Learn Chemistry
Enhancing learning and teaching with the RSC

The Nature of Science: Black Box

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Black box activity 1: Tricky tracks

Teachers' notes

Objectives

- To help the students distinguish between observation and inference.
- To introduce the concept that all ideas are valid unless there is further evidence to suggest otherwise.

Teaching topics

This activity is appropriate for 11–13 years olds and fits into a scheme of work anywhere where observations are made. It can also be successfully used with lower ability 14–15 year olds. A possible follow up activity would be to carry out a series of class 'test tube' experiments, which required careful observation, followed by interpretation.

Background information

This activity assumes the following definitions:

- An observation is what is actually seen.
- An inference is interpreting what you see.

Teaching tips

This activity could be carried out as a whole class exercise, with individual students recording their own answers or in groups of 3–4 students.

The lesson could be introduced as follows:

Scientists are always putting forward ideas or theories to try and explain the things they see happening in the world.

Scientists often test their ideas and theories by carrying out some experiments. Sometimes new ideas come along which do not fit the old ideas. So more experiments have to be carried out to see if the new idea is correct.

Resources

- OHP – if the activity is carried out as a whole class exercise. Photocopiable worksheets **Tricky tracks 1–3** will need to be transferred onto OHT slides.
- Class sets of student worksheets if the activity is to be carried out in groups
  – Tricky tracks 1
  – Tricky tracks 2
  – Tricky tracks 3
  – Questions

Timing

60–70 minutes. Approximately half the time should be used to carry out the worksheet tasks and the rest of the time discussing the answers.

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Possible lesson plan

1. Give out the student worksheet **Tricky tracks 1** and the **Making a model or theory** worksheet. The class starts the worksheets either individually or in groups and collects **Tricky tracks 2** and **3** as required.

   Or if using an OHP, put up **Tricky tracks 1** and give the class 10 minutes to do question 1, before putting up **Tricky tracks 2** and **Tricky tracks 3**.

2. Feedback to the whole class some answers to question 1, by asking different students to read out their accounts. Try and get as many different explanations as you can. It is important to accept all explanations equally.
3. Go through the rest of the questions, pointing out the difference between observation and inference.
4. Finally, link this exercise to scientists, saying that scientists often make similar inferences as they try to interpret their observations. There may be several equally valid theories until new evidence comes along to change it.

Next lesson
Carry out a class practical which involves recording observations and deductions in a table. For example, the reaction of metals and acids, or calcium and water, or iron and sulfur.

Adapting resources

The student worksheet can be easily adapted to meet the needs of less able students by omitting some of the more demanding questions, such as 3 and 7, and renumbering the other questions.

Some students may find question 3 confusing and may become frustrated by the exercise (see answers), but it should present no problems to the more able student.

Answers

1. All answers to question 1 should be accepted.

Possible answers to question 1 could include:

a) Two animals or birds were out hunting in the forest. On meeting each other at the clearing, they had a fight.

b) Two animals or birds had a fight in the forest and then went off home to different places.

c) The tracks lead down to the place where birds meet before going for a swim. During the day many different birds will come and go, that is why you can see so many tracks. The big birds and little birds live in different places and that is why the big tracks go off in a different direction to the small tracks. Most of the birds arrive and leave by air, so you cannot see their tracks on the ground. Usually the small birds and the large birds go to the ponds at different times because the little birds try to avoid the big birds, which often chase them.

d) One day a large male dinosaur was out looking for food. As he was searching a small area he noticed a beautiful female dinosaur coming towards him. It was love at first sight. Being a little shy, he hid behind a rock and when she got closer he jumped out and introduced himself. At first she was afraid, she thought that he was going to attack her and she tried to escape. But when he spoke and told her not to be afraid, they sat down on the rock and had a good chat.

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2. In **Tricky tracks 2** we see two sets of marks. The marks on the left side of the page are bigger than on the right side of the page. Each big mark has three points coming out of a small black blob. The marks form a diagonal line. Each mark is pointing in the same direction.

   The marks on the right hand side of the page have three points coming out of an elongated blob. There are two rows of marks going along the side of the page.

   There are 14 big marks and 34 small marks.

   Only accept answers that describe what is actually seen on the page.

   Do not accept any answers that try to interpret what the marks are.

