Elementary Science

TESS India

Unit 12:

Collecting, recording and displaying data: exploring heat and temperature

Teacher Education through School-based Support in India
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The TESS-India project (Teacher Education through School-based Support) aims to improve the classroom practices of elementary and secondary teachers in India through student-centred and activity-based approaches. This has been realised through 105 teacher development units (TDUs) available online and downloaded in printed form.

Teachers are encouraged to read the whole TDU and try out the activities in their classroom in order to maximise their learning and enhance their practice. The TDUs are written in a supportive manner, with a narrative that helps to establish the context and principles that underpin the activities. The activities are written for the teacher rather than the student, acting as a companion to textbooks.

TESS-India TDUs were co-written by Indian authors and UK subject leads to address Indian curriculum and pedagogic targets and contexts. Originally written in English, the TDUs have then been localised to ensure that they have relevance and resonance in each participating Indian state's context.

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Introduction

Collecting and recording data is a fundamental part of the scientific method. Once data has been recorded and organised, students can begin to draw conclusions about the way the world works around them.

Collecting and handling data allows students to identify patterns, form theories and formulate further questions about their surroundings. Scientific data can be collected from carefully planned experiments, from general observations, or from random discoveries made during play activities.

In this unit you will explore the different ways in which elementary-level students can be encouraged to collect and interpret meaningful scientific data. The unit ends with a consideration of the purpose and value of displaying students' work in the science classroom. TDU 13, *Practical investigations: exploring seed germination*, provides a more detailed explanation of the scientific method.

Learning outcomes

After studying this unit, you should be able to:

- incorporate a variety of ways of collecting, organising and representing scientific data into your elementary science lessons
- support students of all abilities in handling scientific data creatively
- use classroom displays effectively.

1 Collecting, recording and displaying data in the classroom

There are many possible ways of collecting and recording scientific data in the elementary science classroom. These include using tables, charts, graphs, sketches, photos and even video recordings. Older students will probably have explored data handling methods as a discrete subject in the maths curriculum. They will therefore have more experience than younger students of collecting, analysing and reporting on different forms of data.

Younger students can lose interest if collecting and reporting become just another writing task. The challenge for elementary teachers is to devise creative and accessible ways for younger students to organise, interpret and record scientific data.

The following activity asks you to review different ways of collecting scientific data with a colleague.

Activity 1: Ways of recording and representing data

Together with a colleague, examine Table 1, which shows a number of ways that elementary-level students can collect, record and represent scientific data. Discuss which ones you have used in your classroom and which ones are new to you. If your colleague has tried methods that you have not tried yourself, ask them to describe how they used them. Likewise, if you have methods your colleague does not know about, share your experience.

When you have finished discussing the methods listed, share any other ones either of you have used and add these to the table.

Table 1 Collecting, recording and representing data.

Diagrams	Drawing simple diagrams can help students to communicate and record what they have observed. Older students can add labels and explanations to their drawings.
Tables	Students can record words, pictures or numbers on simple tables. Younger students might begin by recording and organising data on pre-prepared tables created by their teacher. As students get older, they should be able to devise their own data collection tables, tailoring them to their particular investigations. It is important that students are taught to use frequency tables from an early age so that they can easily transform information into bar charts (bar graphs) when they have more experience of data handling.

