How many sand grains are there in a bucket – or on a beach?

Planning activities to estimate the number of sand grains in a bucket – or on a beach

How can you make an accurate estimation of the number of sand grains in a bucket of sand?

Work in a group to develop and write down a plan to make this estimation, and then check your ideas with others.

If you get the chance – carry out your plan to estimate the number of grains in a bucket.

How could you make your estimate more accurate?

Now, extend this idea to work out how many sand grains are on a beach like this one.

What would you have to decide before you start? Work together to write down your ideas and devise your plan. When you have done this, think about what problems you might face and how accurate your estimate might be.

How might your estimates be changed:

- by the mean grain size of the sand
- by whether the sand was well sorted (mostly the same size of grains) or poorly sorted (a range of grains of different sizes)

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The back up

Title: How many sand grains are there in a bucket – or on a beach?

Subtitle: Planning activities to estimate the number of sand grains in a bucket – or on a beach

Topic: A planning exercise to estimate large numbers of very small items.

Age range of pupils: 12 years upwards

Time needed to complete activity: 30 minutes

Pupil learning outcomes: Pupils can:

- plan an investigation, including all the steps involved;
- carry out counting and mass or volume measurements;
- use the data collected to calculate the results.

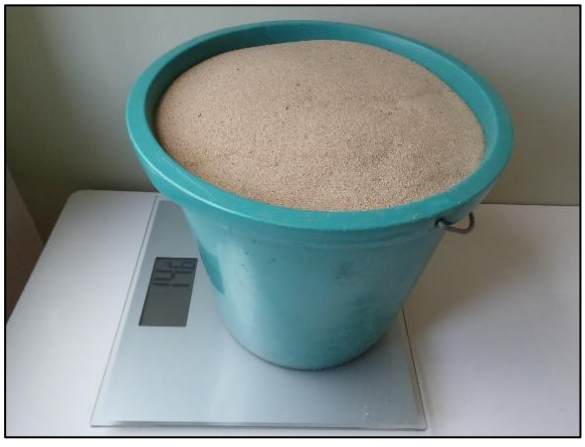
Context:

Estimating the number of sand grains in a bucket – mass calculation

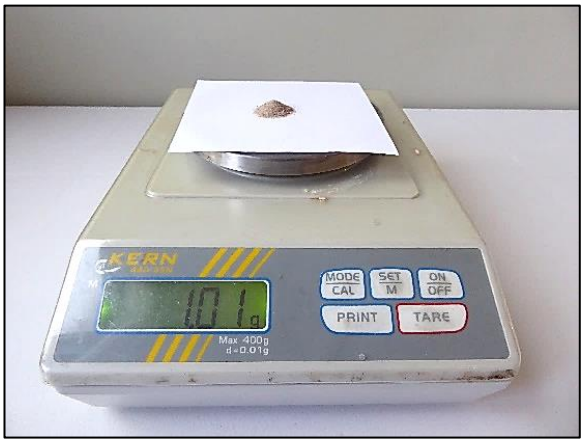
There are at least two different ways of making this estimation, each with different routes. We used mass calculations to work out our estimate, but you could use similar volume calculations, as shown below.

The mass calculation steps we took were:

- Weigh the empty bucket on bathroom scales.
- Fill the bucket with sand.
- Weigh the bucket full of sand.
- Subtract the weight of the bucket from the full bucket to give the number of grammes of sand in the bucket.



- From the bucket take and weigh out on an electronic balance exactly 1.0g of sand (using the same sand ensures the moisture content is the same).



- Pour the sand into a cone and cut it into four using a plastic card.

- Separate one of the cone quarters, form it into another cone and cut that into four too.
- Count the number of grains in the ¼ x ¼ = $^1/_{16}$ of the cone. Do this by dividing the final cone into several small 'pools' of sand on the paper and counting the number of grains in each pool using a hand lens. Write down the answers by each pool as you count.

- Multiply the number of grains by 16 to find the number of grains in 1g of sand.
- Multiply this number by the mass of the bucket in grammes – giving the approximate number of grains in the bucket.