   A typical student answer might be:
   'I can see two sets of bird tracks on the page. One bird is bigger than the other bird.'

   Challenge the student: How do you know they are bird tracks? Could the tracks belong to anything else?

   Explanation: You should now explain that an observation is what you see on the page, not what you think you see on the page.

   The typical student answer given above, had been interpreted by using some other knowledge.

   The student reasoning could be as follows:

   'From previous knowledge, I know that these marks resemble birds tracks. I know that big birds have bigger feet than small birds, therefore I have used bird tracks in my answer.'

   Remind the class of the question, 'What do you observe in **Tricky tracks 2**?'

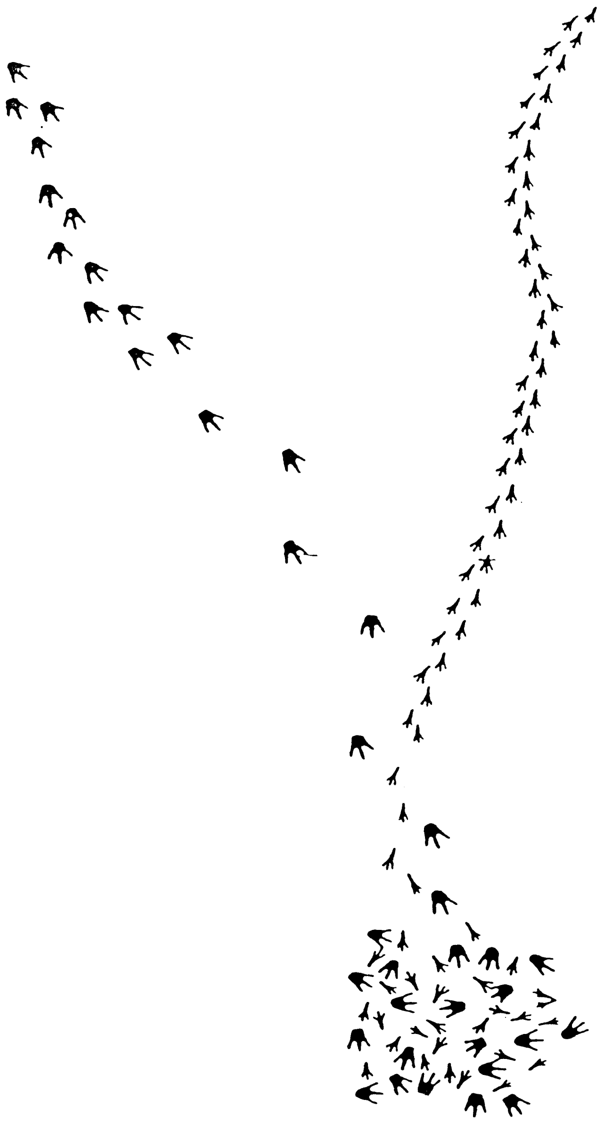
3. This is really a trick question. We do not know that the tracks have been made by animal and we do not know that they are going in the same direction. It should be pointed out that this question has been built on two assumptions. Often in science, we have to be careful about the questions we ask.

4 & 5 These should be treated in the same manner as question 2. You may wish to give the class time to change the answer to their questions, in the light of the answer to question 2.

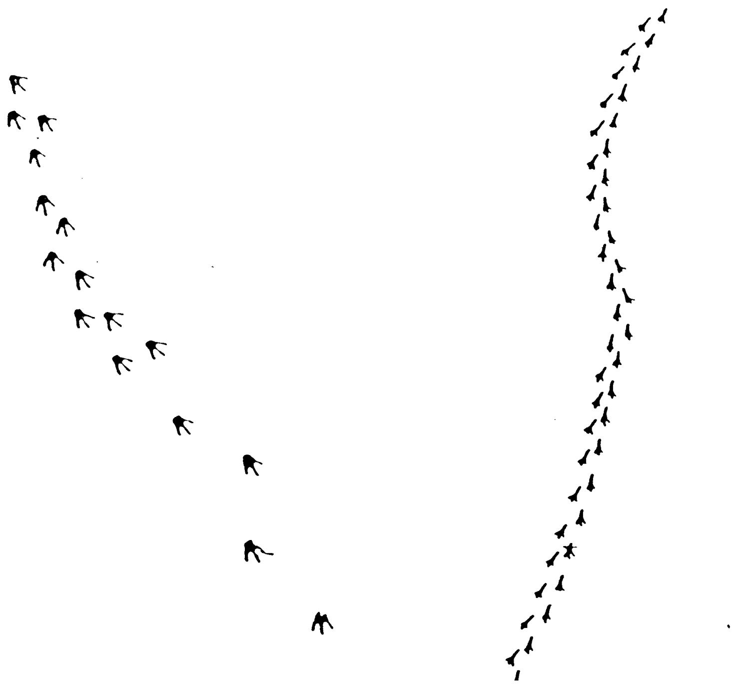
6. Based on the current evidence, we can never know what has really happened. We can only imagine what has happened. Therefore, at each stage all the theories put forward in question 1 are equally valid.