Graphs	Students can use a variety of simple graphs to represent their data. Graphs show comparisons and will therefore support students in identifying patterns and drawing conclusions. Younger students can be helped to complete simple bar charts with vertical or horizontal bars. More experienced students can move on to using line graphs, histograms and pie charts. Students can be supported by creating graphs as a whole class, including making human graphs (see below).
Pictographs	Younger students can use pictures to represent information on a chart or graph. This will help to develop their understanding of more abstract data representation such as bar charts.
Human graphs	Where space is available, students can make a human graph by using themselves to represent particular information. Creating human graphs supports younger students' understanding of graphs, while being fun and motivating for older students. Human graphs can be supplemented by chalk markings to create graph axes, to write numerical scales, to label bars, etc.
Venn and Carroll diagrams	Venn and Carroll diagrams can help students to organise, sort and classify objects according to two or more criteria. A Venn diagram is a type of graphic organiser that uses overlapping circles to represent the common features among different sets of information. A Carroll diagram organises things by asking questions that are answered either 'Yes' or 'No', and classifying the data on a grid composed of four squares.
Photographs	Photographs taken in the classroom can be used to record evidence and can help students to recall what they have done.
Videos	Some schools or teachers may have access to a video camera, or a cell phone or tablet that can record video. Students can record a science lesson as it happens and review the video later in order to draw conclusions. Students can also record a scientific investigation on video or use video to make a scientific report.
ICT	If you or your students can access a computer, there are numerous software packages that will help your students collect and organise scientific data.

Bullet points	Writing in complete sentences can hinder the process of data collection. Notes, ideas, questions and observations can be recorded quickly using bullet points.It is important to avoid making scientific discovery into yet another writing task!
Lists	Lists can be another useful tool for recording information. They can also be used to write brief instructions for carrying out experiments.
Brainstorming	Students can use brainstorming to record what they know about a subject at the beginning of a topic and add to it as their knowledge and understanding develops.
Flowcharts	Flowcharts are useful in demonstrating processes or changes over time.
Circuit diagrams	Students can create their own circuit diagrams to record the electrical circuits they have made.
Mind maps	Mind maps can help students to organise data while representing the relationship between objects.
Reports	Report writing is an ideal way of organising and presenting the findings of an investigation. Younger students can provide verbal reports for their peers.
Posters	Posters combining words, diagrams and flowcharts, can be used to report an experiment or to show what students have learned about a topic more generally.
Leaflets	Making leaflets is another way for students to present their data in a logical way.
Letters	An imaginative idea is to write a letter to your students, setting out a scientific problem and asking them to report the results of their investigations in their own letters back.
Cartoon strips	Students can create a cartoon strip of what happened during a practical investigation and what they found out as a result. They can invent their own cartoon characters to provide the explanations. A cartoon of what happens when water and oil are mixed together is one example of this form of presentation.
Artefacts	Occasionally, the results of an investigation may produce two-dimensional products, which students can tape or glue directly onto a poster or display.

Class books and displays	Class books and displays of examples of students work, such as photos, posters, leaflets, word banks and questions, can help to organise and consolidate students' understanding.

2 Supporting students in collecting, representing and interpreting data

Pause for thought

- What problems do your students have when recording their observations?
- What could you do to support them with data handling in future lessons?

The process of data collection and representation will prove much less abstract and challenging if your students are encouraged to be proactive – for example, by posing scientific questions and suggesting what data needs to be collected and how themselves. This is covered in TDU 5, *Using questions to extend students' understanding of forces*.

The skills needed to collect and represent data can be developed in a number of practical ways, such as:

- using non-standard measures when working with younger students – examples include hand spans or pencils rather than rulers or tape measures to measure distance
- supporting students in the use of standard measures through practical activities involving measuring and weighing, after which the students can transfer these skills to a scientific investigation
- representing data in engaging ways by building large bar charts with blocks, using pictographs or collectively representing data in groups or as a whole class (for example by making human graphs).

Once the data has been collected, students will need support to identify patterns and generalities within it. Being able to extract and interpret data is a key scientific skill that you need to model for your students.

One way of doing this is by introducing a five-minute activity at the beginning or the end of your lessons where you present different forms of data to your students and ask them to tell you what the tables or graphs demonstrate. Careful questioning, including using higher-order forms such as 'Can you explain why …?', will support your students in interpreting the data. Refer back to TDU 5, *Using questions to extend students' understanding of forces*, for examples of higher-order questioning. Be sure to demonstrate to students how to read and create the axis scales on graphs using divisions of 1, 2, 5 and 10 before they are expected to do this on their own.

3 Evaluating work samples

Continuous and comprehensive evaluation

The ongoing and continuous assessment of your students' learning can help you to gauge their progress and inform your subsequent lesson planning.