In our calculation:

- A sixteenth of a cone contained 1444 grains.
- The number of grains in 1g of sand was therefore 1444 x 16 =~ 23,000 grains.
- The mass of sand in the bucket was 14.5kg.
- So the number of sand grains in the bucket was 23,000 x 14.5 x 1000 = 333,500,000 or 3.335×10^8 grains or just over 333 million sand grains.

Estimating the number of sand grains in a bucket – volume calculation

This calculation uses volume.

- Take a small container like a pen top and measure its volume by filling it with water and pouring the water into a small measuring cylinder.
- Dry the pen top and fill it with sand.
- Pour the sand onto a piece of paper in a cone shape.
- Divide the cone into four, then into four again, then into four again, if needed, until you get a small enough cone of grains to count.
- Count the number of grains using the method above.
- Mark the height of the sand in the bucket, and then pour out the sand.
- Measure the volume of the bucket, for example by using a one litre jug to pour water into the bucket several times until it is full to the sand mark.
- Use these measurement to calculate an estimate of the number of grains in the bucket, in a way similar to the above.

Note 1. You could find the volume of the bucket and/or pen cap by weighing them empty and full of water, since 1g water occupies $1cm^3$

Note 2. Measurement by mass is more accurate than measurement by volume.

You could make your estimates more accurate by:

- Asking four different people to count the number of sand grains in each quarter, and averaging the results.
- Asking 2-3 people to count the number of sand grains in one quarter and averaging the results.
- Using several different balances and averaging the results.

You could assess the accuracy of your results by using all the highest values in the different counts (and using different balances), to find a highest possible result. Then by doing the same for the lowest figures. Then calculate the difference. This would give a valuable view on the reliability of your estimate.

Estimating the number of sand grains on a beach

When you know the estimated number of sand grains in a bucket, that information can be used to estimate the number of sand grains on a beach.

But decisions have to be made about:
- where the sides and back of the beach are to be marked
- where the front of the beach is to be taken as. It cannot be the high tide mark, because then the beach would be fully covered. It could be the low tide mark, but should this be the lowest low tide mark of the year (during spring tides) or the highest low tide mark of the year (during neap tides)?
- How deep should your measurement go?

When you have decided the volume of beach you want to consider, then you should plan:
- how you are going measure the dimensions of the beach, for example, the length and breadth of the beach could be measured by pacing; the depth could be measured with a ruler;
- how you can use your bucket of sand estimates to help you in measuring the number of grains on the beach. For example, you could mark out a metre squared of sand and find out how many buckets of sand are filled from that area to your chosen depth;
- finally, you could make your calculation based on the number of sand grains in a bucket and the number of buckets filled by a square metre of sand, multiplied by the surface area of the beach.

How might your estimates be changed
- The coarser the sand, the fewer the grains in the bucket (and on the beach)
- The sorting of the sand will not make much difference, it is the mean grain size which determines the number of grains in the bucket or on the beach.

Following up the activity:
Carry out similar estimates such as:
- number of grains in a bag of sugar;
- number of grains in a salt shaker.

Underlying principles:
- The number of very small items in a container or an area can be estimated by counting a known small proportion of the items and multiplying up.
- Factors can be identified to make the estimation more accurate and that might alter the estimate.

Thinking skill development:
Developing workable plans is a construction activity, whilst if they are developed by a group, there may be cognitive conflict and metacognition involved.

Resource list:
- no resources are needed in the planning stages
- to estimate the number of grains of sand in a bucket by mass:
  - a bucket
  - bathroom scales
  - water
  - enough dry sand to fill the bucket
  - electronic balance
  - plastic card
  - x10 magnifier
  - pencil

- to estimate the number of grains of sand in a bucket by volume:
  - bucket, water, sand, plastic card, x10 magnifier, pencil
  - pen top
  - small measuring cylinder
  - marker pen
  - 1 litre jug

- to estimate the number of sand grains on a beach
  - the results of the calculations above
  - ruler
  - spade

Useful links:
Use a search engine to look up interesting estimates such as the number of sand grains on Earth or the number of water molecules in the oceans.

Source: Chris King of the Earthlearningidea Team.

Beach image:
https://www.geograph.org.uk/browser/#!/q=beach/country+%22England%22/pagesize=30/page=3/image=23635