7. To find out more about the situation we could look try and identify the tracks using a key. Once the tracks were identified, more could be found out about the behaviour of the animals, which may offer support to some theories and not to others.

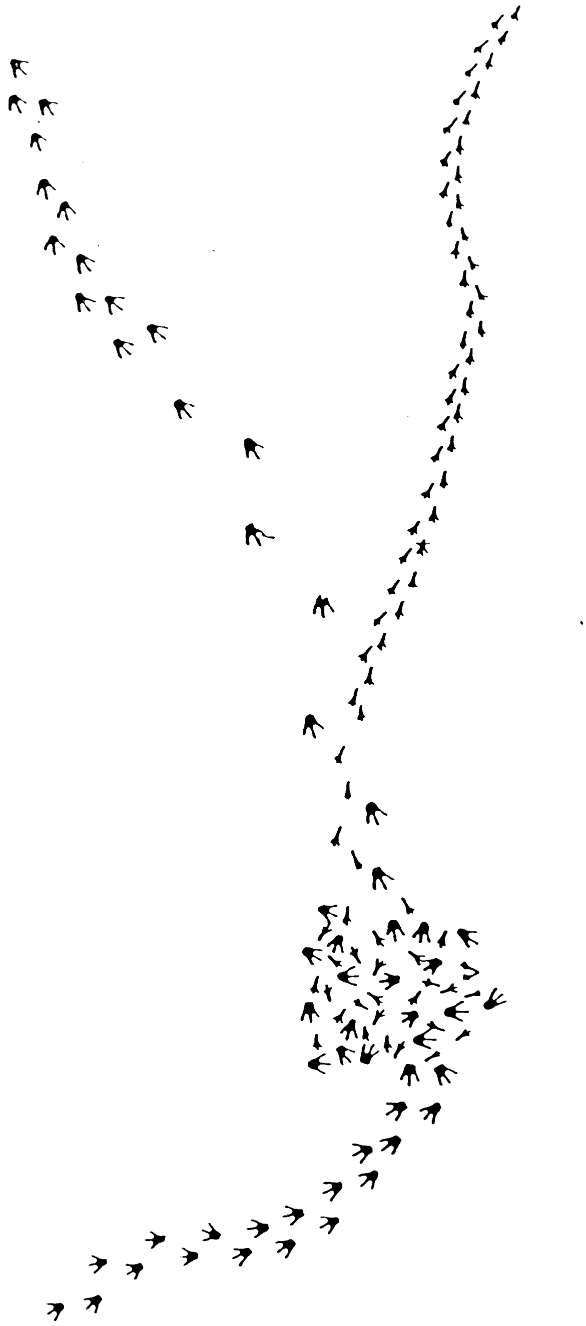
Tricky tracks 1



Tricky tracks 2



Tricky tracks 3



Questions

1. Carefully study **Tricky tracks 1** and write a short account of what you think has happened.

Now collect Tricky tracks 2 from your teacher

2. What do you observe in **Tricky tracks 2**?
3. Why are the two animals heading towards the same point?

Now collect Tricky tracks 3 from your teacher

4. What do you observe in **Tricky tracks 3**?
5. What do you observe in **Tricky tracks 1**?
6. Based on what you have found out so far, do you think we can ever know what has really happened?
7. What could you do to find out more about the situation?

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Black box activity 2: The cube activity

Teachers' notes

Objectives

- To look for patterns and use them to work out the missing information.

