# Levels 7/8 Science Activity

## Thermometers as Speedometers

## Introduction to Numeracy in Science

Mathematics, science, and technology are so pervasive in everyday life that it is important for students to be literate in each of these areas. A scientifically literate person has the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in society, and economic productivity. Clearly, scientific literacy is linked to the application of mathematics in science. In the Victorian Science Curriculum, scientific literacy is addressed in the Science Inquiry Skills, where students are expected to make measurements and to collect, represent, and interpret data. The term for the use of such mathematics in everyday life, and the ability to appraise the use of mathematics for appropriateness, is *numeracy*. Numeracy is considered as one’s ability use, interpret, and communicate mathematical information and ideas. It is seen as a general capability, whereas mathematics is a body of knowledge. To be numerate is to confidently and effectively use mathematics to meet the everyday demands of life (Goos et al., 2019). Numeracy involves the affective dimensions of confidence with mathematics, cultural appreciation, interpreting data, and logical thinking (Ruthven, 2016). The focus is on understanding the cultural scope of quantitative reasoning and developing critical habits. Numeracy extends well beyond the foundational components of mathematics that are more central to arithmetic (Ruthven, 2016).

Numeracy in science is about solving numerical problems and understanding the ways in which numerical information is gathered by counting and measuring. Numeracy also involves understanding how data are analysed, described, and presented in graphs, charts, and tables. Thus, there is a wide range of knowledge, skills, behaviours, and dispositions relevant to science that is enhanced through developing numeracy.

A short audit of the numeracy demands relating to these understandings in Science Levels 7 to 10, as preparation for success in Levels 11 and 12 Sciences (Biology, Chemistry, Environmental Science, Physics, and Psychology), highlighted the following six competencies:

1. Gather data by making observations and taking measurements
2. Process data using calculation, tabulation, and graphing skills
3. Interpret data by identifying patterns and trends
4. Calculate and predict values
5. Make judgments about accuracy of data
6. Consider issues of uncertainty and reliability

In upper primary school, the science curriculum involves the students’ mathematical knowledge and thinking processes. Levels 7 to 10 teachers are expected to build on these processes through developing students’ science inquiry skills. There is an increasing importance of:

1. Creating visual representations to display and describe data
2. Interpreting data
3. Providing explanations for results
4. Understanding social and cultural conditions that impact explanations

In science, numeracy involves the full range of mathematical capabilities: understanding, fluency, reasoning, and problem-solving. These mathematical ways of working are essential as the science concepts and investigations become increasingly more complex, subtle, and sophisticated. For example, being able to predict, to include the possibility of chance, and to measure and generalise from evidence, are the foundational skills of scientific inquiry and have been consistently across all societies throughout history.

## Developing Numeracy Understanding in Science

Teachers are required to provide opportunities for students to develop numeracy skills in an applied environment. Students need to be able to generate and analyse primary data, as well as analyse secondary data. On this basis, the science curriculum is an important site for the development of students’ numeracy capabilities, contextualising numeracy in both the syntax of scientific activity and the substance of particular scientific domains. In the *Numeracy Learning Progression and Science* document(ACARA, n.d.), an outline statement of achievement standards for six numeracy sub-elements is provided:

1. Quantifying numbers
2. Operating with percentages
3. Number patterns and algebraic thinking
4. Comparing units
5. Understanding units of measurement
6. Interpreting and representing data

An exploration of the *Numeracy Learning Progression and Science* document shows that the main emphasis is in the area of data handling. Orton and Roper (2000) and more recently, Ruthven (2016), identified a disappointing scarcity of research attention to the development of numeracy through science. Rather, the research emphasis is the development of numeracy through mathematics. Thus, this mathematics research tends to guide the development of numeracy understanding in science.

Highlighted in Ruthven’s (2016) research, are the affective dimensions of confidence with mathematics and cultural appreciation, indicating an understanding of the cultural scope of quantitative reasoning is of relevance. Goos et al. (2019) argue that attitudes are critical to developing numeracy across the curriculum. All teachers should reinforce positive feelings towards mathematics, encouraging students to use their numeracy skills to interpret their scientific work. Further, data relating to students’ prior experiences, which they have generated themselves through classwork and investigations, have personal meaning, which will also contribute to a more positive attitude towards the use of mathematics.