By taking on the role of observer, by listening to and watching your students as they undertake a scientific investigation, you will gain insights into their developing knowledge and understanding of a particular topic or concept. The way in which students collect and interpret data during an investigation can provide you with evidence of their current level of skill.

Younger or less skilled students can be given pre-prepared tables that support their data collection skills. However, this should be done sparingly as it can also limit independent thought and creativity. It is essential to give students the flexibility to revise their ideas, revisit their analyses and think of new possibilities in relation to their investigations, as these are important skills in scientific enquiry. Allow more competent students the opportunity to create their own tables or adapt other methods of collecting and recording evidence.

In the following activity you will look at some data collection work samples and consider what they tell you about how the students' knowledge and understanding are developing.

Activity 2: Analysing students' data collection skills

Look at the examples of data in Figures 1–6, as collected and represented by five students from the same class. The teacher has made comments about each student's independent additions and thoughts in red pen. After looking at the samples, answer the following questions:

- What data has been collected, and how has it been represented by each student?
- Do you think the student has been encouraged to record their ideas creatively? Why?
- What does each sample tell you about the student's scientific understanding?
- What would you suggest the student does next time to improve their data collection skills?

Figure 1 Work sample 1. The teacher has noted that 'Student chose materials and vocab. independently'.

Figure 2 Work sample 2. The teacher's comments are 'Student completed investigation with working partner – student gives a verbal report of findings and draws conclusions'.

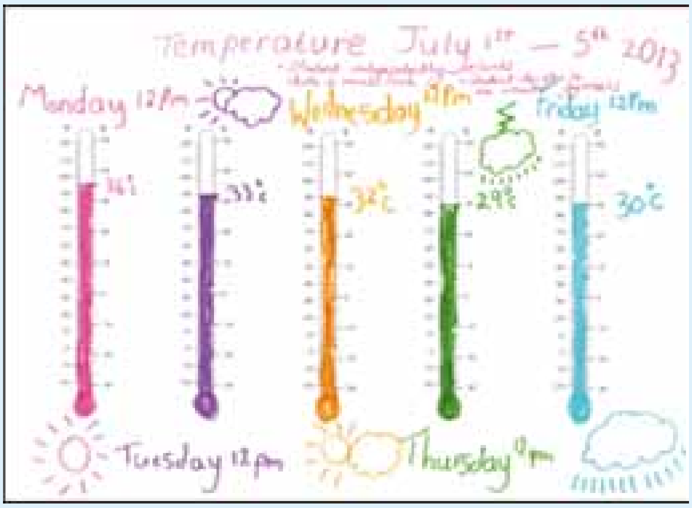

Figure 3 Work sample 3. The teacher has added the comment ‘Student independently records data and reads scale’ and ‘Student decided to use weather symbols’.

