*Physics > Big idea PMA: Matter > Topic PMA1: Heating and cooling*

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| **Key concept (age 11-14)** |
| **PMA1.4: Thermal store of energy** |

**What’s the big idea?**

A big idea in physics is matter. Matter is a more formal word for ‘stuff’. Anything that can be stored in a container, or weighed, is matter. Scientific ideas can help to explain why a given material behaves as it does, and may help scientists to develop new materials with specific properties.

**How does this key concept develop understanding of the big idea?**

This key concept helps to develop the big idea by building on the understanding that increasing the temperature or mass of a material increases the amount of energy in its thermal store, to develop an understanding of how the temperature, mass and specific heat capacity of a material all affect the amount of energy in its thermal store.

****The conceptual progression starts by checking understanding of how temperature and mass affect the amount of energy in the thermal store of an object separately. It then supports the development of ideas about the difference between energy and temperature in order to enable understanding of how changes to the amount of energy in the thermal store of a material are determined by a combination of its temperature, mass and specific heat capacity.

**Using the progression toolkit to support student learning**

Use diagnostic questions to identify quickly where your students are in their conceptual progression. Then decide how to best focus and sequence your teaching. Use further diagnostic questions and response activities to move student understanding forwards.

**Progression toolkit: Thermal store of energy**

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| **Learning focus** | Each different material will have more energy in its thermal store if either its temperature or mass is increased. | | | | |
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| **As students’ conceptual understanding progresses they can:** | **C o n c e p t u a l p r o g r e s s I o n** | | | | |
| Identify which of two objects or substances has the most energy in its thermal store when the only difference between them is temperature. | Identify which of two objects or substances has the most energy in its thermal store when the only difference between them is their mass. | Explain the difference between energy (in a thermal store) and temperature. | Describe how the specific heat capacity of a material affects the amount of energy in its thermal store. | Use the equation E = mcΔT to calculate the energy needed to increase the temperature of a material.  **B** |
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| **Diagnostic questions** | Thermal store of energy | | Three bears | Specific heat capacity |  |
| Hot fill |
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| **Response**  **activities** |  | The same Bunsen | Energy vs temperature | Hot metal | How much energy? |

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| Key: | | | |
| **P** | Prior understanding from earlier stages of learning | **B** | Bridge to later stages of learning |

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| **Thermal store of energy** | **Three bears** | **Hot fill** | **Specific heat capacity** | **The same Bunsen** |
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| Simple multiple choice | Confidence grid | Focused cloze | Confidence grid | Predict, explain, observe, explain practical/demonstration |
| **Energy vs temperature** | **Hot metal** | **How much energy?** |  |  |
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| Challenge to thinking - modelling | Predict, explain, observe, explain practical/demonstration | Application and practice calculations |  |  |

**What’s the science story?**

The temperature of an object is a measure of how hot it is. It can be measured using a thermometer (in degrees Celsius, oC). To raise the temperature of an object, energy has to be transferred to it (gained by it). To lower the temperature of an object, energy has to be transferred from it (lost by it).

The amount of energy stored in a hot object depends on its temperature – the hotter the object, the more energy is stored. Also if two objects made of the same material are at the same temperature, the bigger (more massive) object stores more energy.

**What does the research say?**

In teaching energy the BEST resources have adopted a framework based on ‘energy stores’ and ‘energy pathways’ which is advocated by, amongst others, Boohan (2014), Millar (2014) and Tracy (2014). As Millar (2014) says, this approach “is not perfect - but it is adequate and significantly better than [approaches] based on lists of ‘forms of energy’.” A clear guide to this approach can be found on the Institute of Physics’ website (Institute of Physics) or in ‘BEST Approaches: Teaching energy’ (Fairhurst, 2018).

The difference between temperature and a thermal store of energy is a crucial idea in the understanding of thermal concepts. When an object is warmed up its temperature rises, the amount of energy in its thermal store increases and the particles in the object move or vibrate more. All of these changes are interconnected and happen at the same time. Heating an object makes its particles move around more; temperature is a measure of the average kinetic energy of the particles; and the extra kinetic energy of all the particles adds to the energy in the thermal store (Institute of Physics). It has been found that about a quarter of students aged 10-16 do not distinguish between temperature and energy in a thermal store. They often have the misunderstanding that temperature is a means of measuring energy in a thermal store. (Driver et al., 1994; Tiberghien, 1983)

Most students correctly understand that raising the temperature of a particular object also increases the energy in its thermal store. However, fewer than half of 11- to 14-year-olds understand that, when they are at the same temperature, a larger mass of a material contains more energy in its thermal store than a smaller mass of the same material. It is common for students to think that an object at a higher temperature has more energy in its thermal store than an object at a lower temperature, even when the hotter object has a much smaller mass. (Gonen and Kocakaya, 2010)

Apart from mass and temperature, the other factor that affects the amount of energy in the thermal store of a material is the specific heat capacity of the material. It is common for students to experience specific heat capacity, c, for the first time as the constant in the equation E=mcΔT (which they often learn in their later studies at age 14-16). Although they are often able to calculate values with this equation, students do not often understand what specific heat capacity tells us about a material. Using an investigative approach has been shown to help develop a clearer understanding of specific heat capacity. (Herrington, 2011)

The progression toolkit for a *thermal store of energy* reminds students that increasing the temperature or mass of a material increases the amount of energy in its thermal store. A model is used to revise the difference between energy and temperature, which students can use to support their predictions of what happens to the amount of energy in the thermal store of a material when both its temperature and mass are changed at the same time. By investigating the heating effects of hot objects made from different materials, students are given the opportunity to develop a clear understanding of what specific heat capacity tells us about a material. A bridging activity introduces them to the equation E=mcΔT in order to calculate changes to the amount of energy in a thermal store.

**Guidance notes**

The use of the word ‘heat’ as a noun in colloquial speech can cause problems because it implies that ‘heat’ is a substance that can flow. For example in the phrases: ‘close the door to keep the heat in’; or ‘the kettle has gained heat’ (Erickson and Tiberghien, 1985). For this reason is good practice to avoid using the word ‘heat’ when describing heating and cooling effects.

**References**

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