Numeracy in science is not just using mathematics to understand science (i.e., mathematicising science). Instead, it can be considered to be a two-way process (New Zealand Ministry of Education, 2019) to develop students’ numeracy and mathematical skills, by changing information from text to data and data to text. There are several ways that a teacher can do this, by having their students:

* Interpret data in a table or on a graph to describe apparent trends
* Identify information in text and representing it as a table or graph
* Use information from text to solve a scientific problem

As a science teacher, it is important that your lessons assist students to develop their numeracy capabilities. In order to support students’ numeracy development in science, it is important to:

* *Develop students’ mathematical and numeracy confidence* – teachers may have emphasised a right or wrong answer during prior mathematics learning experiences. By considering and fostering the development of Dweck’s (2006) growth mindset, students who have struggled in mathematics in the past, can become more confident in using mathematics and increase their belief in their mathematical abilities.
* *Improve the perception of mathematics* – teachers can help students to recognise that mathematics derives from sensible concepts and ideas and underpins much of what we do in science and real life. As such, teachers will challenge perceptions that mathematics is abstract, and unrelated to real life.
* *Use and explain mathematical language* – the use of mathematical conventions, symbols, and interpretation can be cryptic to many students. Misunderstanding may develop due to the presence of homonyms in mathematics (e.g., volume: the amount of three-dimensional space that an object takes up) that mean something quite different in science (e.g., volume: perception of loudness). Teachers should always explain terms, especially where they have multiple meanings.
* *Increase students’ familiarity with mathematical concepts and skills* –students may not have familiarity with a mathematics concept, which can cause problems for the science teacher who might assume that students understand the concept.

## Lesson Plan: Thermometers as Speedometers

For the teaching of particle theory, it is important that models (an explanation of what is observed) and phenomena (something that actually happens) are differentiated. Models are analogies; as such, they are not true and have faults. For phenomena, there is a need to explain what is observed using models. If the teacher does not differentiate between models and phenomena descriptions, students can become confused, often adopting the everyday meaning of the word “model” (i.e., scale reproductions such as model railways) instead of an abstract representation to explain what we understand.

In teaching the particle model as an arrangement of particles in solid, liquids, and gases, and linking the particle model to heat and temperature, care is needed to explore the model in terms of its relationship to the phenomena, as well as its limitations and predictive powers. Thus, this activity (modified from The Physics Classroom, 2020) is an extension of the commonly found states of matter models.

Add heat

Consider the common model presented in a textbook, or one scribbled on the board: circles packed closely together for a solid, with a small amount of movement; circles in close proximity to each other for a liquid, with a greater amount for movement; and highly active circles for a gas, with a great amount of free movement. If the solid (e.g., ice) is heated sufficiently, it becomes a liquid and then a gas. In such cases, heat is external to the object, but to understand particle theory, students also need an understanding that the external heat creates an internal movement of the particles, and that the amount of internal movement can be measured in terms of temperature.

## Prerequisite/Corequisite Knowledge: Science

* Basic understanding of laboratory safety
* Ability to read a thermometer and identify the units of measure
* Ability to record data at set time intervals
* Ability to record and plot temperature data on a line graph for analysis

## Background Mathematical Skills and Understandings

Science teachers are not expected to teach the mathematical knowledge and skills that students will draw on when engaging with this activity. The students will have learnt and should be adept with the required mathematical knowledge and skills to complete the activity. According to the Victorian Curriculum Mathematics, the required mathematical knowledge and skills should have been developed in earlier years of schooling, that is, by the end of Level 6.

For this activity, the background mathematical knowledge and skills needed to complete the activity are:

* Knowledge of the measurement units for time and temperature
* Using thermometers to measure and compare temperatures
* Recording measurements of temperature and time
* Plotting two sets of ordered pairs (temperature and time) on a graph (with or without technology)
* Interpreting the patterns of the graphs of ordered pairs