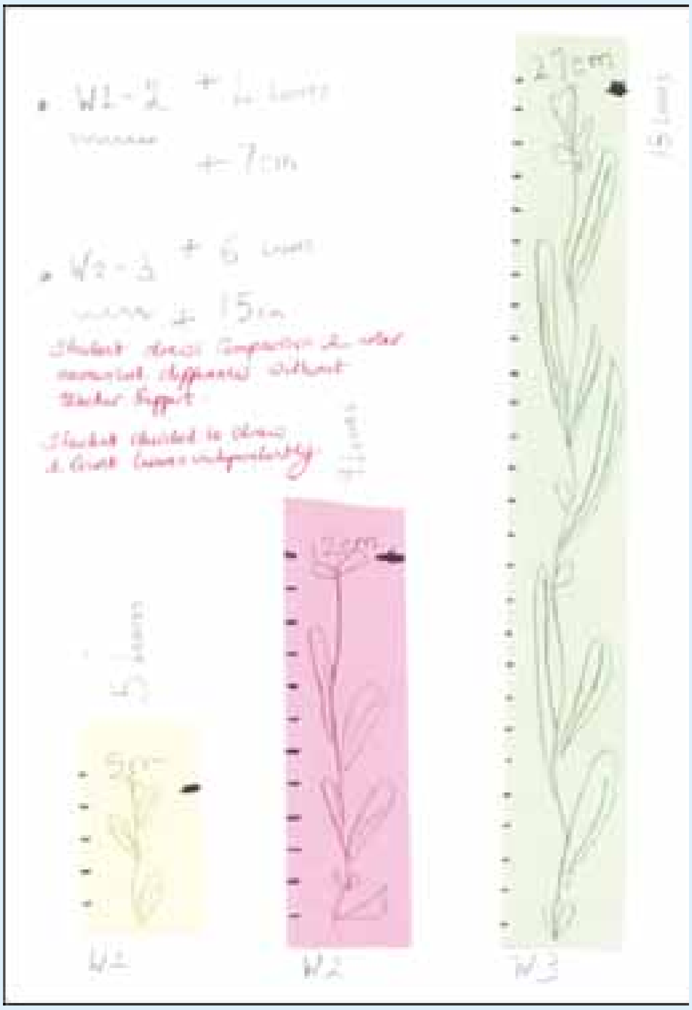

Figure 4 Work sample 4. The teacher has added ‘Student draws comparison and notes numerical differences without teacher support’ and ‘Student decided to draw and count leaves independently’.

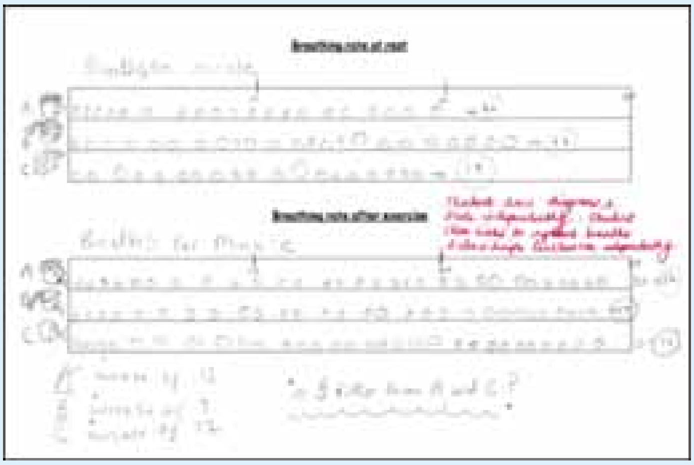

Figure 5 Work sample 5A. The teacher has added ‘Student drew diagram and scale independently. Student chose circles to represent breaths and drew simple conclusion independently’.

