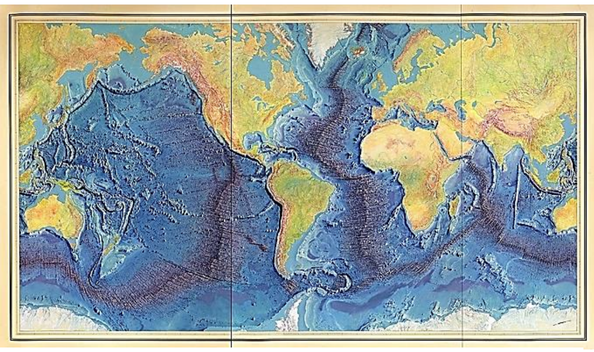
Modelling seafloor mapping
How to simulate an echo-sounder study of seafloor topography

The image of the world ocean floor has become familiar to the public after the publication of the famous map by Bruce Heezen and Marie Tharp in 1977 and, more recently, from the beautiful images on Google Earth.



Manuscript painting of Heezen Tharp World ocean floor map by Berann. Library of Congress, *public domain*

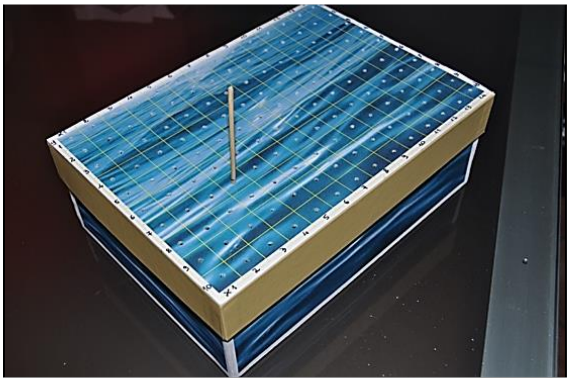
The Heezen-Tharp map made oceanic ridges and rifts visible for the first time and contributed to the development of plate tectonic theory.

The Heezen-Tharp map was painstakingly hand painted from thousands of sonar readings recorded by research ships since the 1950s. Since then much more data have been collected, from satellites (European Space Agency's CryoSat-2 satellite and NASA's Jason-1) to modern multi-beam echosounders mounted on research, government, industry and private vessels (Seabed 2030 Project).

The aim of the Seabed 2030 Project is to increase the coverage by high-resolution maps, which currently cover only 15% of Earth's seafloor, to all oceans. Have you ever wondered how these images are obtained? A multi-beam echo-sounder on the ship's hull emits a fan-shaped array of sound waves (typically at 12 kiloHertz, kHz) towards the sea floor. The sound waves bounce back to the ship in a time interval proportional to the travelled distance and the travel time is converted into a depth. Many measurements taken along the ship's path allow us to reconstruct a 3D image of the seafloor

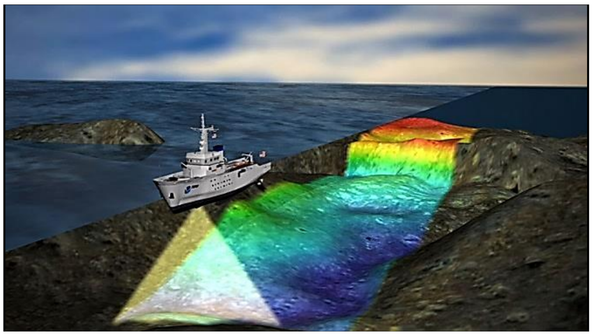
In this activity we are going to simulate the method used by echo-sounders to obtain the image of seafloor topography.

Prepare "sounding boxes" in advance, one for each group. Do this by using a cardboard shoe box or another box of similar size. Print a grid (2cm x 2 cm cells) on a sheet of paper the same size as the box lid (with a marine or blue background for a more "realistic" effect) and mark the sides of the grid with numbers (or numbers on one axis and letters on the other axis) to give coordinates to each cell. Glue the printed grid on the box lid. Make a hole in the centre of each cell using a pointed object like a steel skewer as shown.



