):

This a creative activity that can nicely round off your other lessons about oceanic animals and organisms. The pupils will choose a character to recreate in sculpting clay. As the pupils make these, then you can have other conversations with them about relevant topics.

Materials:

To make the sculptures, pupils should have the following at their disposal:

- Modelling clay
- Paints and/or pens to add color to give their creations more character.

Teaching Time:

90+ minutes.

Example of sculpting some ocean micro-organisms called Foraminifera.
(Illustrator Heike Jane Zimmermann in a photo by Davide Oddone)

More information:

ArcOD Arctic Ocean Diversity Program http://www.arcodiv.org/

IN SHORT (FOR THE TEACHER):

The Arctic Ocean is a unique ecosystem populated by a multitude of unique life forms highly adapted to the extreme and seasonal conditions of this environment.

Many of the species in the Arctic -like polar bears, walrus, narwhals, and seals- are very well known to people around the world. There are, however, countless smaller species in the Arctic Ocean that are lesser known. These species hold an abundance of knowledge about our planet's history, and the interactions in the Arctic ecosystems and how they function.

Because the Arctic Ocean is the region where the impacts of climate change are strongest, knowledge of its biodiversity is critical to understand how climate change is affecting life on Earth.

Learning procedure:

You, the teacher, can choose 2-4 different species from the arctic ocean that the pupils probably know little about. Present these species to the class in a presentation with photos and come background information. The images can be used by the pupils to sculpt their own versions of the species.

Pupils are then given the time and support to craft their species of choice, talking to each other and you in the process. You can also sculpt your own model as well.

While everyone is crafting their models, you can share some more information on the differences between micro-, meio-, and macrofauna, as well as more specific details regarding each species.

SCULPTING FORAMINIFERA

Focus:
To appreciate the biodiversity of the Arctic Ocean and ocean floor, with a particular focus on lesser-known species like foraminifera.

Learning objectives:
In this activity, pupils will identify (one, two, or several) foraminifera species living at or close to the Arctic Ocean floor and sculpt them using modelling clay.

Key words:
Foraminifera, Benthic, Planktonic.

This specific lesson plan was developed in a close collaboration with:
Filip Maric, Margherita Paola Poto, Heike Jane Zimmermann and Giuliana Panieri.

Edited by: Giuliana Panieri and Mathew Stiller-Reeve
Layout and Graphics: Heike Jane Zimmermann

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IN SHORT (FOR THE TEACHER):

This a creative activity that can help to consolidate knowledge about foraminifera, which are seldom discussed in the classroom. Foraminifera are hugely diverse and abundant in the ocean and have been found on Earth for hundreds of millions of years! You will need to do some background research about foraminifera to present to your class and share stories whilst you and your students sculpt.

Materials:

To make the sculptures, pupils should have the following at their disposal:

- Modelling clay
- Paints and/or pens to add color to give their creations more character.

Teaching Time:

90+ minutes.

Example of sculpting some ocean micro-organisms called Foraminifera.
(Illustrator Heike Jane Zimmermann in a photo by Davide Oddone)

More information:

ArcOD Arctic Ocean Diversity Program http://www.arcodiv.org/

BACKGROUND STORY:

Foraminifera have been living on Earth since the early Cambrian period, some 500 million years ago. This means that foraminifera have been on Earth much longer than the dinosaurs and, in contrast to these, are still living among us nearly everywhere on the planet. There are more than 20,000 known species of foraminifera and more are continuously being discovered.

Foraminifera live in all kinds of environments, swimming in the ocean, at the ocean floor, in freshwater systems, and their shells can be found in many well-known places on land, including sandy beaches, fossilized in the Dolomites and large parts of the Alpine regions, in the pyramids of Egypt and more.

Because of their calcium carbonate shells that are well-preserved as fossils, foraminifera can tell scientists about past and present climate and environmental changes on Earth.