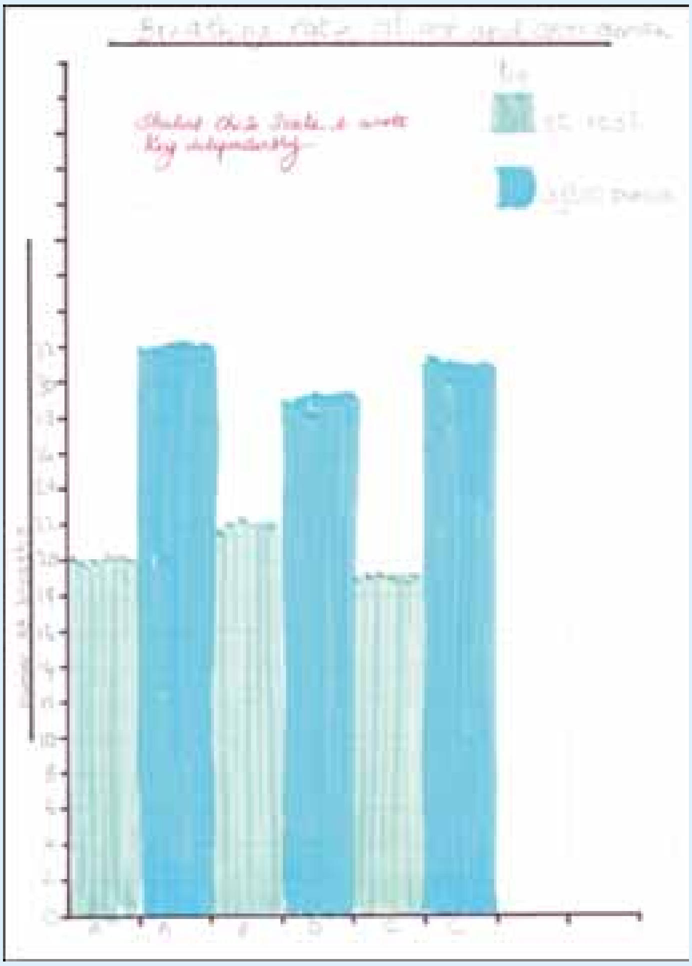

Figure 6 Work sample 5B. The teacher has added the comment ‘Student chose scale and wrote key independently’.

Table 2 demonstrates how you can organise your notes for each sample.

Table 2 Analysing sample 1.

	Question	**Answer**
1	What data has been collected, and how has it been represented by each student?	The student has collected physical data. The student has selected materials with different properties and stuck them onto a grid.
2	Do you think the student has been encouraged to record their ideas creatively? Why?	Yes. Collecting and sticking samples of materials onto a grid enables the student to record data in an engaging way.
3	What does each sample tell you about the student's scientific understanding?	The student understands that materials have different properties. The student is able to use scientific vocabulary to describe materials.
4	What would you suggest the student does next time to improve their data collection skills?	The student could organise and sort the materials into similar types or varying degrees of hardness or flexibility.

Pause for thought

- What have you learnt by looking at the work samples?
- What ideas will you use in your future classroom practice?

4 Handling data during investigative work

Case Study: Mrs Singh supports a small group in conducting a heat-related experiment

Mrs Singh, a Class V teacher, identified nine students in her class who were struggling with collecting and interpreting data during investigative work. She decided to work with them in a small group, while the rest of her class completed the same investigation independently. Read how she went about this.

Before beginning the investigation into water temperature, I decided to quickly review some of the data collection skills that the small group would need while they were performing the experiment. They would need to measure amounts of water with accuracy and read a thermometer scale in divisions of two degrees.

I gave the group two identical glass beakers and a jug of water. I explained that the scale on the side of each beaker represented millilitres and that each mark represented 10 ml. I practised counting in tens with the students before asking them to pour given amounts of water into one of the beakers. When they were confident with measuring in millilitres, I asked them to measure out 50 ml of water into one beaker and 100 ml into the other, ready to use during the experiment.

Earlier I had prepared a large picture of the thermometer that we would be using. I explained to the group that the thermometer measured temperature in degrees Celsius, and that each of the smaller marks along the scale represented 2 °C, while the more prominent marks represented divisions of 10 °C. I pointed to a mark on the thermometer scale and asked what the temperature was. When the students were used to reading the scale in divisions of 2 and 10 degrees, I explained that if the temperature was between two marks, we would read that as being half of 2, which is 1. We read the scale a few more times with this in mind.

I showed the group of students the two beakers of water that they had measured earlier and asked them ‘What do you think will happen if we heat the two identical beakers that contain different amounts of water for the same period of time?’

After discussing the question with a partner, the students then shared their ideas with the rest of the group. One student suggested that both beakers would have the same temperature, while another student said that they thought the beaker containing the smaller amount of water would have a higher temperature. I wrote both predictions on the board to refer to later.

I explained to the group that we were going to heat both beakers of water using spirit lamps [Figure 7], ensuring that the same heat was applied to each to make sure that it was a fair test. I decided to use an enlarged data collection table that I had prepared beforehand so that all the group members could be involved in recording the information. The group took an initial temperature reading of 24 °C in both beakers. They were able to read the scale on the thermometer independently but needed a little support to record the first temperature on the table [Figure 8]. The group recorded the temperature of each beaker at regular intervals and made observations about which beaker boiled first.