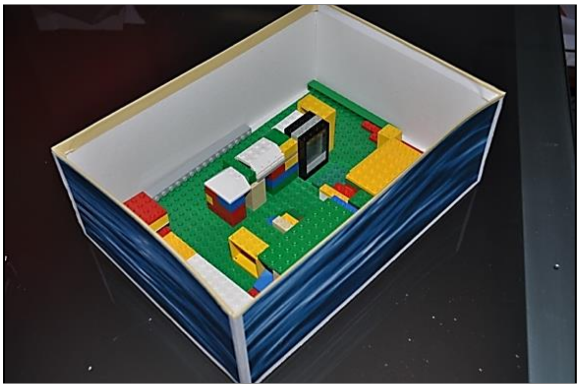
Sounding box: note the grid on the box lid and the skewer probe. *Photo by Giulia Realdon CC BY SA*

Build your "sea bed" using a number of Lego™ bricks on a Lego™ rectangular base or on the bottom of the box using Plasticine™. Make a number of "sounding probes" using wooden skewers: cut off the pointed tip (for safety reasons) and mark 1 cm intervals on the blunt skewers.



R/V Falkor, multi-beam seafloor mapping. NOAA, *public domain*

Print a table with a grid similar to the one on the box lid for recording the measured depths. Prepare a spreadsheet with the same grid as the printed table and a second table similar to the first one, but with a pre-set formula to calculate the measured "sea floor" height: = box depth – measured depth.



Sounding box bottom with Lego bricks simulating the seafloor. *Photo by Giulia Realdon CC BY SA*

Give each group a "sounding box", 2-3 probes and a printed table.

Explain to them that the model is aimed at simulating the exploration of the sea floor by means of echo-sounding. To draw the topography of the surface, students will probe the bottom of the box with the skewers and will reconstruct its topography as a 3D diagram by means of a spreadsheet.

Ask the pupils to do the following:

- allocate the roles within each group (*they should decide who will take measurements, who will record them, who will enter the data in the spreadsheet table, …);*
- explore the box bottom, probing through each grid cell with a probe (blunt skewer).

Ask the students: How are you going to gather data systematically? *(they should follow lines or columns)*

Then they should:

- read each measurement on the probe and its grid coordinates;
- record each measurement in the paper table according to its coordinates;
- enter the recorded data in the first table in the spreadsheet provided.

Ask the pupils what kind of graph they will obtain with these data *(They will obtain a "negative" image of the "sea floor". To obtain the real image of the "sea floor" they will need to subtract the recorded depth from the box depth).*

Then they should:

- copy the data from the first table and paste it in into the second one (with the formula);
- select the completed second table and click on "insert chart" from the menu, choosing "surface" chart";
- click on the chart obtained and select "chart area format" on the pop-up menu, then click on the option tab to access 3D rotation, to give a better view of the modelled surface.

Say to the pupils: imagine you are assessing the depth of sea floor by echo-sounding. The signal sent from the echo-sounder (called a "ping") travels in sea water at about 1500 ms^{-1}. If the ping echo is returned in 4s, how deep is the sea floor? *(They will have to use the formula: distance (m) = ½ sound velocity (m/s) x time (s). The measured depth is 3000 m)*

Ask the pupils:

- Which of the following has the least known surface topography? The moon, Mars or the sea floor? *(Possible answer: the moon surface resolution is about 7m (information is known from points 7m apart across the surface), Mars surface resolution is about 20 m, the sea floor is the least explored and known, the resolution of most sea floor maps is between 1.5 and 5 km, the Seabed 2030 programme is increasing this to 100 – 500m).*
- Why, in your opinion is it important to study sea floor topography? (*Possible answers include: We need to know sea floor geological structures to mitigate natural hazards (such as sea floor landslides causing tsunamis), to discover exploitable resources, to regulate the use of international waters and to explore sea floor ecosystems for their protection and sustainable use. to monitor sea-floor spreading rates?).*
- Which other applications does this technique have? *(Possible answers include: to produce better nautical maps, to explore for oil, gas and mineral extraction, to lay and repair undersea cables, for military use, …)*

……

The back up

Title: Modelling seafloor mapping.