Learning procedure:

You, the teacher, can choose 2-4 different foraminifera from the Arctic Ocean (see the next page for some examples). Present these species to the class in a presentation with photos and come background information. The photos you use (or the ones on the next page) can be used by the pupils to sculpt their own versions of the species.

Pupils are then given the time and support to craft their species of choice, talking to each other and you in the process. You can also sculpt your own model as well.

While everyone is crafting their models, you can share some more information on the differences between micro-, meio-, and macrofauna, as well as more specific details regarding each species.

Example of fossilized Foraminifera
(Image: fickleandfreckled via Flickr Creative Commons)

OCEAN SENSES
– TOUCH –

SEDIMENTATION

Focus:

To understand the role of sedimentation in creating the unique conditions of ocean floor ecosystems.

Learning objectives:

With this activity, pupils will gain a basic understanding of how sediments in the ocean settle on the ocean floor (sedimentation) and what this looks like.

Key words:

Settling, sediment, terrigenous, pelagic.

This specific lesson plan was developed in a close collaboration with:
Filip Maric, Margherita Paola Poto and Giuliana Panieri.

Edited by: *Giuliana Panieri and Mathew Stiller-Reeve*
Layout and Graphics: *Heike Jane Zimmermann*

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IN SHORT (FOR THE TEACHER):

In this activity, your pupils will gain hands-on experience in how sediments settle (sedimentation) on the ocean floor. You can discuss different types of sediments with your pupils and extend the discussion afterwards to processes that form sedimentary rocks.

Materials:

Each pair of pupils will have the following:

- Transparent plastic bottle, water glass or bowl filled with water.
- A mixture of sediment, sand, and very small pebbles.

Teaching Time:

30-45 minutes.

Classroom organization:

Pupils will ideally work in pairs.

Example of layers of sediment in a water bottle.

BACKGROUND STORY:

The term sedimentation is the process where sediment settles after being suspended in the water column. In the ocean, these sediments settle on the ocean floor in layers. If these layers get thick enough, the resulting heat and pressure can reform them into sedimentary rocks. The top layer of the ocean floor consists of sediment that can range in thickness from a few millimeters to thousands of meters.

Two of the main types of sea floor sediment are terrigenous and pelagic.

Terrigenous sediment is derived from land, transported by rivers, wind, ocean currents, and glaciers, and usually deposited on the continental shelf, continental rise, and abyssal plain. It is further contoured by strong currents along the continental rise. See next page for an example.

Pelagic sediment is composed of clay particles and micro skeletons of marine organisms like foraminifera that settle slowly to the ocean floor. Some of these organic sediments are called calcareous or siliceous “oozes” because they are so thick and gooey. The clay component (or sometimes volcanic ash) is generally carried from land by wind and falls on the surface of the ocean.

Learning procedure:

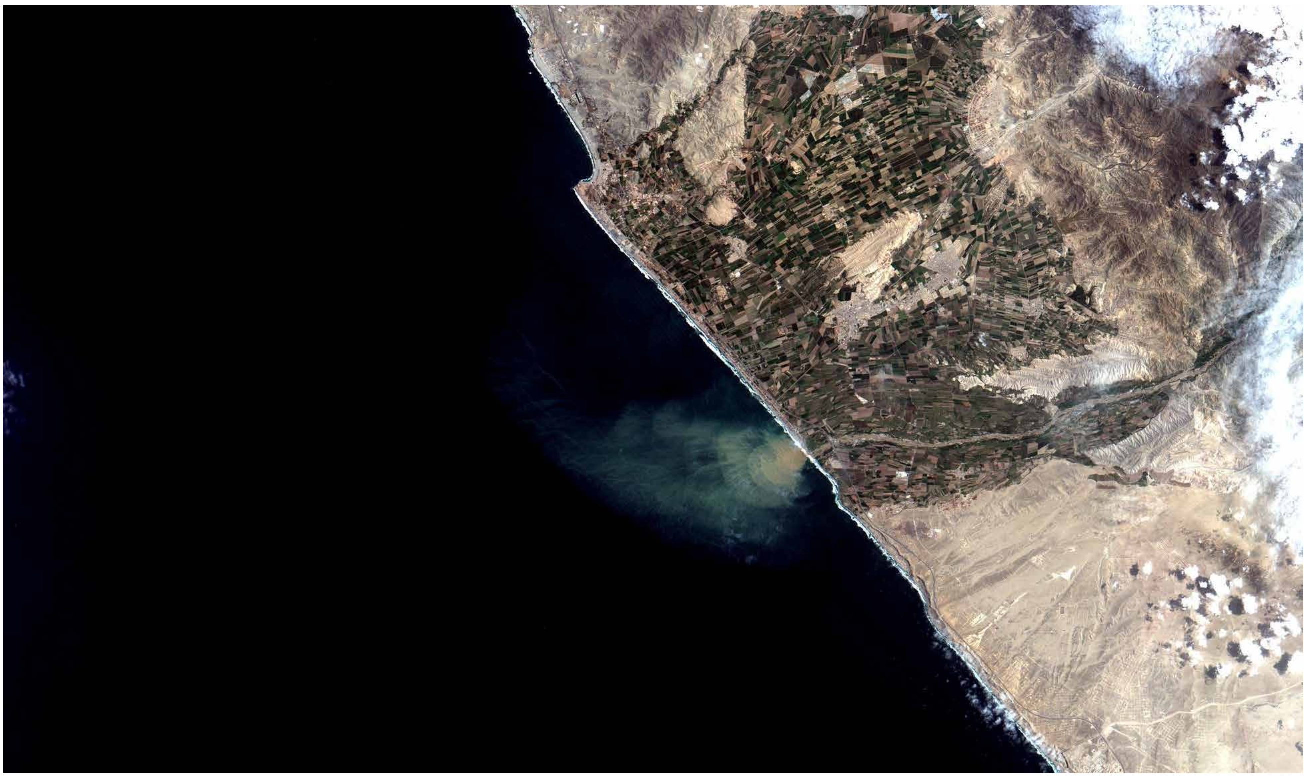
Fill the container (bottle, glass, bowl) roughly ¾-full of water and have pupils slowly drizzle the sand/sediment mix into it. They will then observe how the sediment settles and forms layers of with the largest particles at the bottom.

Shaking or stirring the glass can additionally inspire discussion about the fact that settling, and sedimentation of the ocean floor are influenced by many factors, including ocean currents.

An alternative approach could be to drizzle sand from one hand onto another, so the pupils not only see how the sand settles on a surface, but also feel it.

More information:

http://www.waterencyclopedia.com/Oc-Po/Ocean-Floor-Sediments.html
https://www.cliffsnotes.com/study-guides/geology/the-ocean-floor/ocean-floor-sediments
https://opentextbc.ca/geology/chapter/18-3-sea-floor-sediments/



An example of terrigenous sediment been transported into the ocean by the Rio Cañete from São Vicente do Cañete, Peru.
(Image: Coordenação-Geral de Observação da Terra/INPE)

HUMAN IMPACT: PLASTIC POLLUTION

Focus:
To comprehend that plastic pollution is a major problem and is having an impact on oceans everywhere. These impacts are seen on beaches and shorelines and all the way to the deepest places in the ocean.

Learning objectives:
In this activity, pupils will gain an appreciation for the extent of plastic pollution in and around oceans. They will start to understand how plastic pollution can have a negative impact on life below the surface of the sea.

Key words:
Ocean pollution, plastics, microplastics.

This specific lesson plan was developed in a close collaboration with:
Filip Maric, Margherita Paola Poto and Giuliana Panieri.

Edited by: *Giuliana Panieri and Mathew Stiller-Reeve*
Layout and Graphics: *Heike Jane Zimmermann*

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IN SHORT (FOR THE TEACHER):

During this activity, your pupils will understand how much the global problem of plastic pollution impacts the waterways and coasts near you. This requires an excursion and equipment to collect garbage/plastics. The pupils will observe the environment and collect the garbage (which you will ensure is disposed of properly afterwards). This activity is meant to inspire discussion on location and back in the classroom.