Figure 7 Heating the two beakers with spirit lamps.

Understanding the difference between Heat & Temperature

S.No.	Time ([redacted] Minutes)	Temperature ([redacted] ml. water sample)	Temperature ([redacted] ml. water sample)
1.	0	24 °C	23 °C
2.	1	37 °C	27 °C
3.	2	43 °C	31 °C
4.	3	61 °C	37 °C
5.	4	74 °C	44 °C
6.	5	85 °C	50 °C
7.	6	95 °C	54 °C
8.	7	100 °C	59 °C
9.	8		66 °C
10.	9		71 °C
11.	10		76 °C
12.	11		81 °C
13.	12		85 °C
14.	13		89 °C
15.	14		93 °C
16.	15		96 °C
17.	16		97 °C
18.	17		98 °C
19.	18		100 °C
20.			
21.			
22.			

Figure 8 The students' results, presented as a table.

The students completed the rest of the experiment without my support. When all the data had been collected, I asked them to tell me the result.

One student said 'The 100 ml beaker took more time to boil than the 50 ml beaker.' I then asked my students 'How can we find out how much longer the 100 ml beaker took to boil than the 50 ml beaker?' With some support, they established that taking seven minutes away from eighteen minutes would provide them with the answer.

I asked them what else their results showed. Someone said 'the beaker that had 50 ml of water boiled faster than the 100 ml beaker of water', while another suggested that 'both beakers of water boiled at 100 °C and that larger amounts of water need longer to boil'.

After they had interpreted the data, I went on to ask my students 'Is there any other way to represent this data that will be easier for us to see our results?' One student suggested that we could draw a graph. We therefore created a graph together. I showed them how to label the X and Y axes, and demonstrated how to plot the data points of temperature on the graph. The students completed the rest of the graph without my help [Figure 9]. I later added the table of results and the graph to a classroom display related to temperature and rate of change.

Graph showing rate of change of temperature

Initial temperature of water in two beakers = 24 °C

Readings taken at an interval of one minute.

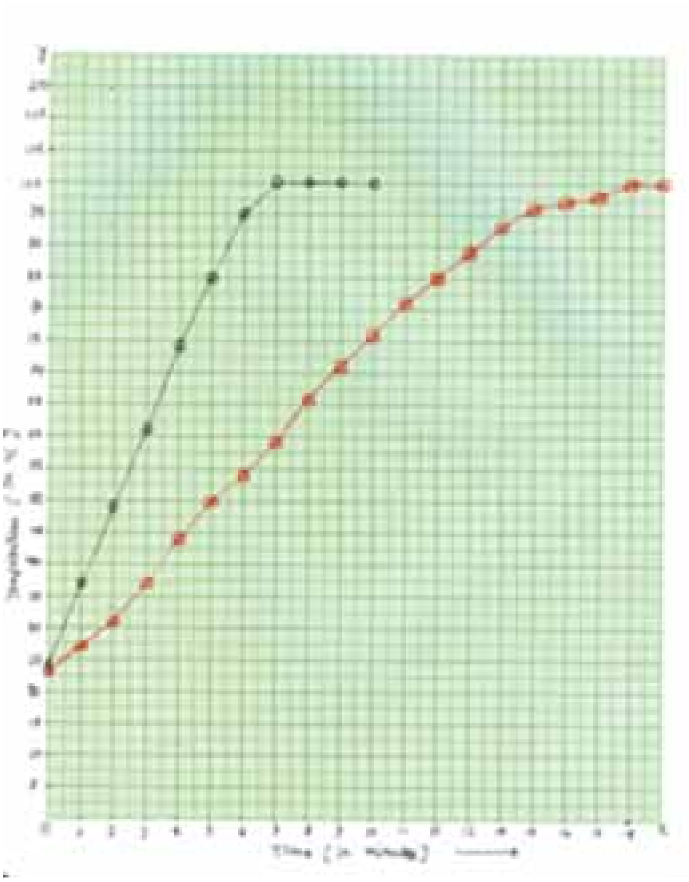

Figure 9 The students' results, presented as a graph.