Outline

The search for patterns based on data is a large part of the scientific method. The patterns can then be used to predict further data points and then are often applied to other systems. It should be emphasised that scientific knowledge is based partly on observation and experiment, and partly on human creativity in interpretation.

Teaching topics

This activity is appropriate for 11–12 year olds and can be easily fitted into a scheme of work. The exercise could be used to lead into some 'real data' interpretation exercises either using data gathered from their own experiments or data from secondary sources.

Teaching tips

This activity could be carried out in groups of 2–4.

Resources (for each group)

- Copies of the templates for the three cubes or cubes already made up
- Scissors
- Sellotape
- Card or paper (for making more cubes)
- Student worksheets
  – The cube activity

Timing

One lesson. It can be easily lengthened or shortened by varying the different number of cubes given to the class.

Possible lesson plan

1. Hand out a set of cubes to each group (or get them to make up the cubes from the templates).
2. Ask the students to work out the missing number, by recording their observations and explaining how they got their answers.
3. At the end of the activity ask different groups to present their answers to the rest of the class.
4. Ask if other groups have got the same answer by a different route.

5. Give the correct answers if no one has got them right.
6. This could then lead to a class discussion on the creativity involved in interpreting results.
7. When they have finished, get the students to make up their own cubes from the blank cube on the template and give them to other groups to solve. You could suggest that their cubes used letters as well as numbers.

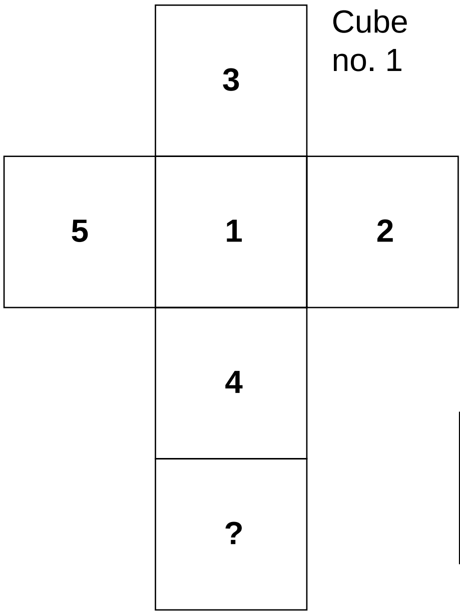
Answers

There may be other valid patterns not included in the table.

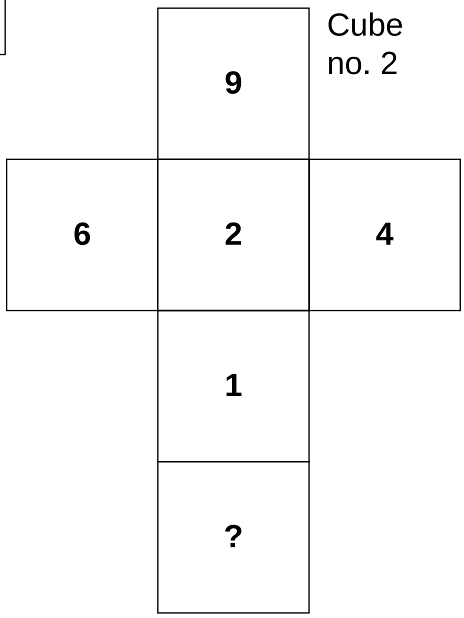
Cube	Answer	Possible pattern
1	6	Consecutive numbers 1–6 Or opposite sides of the cubes add up to 7 Or numbers are arranged in the same pattern as found on a dice
2	8	Opposite sides of the cube add up to 10
3	36	The numbers on the cube are the squares of numbers 1–6