Materials:

Ideally, this is an excursion activity where pupils visit the coastline of a sea/river/waterway near you. The pupils will need the following:

- Protective gloves
- Bags/containers to collect garbage.

Teaching Time:

The amount of time will depend on the distance to the chosen location and how much time you spend investigating and discussing.

Image showing plastic and ocean pollution
(Image: Ocean plastics Photo by Naja Bertolt Jensen on Unsplash)

More information:

https://www.nationalgeographic.com/environment/article/plastic-pollution
https://www.unep.org/plastic-pollution

BACKGROUND STORY:

Every minute, the equivalent of one garbage truck of plastic is dumped into our oceans. Every year, about 8 million tons of plastic waste escapes into the oceans from coastal nations.

The solution is to prevent plastic waste from entering rivers and seas in the first place. This could be accomplished with improved waste management systems and recycling, better product design that considers the short life of disposable packaging, and a reduction in the manufacturing of unnecessary single-use plastics.

Learning procedure:

Visit a local beach or waterway and collect plastic and other garbage that has accumulated around it. Gather the garbage together and reflect on how much plastic there must be around the ocean if this is how much you find in only one place. If there is a lot of plastic, you can discuss where it might come from. If there is little garbage, then you can discuss why. These discussions can be combined with other lessons on ocean/river circulation and how human's impact our planet, for example.

Collecting plastic and rubbish on a beach (Image: Anatasia Nelen on Unsplash)

OCEAN SENSES
– TOUCH –

HUMAN IMPACT: ECOLOGICAL FOOTPRINTS

Focus:

To understand the meaning of the human ecological footprint. Pupils will think about questions like how do our actions (e.g., research) affect the environment around us and, what can we do to reduce the human impact on the oceans?

Learning objectives:

In this activity, pupils will learn to develop an understanding of their relationship with the oceans and the marine environment and hopefully be inspired to turn their knowledge into action.

Key words:

Human impact, footprints, action.

This specific lesson plan was developed in a close collaboration with:
Filip Maric, Margherita Paola Poto and Giuliana Panieri.

Edited by: *Giuliana Panieri and Mathew Stiller-Reeve*
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IN SHORT (FOR THE TEACHER):

In this activity, you and your class will connect ideas about ecological footprints with the hands-on task of making one's own footprints in sand (or snow or soil).

Your pupils will make their own footprints and then consider what that means. They will consider how one can smoothen over or remove one's footprints on different surfaces.

Materials:

This activity is probably best done outside in an area where there is sand or another appropriate surface to make footprints. If you need to carry out the activity inside, then you may need the following:

- An old sheet or tablecloth (to protect your work surface)
- Sand to empty onto the old sheet or tablecloth.
- A device to take photos.
- A photo frame to place around some of the footprint to then take photos.

Teaching Time:

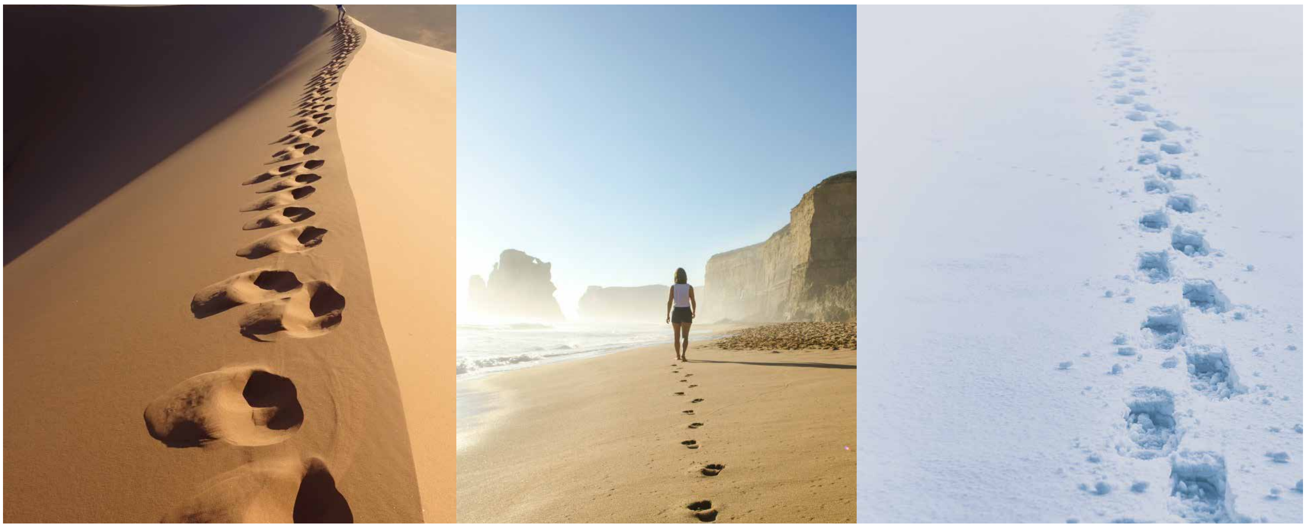
The amount of time will depend on the distance to the chosen location outside, or the time needed to set things up in the classroom.

Classrom organisation:

Pupils can work in pairs or small groups to make footprints and take photos. The discussion afterwards can include the whole class together.

BACKGROUND STORY:

The ecological footprint measures the demands made by a person or group of people on global natural resources. It has become one of the most widely used measures of humanity's effect on the environment. It has been used to highlight both the apparent unsustainability of current practices and the inequalities in resource consumption between and within countries. (Source: Hayden, Anders. "ecological footprint", Encyclopedia Britannica, 26 Dec. 2019, https://www.britannica.com/science/ecological-footprint. Accessed 7 June 2022)



Examples of footprints in the desert (Image left: Éric Deschaintre on Unsplash), the beach (Image middle: Brian Mann on Unsplash) and in the snow (Image right: Eberhard Grossgasteiger on Unsplash)

Learning procedure:

You can start by discussing what an ecological footprint is with your class. Once this discussion is complete, you and your pupils will make your footprints. If you need to carry out this activity in the classroom, start by covering the work surface with something to catch the sand. Make an imprint on the sand with your foot. Place the frames around some of the footprints and take some photos.

This activity can also be done outside if you live near an area with snow, sand, or bare soil. Make some footprints on the surface and use your frames to frame them. You can also take photos of the prints and display them in your classroom. Use these footprints (and photos) to have a deeper discussion with your class. You can also make a small exhibition of the photos to display in the classroom.

Discussion points:

- Share your ideas on what you see in the frames/photos.
- Footprints on different surfaces require different processes to remove. For example, at the beach, waves may smooth over the footprints. In the desert, the wind might do this job. But what about snow? What needs to happen to get rid of the prints? If we need to smooth over the footprints manually, does the surface look the same as before?
- How are the footprints we have made similar to our ecological footprints? What are our ecological footprints on land and in the ocean? Are our ecological footprints easy to smooth over? What is required to do this, and do our efforts leave a mark?

The lesson plans were developed as part of the project Advancing Knowledge of Methane in the Arctic (AKMA) based at UiT - The Arctic University of Norway in Tromsø with funding from INTPART - International Partnership for outstanding education, research and innovation - a Norwegian Research Council programme. The development work began during the AKMA Ocean Senses scientific expedition onboard RF Kronprins Håkon 11-22 May 2022. Special thanks to Gloria Gordini and Elena Astore for useful suggestions.

The expedition brought together scientists, social scientists, humanities scholars, teachers, and artists to collaborate and create lesson plans that would bring the ocean floor to life in the classroom.

If you have further questions, please get in touch with the leader of AKMA,
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