Mrs Singh's reflection on the lesson

I feel that over the course of the lesson, the group of students I worked with became more confident at collecting, recording and interpreting data. The initial work we did to practise reading and using temperature scales enabled the students to record data independently. Had we not done this, they would not have been able to complete the experiment and would not have made the connections they did regarding water volume, temperature and boiling points.

Drawing a graph highlighted the similarities and differences between the water samples. I still feel that these eight students will need support when handling data during investigative work. However, their confidence and understanding of data collection and interpretation are definitely growing.

Activity 3: Reviewing the case study

Re-read the case study and make notes on your answers to the following points:

- How did Mrs Singh support the students in her class who found data handling challenging?
- How did these students' learning improve in the lesson?

5 Putting data handling into practice

In the following activity you will plan and carry out a simple investigation that provides opportunities for your class to collect and interpret data.

Activity 4: Planning a lesson to include collection and representation of data

Look at the activity idea below and create a more detailed lesson plan that will support and encourage your students to collect, organise and interpret data. Adapt the lesson to suit the age range and needs of your students. Alternatively, use your own idea for a lesson. A lesson plan template can be found in Resource 3 of TDU 1, *Using brainstorming to elicit prior knowledge: sound and musical instruments*.

Refer back to the work samples and data collection ideas that you have explored so far in this unit. Consider what support your students may need when collecting data and how they can be encouraged to represent data in creative and engaging ways. If you prefer, allow your students to devise their own way of collecting and recording data, as this will give you an indication of their level of competency in doing so.

Keeping it Warm

Outcomes

By the end of the lesson, your students should be able to:

- understand that not all materials are good thermal insulators
- record, organise and interpret the data from their own investigation.

Resources needed

A measuring jug, small containers (such as recycled yoghurt pots) to hold water, samples of different material (large enough to wrap around the containers), a thermometer, a stopwatch, rubber bands (to hold the material in place around the container) and hot water.

Introducing the investigation

You could write a letter to your class from an imaginary person who needs to keep their tea warm for as long as possible. Your students could then write a letter back and report their findings.

Conducting the investigation

1. Ask your students to suggest materials that could keep them or other things warm. Discuss possible ways that they could investigate the best material to keep a liquid warm.
2. Explain that they will be given containers of warm water and samples of different materials to use during the investigation.

3. Discuss with them how the investigation can be carried out and how they will be able to tell which materials make good insulators.
4. Ask your students to consider how to make sure their tests are fair – for example, by using containers made from the same material, or by using the same volume of water.
5. Agree the best way to measure, record and present their data, allowing your students the flexibility to add their own ideas and observations.
6. Ask your students to carry out the investigation. They should identify good thermal insulators by wrapping different material samples around the containers of warm water and monitoring the water temperature. Support them in making observations, and in collecting, recording and organising the data during the investigation.
7. At the end of the investigation, help your students to interpret their data and draw conclusions.
8. Conclude the activity by getting your students to write a report about their findings.

Pause for thought

After planning and delivering your lesson, make brief notes to answer the following questions:

- What went well during the investigation?
- How did your students collect and organise the data?
- Did any students struggle or excel when handling and interpreting the data?
- What do you need to do to improve your students' data handling skills next time?
- If you had the chance to teach this lesson again, would you do anything differently? What? Why?

6 Effective classroom displays

Classroom displays of the experimental data collected by your students will help them to recall their shared experiences and understanding of particular concepts. Displaying students' data and conclusions can provide evidence of the learning that has taken place in the science classroom and can be used as a point of reference when exploring related topics in the future.

Look at the following photographs of science displays in an elementary science classroom, in Figures 10 to 13. Do you think they are effective? Why?

Figure 10 Interactive, cross-curriculum display on the human skeleton.

Figure 11 Classroom display related to the human skeleton.