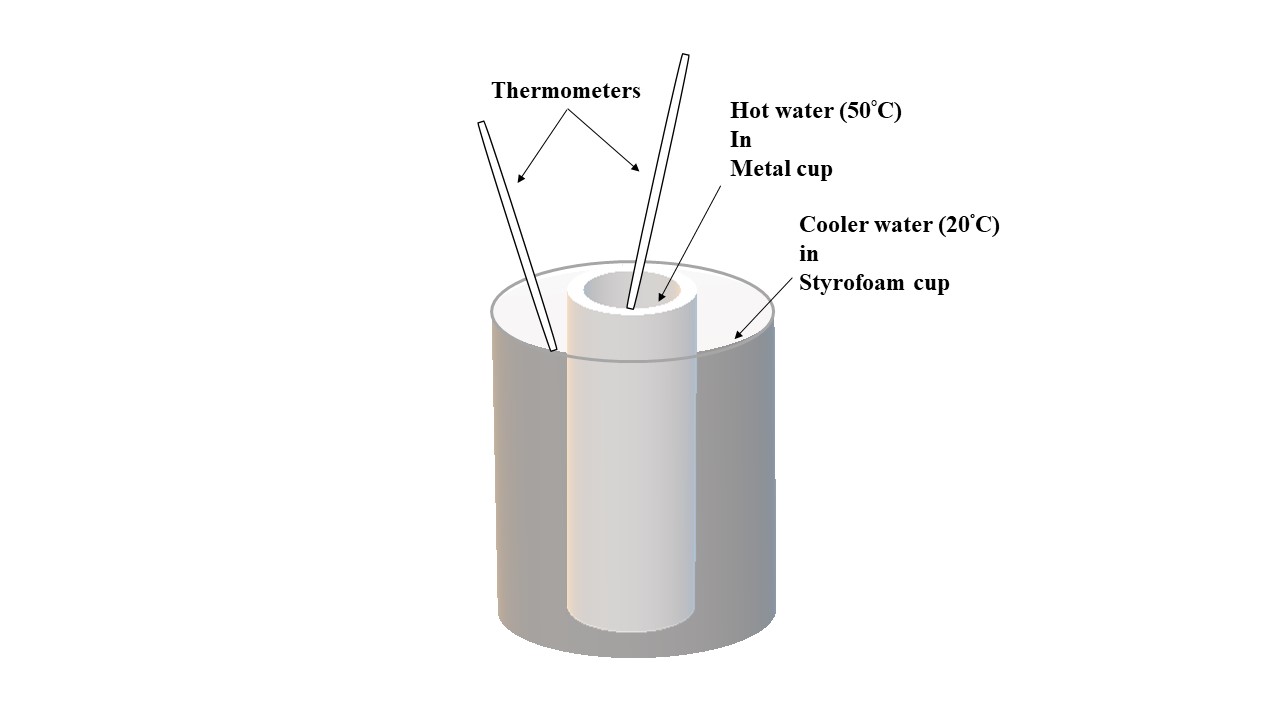
Students may need some assistance in deciding which variables to place on the horizontal (x) and vertical (y) axes, and the scales to use on each axis.

## Lesson Description

1. Conduct a class discussion about the effects of placing a cup of hot chocolate on a tabletop and a cup of iced water on the same tabletop. Touching the tabletop where the cups sat would enable students to feel a warmer or cooler spot than before the cups were placed on the tabletop. As the tabletop was heated by the cup of hot chocolate, the particles in the tabletop began to move with greater speed, which is reflected by a warmer feeling. It is in this sense that a thermometer can be thought of as a speedometer – measuring the speed of the moving particles that make up the object. In this activity, student attention is focused on this transfer of heat – the movement of particles and kinetic energy.
2. Arrange students in groups of four or five students with the following equipment:

* A small metal cup or container of hot water (50°C)
* A larger Styrofoam cup of cooler water (20°C)
* Two thermometers
* Prepared blank graph paper or electronic spreadsheet/graph generator
* Timer/watch/clock indicating minutes (analogue or digital)

The metal cup of hot water is placed inside the Styrofoam cup of cooler water and the water temperatures are read using thermometers and recorded in a table. The cup sizes need to be different to ensure that there is sufficient room for a thermometer to be used in the Styrofoam cup (See diagram of apparatus).



1. Ask the class to predict what will happen to the water temperatures over time.

* When the cooler water has warmed, and the hot water has cooled, will their temperatures be the same or different? Why?
* Will the cooler water warm up to a lower temperature than the temperature to which the hot water will cool down?
* Will the temperature lines intersect on the graph (i.e., cross over each other)?

1. The class then takes the two temperatures at minute intervals, recording the data in a table and plotting their temperatures on the same set of axes using a line graph.
2. When students have completed the data recording and plotting, and equipment is packed away, a discussion can follow of why the slope of the lines is initially steep and then becomes flatter as the lines converge over time.

* Do not expect the students to be familiar with the concept of gradient of a slope as they have not yet encountered this topic in mathematics. However, the students can understand the steepness of a slope (as being steep or gentle hill on which to ride a bicycle).
* Discuss the positive and negative slopes in terms of gaining and losing heat, and increases and decreases of particle motion.
* Discuss that as the slope of the lines flattens, the heat transfer becomes minimal.   
  The particles in each water sample contain the same kinetic energy levels and reach an equilibrium.

1. As a final activity, the students can discuss, in small groups, how they can do a role-play to represent the movement of either the particles in the cold or hot water samples at a point in time. Different groups could represent different points in time, and then present to class in order of the time sequence.