Subtitle: How to simulate an echo-sounder study of seafloor topography.

Topic: An activity simulating sea floor topography, sea floor mapping and echo-sounding techniques.

Age range of pupils: 10-16 years

Time needed to complete activity: 50 minutes

Pupil learning outcomes: Pupils can:

- explain the methods used to measure the depth of the seafloor and to map seafloor topography;
- use an analogue model of seafloor topography mapping;
- build a 3D graph of the model sea bottom;
- carry out simple calculations to work out sea floor depth from sound travel time;
- explain the need to explore the sea floor;
- describe the possible applications of this technique.

Context:
The activity is suitable for an oceanography module in secondary school but also for introducing the study of the ocean in primary school. It gives the opportunity to learn about the methods used to explore seafloor topography and build seafloor maps and is linked with the history of plate tectonic theory. Moreover, it offers a view on what is known of the deep sea and what is still to explore.

This is one of four linked Earthlearningideas on seafloor mapping, shown in the Table on page 3.

Following up the activity:
The activity can be extended to address cartography and the methods used to build geological maps. It could be followed, for instance, by the Earthlearningideas: Geological mapping from scratch 1, Geological mapping from scratch 2, or Geological mapping from scratch 3.

Underlying principles:
- Seafloor mapping cannot use photos like land mapping.
- Seafloor mapping uses methods based on soundwaves: sea depth is measured from the time required by a "ping" to travel from an echosounder mounted on a ship's hull to the sea floor and back.
- The first maps of the world's seafloors were drawn from point measurement of depths taken by sonar a few years after World War II (in the 1950s).
- Modern multi-beam swath bathymetry allows us to scan sea floors along strips of a certain width and to reconstruct 3D images of the seafloor topography.

Thinking skill development:
Through the use of the "sounding box" (an analogue model), pupils can understand the building of a 3D image of an inaccessible surface: they will need to translate their probe measure (depth) into topography (relief), possibly facing a cognitive conflict; other cognitive conflicts may arise in comparing knowledge of the sea floor (Earth) to knowledge of alien surfaces (moon, Mars). Finally, pupils are asked to envisage other possible uses of echo-sounding, so eliciting their bridging skills.

Resource list:

For each group:
- cardboard shoe box
- printed grid for the box lid
- steel skewer to make holes in the box lids
- 2 x 20 cm wooden skewers (remember to cut off the pointed tip)
- a marker to mark 1 cm segments on the wooden skewers
- a printed table to record the measurements
- computers with spreadsheet software prepare the data table and the relief table (to be completed by the pupils)

Useful links:
Type, 'Mapwork from scratch' into the Earthlearningidea search engine to find maps giving a simple introduction to geological mapping.
See the NOAA web pages on seafloor mapping: https://oceanexplorer.noaa.gov/world-oceans-day-2015/mapping-the-seafloor-one-ping-at-a-time.html
The brochure of The Nippon Foundation-GEBCO Seabed 2030 project is at: https://www.gebco.net/documents/seabed2030_brochure.pdf

Source: Giulia Realdon, modified from Discover your world with NOAA: an activity book https://celebrating200years.noaa.gov/edufun/book/welcome.html#book

The Earthlearningidea ocean floor mapping activities	
Measuring the depths of seas and oceans: How is it done? A simple demonstration of how we measure sea floor depths and relief	https://www.earthlearningidea.com/PDF/350_Sea_floor_mapping1.pdf
Modelling seafloor mapping: How to simulate an echo sounder study of seafloor topography	https://www.earthlearningidea.com/PDF/351_Sea_floor_mapping2.pdf
Sounding the Pacific Ocean: An echo sounder traverse of the eastern Pacific	https://www.earthlearningidea.com/PDF/352_Sea_floor_mapping3.pdf
Marie Tharp: 'The valley will be coming up soon'. Bruce Heezen: 'What valley?' A woman scientist in a man's world – what was it like?	https://www.earthlearningidea.com/PDF/353_Sea_floor_mapping4.pdf