The cube activity

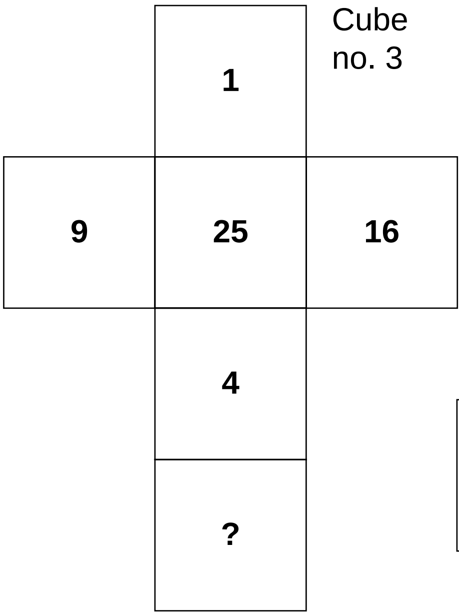
Cube no. 1



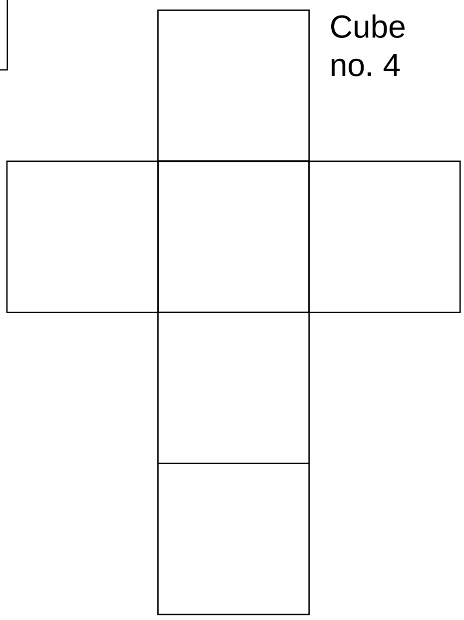
Cube no. 2



Cube no. 3



Cube no. 4



Black box activity 3: A model tube

Teachers' notes

Objective

- To understand the concept of modelling.

Outline

Black box investigations are a good way for students to learn about scientific theory and modelling because as the name suggests they are working in the dark. In real life scientists spend a lot of time working in the dark, trying to piece together data collected from various sources.

Teaching topics

This activity is appropriate for 11–14 year olds and could be used at any point in the scheme of work because no specific knowledge is required. However, it does lead nicely into thinking about a scientific model such as the particle theory of matter or the atom.

Resources

- 1 cardboard tube about 30 cm long (*eg* from the centre of kitchen roll)
- 1 plastic ring (optional, you can simply loop the lower rope over the upper rope)
- Rubber bungs or tape (to seal the ends of the cardboard tube)
- String.

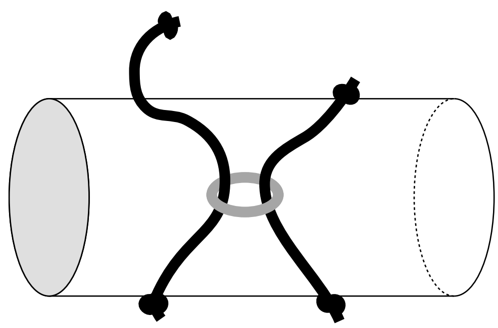


Figure 2 The inside of the model tube

For each group

- Toilet roll tubes
- String, tapes
- Plastic rings optional.

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Timing

60–70 minutes

Possible lesson plan

1. Demonstrate the model tube to the class, pulling on different strings. Each time one string is pulled another will move. The pattern of movement will look quite complex. Tell the class that they are going to make a model of the tube, but they are not allowed to look inside.
2. Ask the class to observe carefully as the first string is pulled.
3. Ask the class to 'hypothesise' as to what is happening inside the tube.
4. Each member of the class should now draw a rough model of the inside of the tube.
5. Carry out a second test, by pulling a different string.
6. Ask the class to make another hypothesis.
7. According to the new evidence and hypothesis, the rough diagram should now be modified.
8. This process can be repeated until you think that the students have a good idea of what is happening in the inside of the tube.
9. Ask the class to make their models.
10. Gather the class together to compare the student's models with the original one. The discussion that follows will depend upon the quality of the models. You should aim to talk about the different models that are offered, about difficulties encountered, maybe frustrations experienced from not being allowed to look inside and stress that a model can never be the real thing.
11. The process of making a model should then be linked to science. You may wish to formally go through the process they have just carried out (see flow chart **Making a model or theory** in the introductory notes). Find out if certain students were influenced by what other people in the room were doing. Was there collaboration? Did some people give up on their own ideas and team up with others? Point out that real scientists often start out with their own ideas, but often the real progress is made when they exchange ideas and theories with other scientists. Often scientists team up and work together.