Table 1: Links to the Victorian Curriculum – Science

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| --- | --- | --- |
| Strand and Sub-Strand  (if applicable) | Content Description (Code) | Elaboration(s) |
| Science Inquiry Skills | In fair tests, measure and control variables, and select equipment to collect data with accuracy appropriate to the task (VCSIS109)  Construct and use a range of representations including graphs, keys and models to record and summarise data from students’ own investigations and secondary sources, and to represent and analyse patterns and relationships (VCSIS110)  *Analysing and evaluating*  Use scientific knowledge and findings from investigations to identify relationships, evaluate claims and draw conclusions (VCSIS111) | Identifying and explaining the differences between controlled, dependent and independent variables  Using specialised equipment to increase the accuracy of measurement within an investigation  Understanding different types of diagrammatic, graphical and physical representations and considering their strengths and limitations  Comparing and contrasting data from a number of sources in order to create a summary of collected data  Using diagrammatic representations to convey abstract ideas and to simplify complex situations  Drawing conclusions based on a range of evidence including from primary and secondary sources |
| Science Understanding | The properties of the different states of matter can be explained in terms of the motion and arrangement of particles (VCSSU096)  Energy appears in different forms including movement (kinetic energy), heat, light, chemical energy and potential energy; devices can change energy from one form to another (VCSSU104) | Modelling the arrangement of particles in solids, liquids and gases  Using the particle model to distinguish between the properties of liquid water, ice and steam  Recognising that kinetic energy is the energy possessed by moving bodies |

Table 2: Links to the 21st Century Numeracy Model (Goos et al., 2014)

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| --- | --- |
| Aspect of the Model | How This Aspect is Addressed by the Lesson |
| Attention to Real-Life Contexts   * Citizenship * Work * Personal and Social Life | Students will apply mathematics relevant to predictions of temperature change over time. For example, they will recognise that drinks cool over time or warm to room temperature if left standing. |
| Application of Mathematical Knowledge   * Problem Solving * Estimation * Concepts * Skills | Students can make use of, and sense of, the data represented in the graph. Students will monitor time, read temperatures, record the temperatures on a graph, and interpret the data in the graph. |
| Use of Tools   * Physical * Representational * Digital | Students can imagine kinetic energy through the use of graphs, that may have been created using technology (e.g., computer program), or by hand (using graph paper). Students will use a timing device (e.g., analogue clock) and read times at minute intervals to indicate when they need to record temperatures (°C) from thermometers. They will display their findings in tables and line graphs, which are representational tools. |
| Promotion of Positive Dispositions   * Confidence * Flexibility * Initiative * Risk | Students will feel confident to show initiative to interpret the mathematics to predict heating and cooling variables. Students will be willing to engage with, and then persist, when challenged by graphical representations of authentic scientific data. The links to this real-life phenomenon will enhance students’ disposition towards mathematics. |
| Critical Orientation   * Interpreting Mathematical Results * Making Evidence-Based Judgements | Students will develop an interpretive, evaluative, and analytical stance towards particle theory by providing explanations for the patterns observed. They will form evidence-based opinions and make judgements or decisions related to the relationship between the properties of matter and heat. Applying a critical orientation to numeracy will enable students to present alternative arguments by looking at their data and making informed interpretations. |

## References

Australian Curriculum, Assessment and Reporting Authority. (n.d.). *Numeracy learning progression and science*. https://www. australiancurriculum.edu.au/media/ 3668/numeracy-science.pdf

Dweck, C. S. (2006). *Mindset: The new psychology of success*. Random House Publishing Group.

Goos, M., Geiger, V., Dole, S., Forgasz, H., & Bennison, A. (2019). *Numeracy across the curriculum: Research-based strategies for enhancing teaching and learning* (1st ed.). Allen & Unwin.

New Zealand Ministry of Education. (2019). *Developing literacy and numeracy skills*. <https://seniorsecondary.tki.org.nz/Science/Pedagogy/Literacy-and-numeracy-skills#:~:text=A%20key%20strategy%20for%20developing,and%20graphs %20to%20describe%20trends&text=taking%20information%20from%20a%20piece%20of%20text,an%20algebraic%20problem%20in%20physics.>

Orton, T., & Roper, T. (2000) Science and mathematics: A relationship in need of counselling? *Studies in Science Education*, *35*(1), 123–153.<https://doi.org/10.1080/03057260008560157>

The Physics Classroom. (2020). *Thermal physics.* <https://www.physicsclassroom.com/class/thermalP>

Ruthven, K. (2016). Numeracy in, across and beyond the school curriculum. In D. Wyse, L. Hayward, & J. Pandya (Eds.), The SAGE handbook of curriculum, pedagogy and assessment (Vol. 2, pp. 638–653). SAGE Publications.