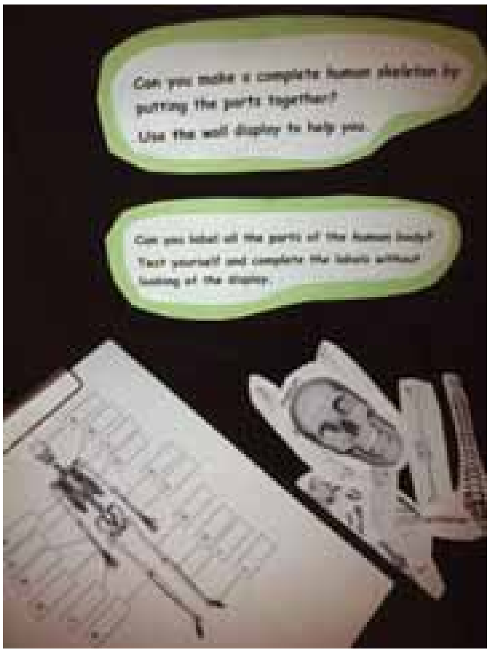

Figure 12 Interactive display activities.

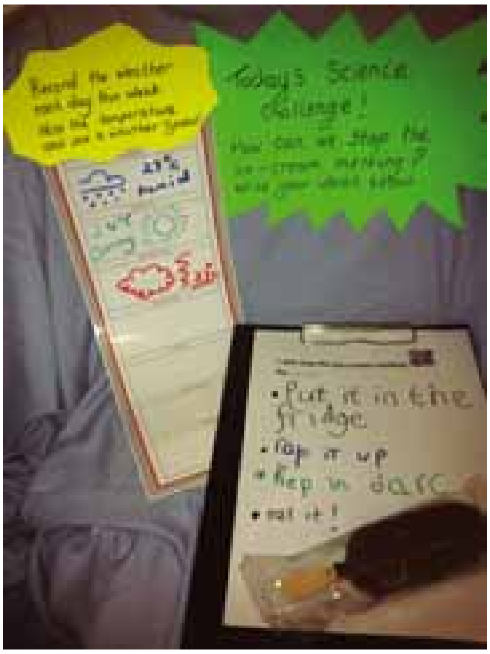

Figure 13 Classroom display investigating heat and temperature.

Pause for thought

- Why do you think it is important to display your students' work?
- What do you think a good science display should look like?
- What features should an effective science display contain?

- Consider the displays that you and your students have made that you have been proud of and those that have impressed you in your colleagues' classrooms. What was it that made them appealing?

An effective science display should be bright and engaging and should:

- provide access to reference materials such as books and posters
- include scientific vocabulary and definitions
- ask higher-order questions that promote students' thinking skills
- contain varied examples of students' work, including brainstorming activities, diagrams and images.

Putting your students' work on display demonstrates that their contribution to learning is of value and will help them to relive and recall shared experiences and understanding. Classroom displays therefore have the dual purpose of showcasing students' work and reinforcing their learning of science.

Pause for thought

- How effectively do you use displays in your classroom to extend learning in science?
- How could you improve your use of displays?
- How could you integrate your students' work into future displays?

7 Summary

Students need to develop their skills of data collection, organisation and interpretation in order to make sense of scientific phenomena. They should have access to, and experience of, the rich and varied ways that data can be collected and represented.

You will need to teach your students how to analyse data so that they can draw conclusions and formulate further questions. Effective data handling is an integral part of the scientific method and forms the foundation of every effective investigation.

In this unit you have explored the varied ways that elementary students of all abilities can access and present scientific data. Displays of student work in the classroom can be used not only to showcase students' work but to extend and support their learning.

References

Canada's Schoolnet (undated) 'Temperature and heat' (online), The Schoolnet Resource Database for the Common Framework of Science Learning Outcomes, ITP Nelson. Available from: http://resources.yesican-science.ca/lpdd/g07/lp/nelson/nel06 (accessed 23 January 2014).

Acknowledgements

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Figures 1–6 and 11–13: photos by Christine James for TESS-India/The Open University.

Figures 7–9: Vijay Trivedi for TESS-India/The Open University.

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