How to weigh a dinosaur

Using a dinosaur footprint impression to estimate how heavy the animal was

Dinosaurs sometimes left footprints in wet mud or sand, which hardened to leave ***trace fossils***. We can work out how heavy the dinosaur was, if we can compare the footprint with the mark made by a known weight in the classroom.
(We are giving a worked example here, to make it easier to follow the calculations, but other values may be obtained in the school, depending on the equipment available
Fill a container with sand, and soak it thoroughly with water. Pour off any excess water.
Stand a 10cm tall rectangular block of 2 x 2 cm (i.e. 4 cm^2 cross section) upright on the wet sand.
Place a 1kg mass on top of the block and let it sink into the wet sand (If you can't find a 1 kg mass, a 1 litre plastic bottle full of water would do instead, since it has a mass of 1 kg). A mass of 1 kg imposes a force of about 10 Newtons.
Measure the depth in cm to which the bottom of the block sinks into the sand *(1.5 cm)*
Pressure = force/area, so the pressure exerted by the block = *10/2x2 = 2.5 N/cm^2.*

The diagram on page 3 shows one footprint left by a small **two-legged** dinosaur.
Measure the area of the dinosaur footprint, by counting squares on the diagram, where each square represents 25 cm^2. *(325 cm^2)*.
Estimate the average depth in cm of the footprint from the side view in the diagram *(3 cm)*.
Assume that the 'sinking depth' is proportional to pressure (i.e. if pressure is twice as great it will sink in twice as deeply). Calculate the pressure exerted by the dinosaur's foot *(2.5 x 3/1.5 = 5 N/cm^2)*.

Force = pressure x area, so force (i.e. weight) = *5 x 325 = 1625 N*.
There are about 10 N per kg, so the mass of the dinosaur acting on the one foot would have been *1625/10 = 162.5 kg*. This is the weight of a person about 2.7 metres (9 feet) tall – a giant!

Does this represent the total mass of the dinosaur? What other explanation could there be?

A teacher demonstrates how to measure pressure in the sand container
(Photo: P. Kennett)

The back up

Title: How to weigh a dinosaur

Subtitle: Using a dinosaur footprint impression to estimate how heavy the animal was

Topic: How can the relationship between pressure, force and area be used to estimate the mass of a two-legged dinosaur from the area and depth of one of its fossilised footprints?

Age range of pupils: 14 - 18 years

Time needed to complete activity: 30 mins

Pupil learning outcomes: Most pupils can:

- calculate a pressure from a given force and area;
- invert the equation and calculate an unknown force from a known pressure and area;
- debate whether the result gives the mass of the dinosaur, or if it needs to be doubled to account for it being two-legged;
- appreciate that such calculations can only be an approximation.

Context: The lesson introduces the concept that an imprint (trace fossil) is just as much a fossil as the remains of the actual body – and can sometimes give very valuable information on the lifestyles of organisms. It provides a useful link between physics, mathematics and geology.

Following up the activity:
Pupils will want to debate whether the calculations based on one footprint alone represent the total weight of the dinosaur. It had two legs, so surely we should double the value? However, there must have been a point at which the whole weight of the animal was transmitted to the ground by one leg alone, as it lifted the other to walk.
Pupils who know their own mass could try to resolve this issue by making and measuring their own footprints in a wet sand pit.
Ask pupils what difference it would make if the animal had been running, instead of walking. Again, they can carry out their own investigation in a sandpit.

Underlying principles: Pressure = force/area.

- Trace fossils can often reveal as much information about the lifestyle of an organism as the fossilised remains of the organism itself – and sometimes more.

Thinking skill development:

- The relationship between the force applied and the depth of the "print" establishes a pattern.
- Applying this learning to the dinosaur print is a bridging activity.
- The debate about how much of the mass of the dinosaur is represented by just one footprint involves cognitive conflict.

Resource list:

- soft, very wet sand in a deep container (eg 10 cm)
- a 1 kg mass, or a 1 litre plastic bottle full of water (which imposes a force of 10N)
- calculator and ruler
- a rectangular block, 2 cm x 2 cm by, say 10 cm long, preferably marked at 1 cm intervals
- outline drawing of a single dinosaur footprint on a 5 cm grid for estimating the area (attached)

Useful links: Try the Earthlearningidea activity 'The meeting of the dinosaurs – 100 million years ago', published 3rd March 2008. Also:
http://www.sorbygeology.group.shef.ac.uk/dino.html
http://www.enchantedlearning.com/subjects/dinosaurs/dinotemplates/Footprint.shtml
http://www.uc.edu/geology/geologylist/dinotracks.html
http://www.scienceviews.com/dinosaurs/dinotracks.html

Source: Earth Science Education Unit (2005) *Through the lab window to the world: teaching Key Stage 3 physics.*
Thanks are due to Dr Martin Whyte of Sheffield University for his helpful comments on a draft of this activity.

Footprint of a two-legged dinosaur

(shown at half actual size)