Physics > Big idea PFM: Forces and motion > Topic PFM1: Forces

Key concept (age 11-14)

PFM1.5: Energy stores and transfers

What's the big idea?

A big idea in physics is force, because it is the key to explaining changes in the motion or the shape of an object. The motion of an object can be explained or predicted if you know the sizes and directions of all the forces that act on it. Understanding forces helps us to predict and control the physical world around us.

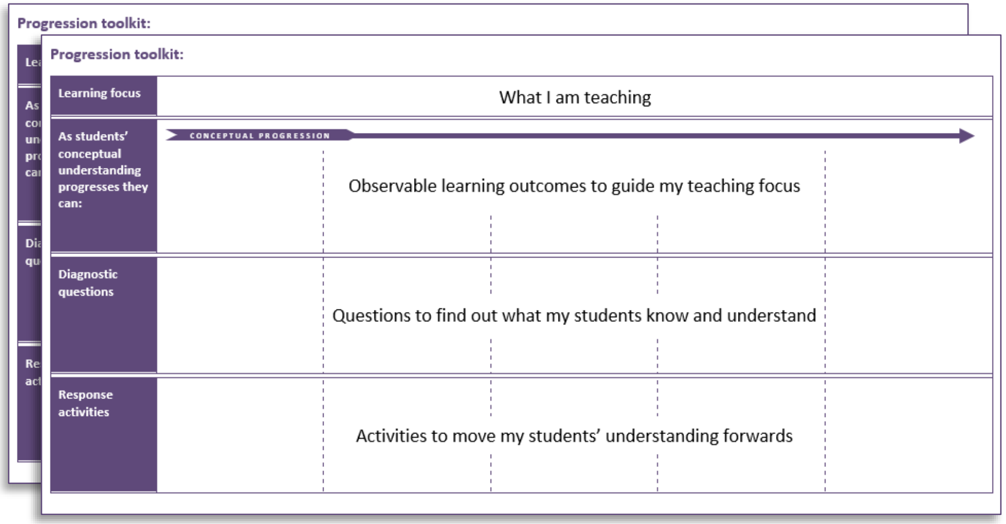
How does this key concept develop understanding of the big idea?

This key concept develops the big idea by building on the idea that some kind of energy store is necessary for something to happen, in order to develop the understanding that when forces make things change they transfer energy between different energy stores.

The conceptual progression starts by checking understanding that objects can store energy in several different ways. It then supports the development of the understanding that when things happen, energy is transferred between energy stores. Analysing how forces transfer energy mechanically develops understanding of how this happens, and of how in every event energy is almost invariably dissipated by heating.

How can you use 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: Energy stores and transfers

Learning focus	An energy store of some kind is necessary for something to happen, and something happens when energy transfers between energy stores.				
As students' conceptual understanding progresses they can:	CONCEPTUAL PROGRESSION → Identify objects that have a store of energy	Identify the energy stores that a range of different objects have	Identify the energy stores at the start and the end of an event	Use precise language to describe transfers of energy between energy stores	Represent energy transfers in events using Sankey diagrams **B**
Diagnostic questions	Energy stores	Types of energy store	Energy transfers	Moving energy to different stores	Sankey diagrams
Response activities		Energy stores circus			

Key:

B Bridge to later stages of learning

Progression toolkit: Energy stores and transfers

Learning focus	When a force makes things change it mechanically transfers energy between different energy stores. Friction transfers energy mechanically into a heat store of energy.				
As students' conceptual understanding progresses they can:	CONCEPTUAL PROGRESSION → Identify actions that transfer energy	Identify different ways that energy can be transferred	Identify where energy is transferred by rubbing	Describe how energy can be transferred in different ways	Explain how energy is almost always transferred to the heat store of the surroundings
Diagnostic questions	Is energy transferred?	How is energy transferred?	Heating by friction	Slower football	Falling apple
					Push up
Response activities		Energy transfers circus			
					Steady speed

What's the science story?

To lift something up, move something against a resistance a supply of energy is needed.

In any event where two or more objects interact, if some objects lose energy, others gain energy. The total amount of energy stored in all of the objects involved is the same at the end as it was at the beginning.

When forces transfer energy we can identify objects, or groups of objects, that have gained (or lost) energy by noticing that they:

- are moving faster (or slower) than they were
- are hotter (or cooler) than they were
- have been raised (or lowered) in a gravity field
- are springy and have been distorted (stretched, compressed, bent, twisted), or allowed to spring back from a distorted state
- are magnets/electric charges which have been moved apart/together in a magnetic/electric field

Convenient labels for these different ways in which energy can be stored are (respectively): kinetic, heat (thermal), gravitational, elastic, and electromagnetic.

When a person pushes or pulls an object their chemical store of energy empties a little.

During an event, when a force is acting, energy is transferred from the initial energy store(s) to the final energy store(s) by mechanical working.

Many devices change the way in which energy is being transferred, without storing any themselves. For example, energy is often transferred to a motor electrically and from it mechanically.

At the end of many events, some energy is often stored in the surroundings, which have become hotter. This is a consequence of friction or drag (air or fluid resistance).

Although energy is always conserved in any event or process, it also gets more spread out amongst the objects involved: it is dissipated.

What does the research say?

Energy is hard to teach both because it is an abstract idea that is really difficult to define, and because there are many contradictions between the everyday and scientific usage of the word energy.

When Solomon (1983) asked children to write three or four sentences showing how they use the word energy she found that children predominantly think about energy in terms of:

- human activity – 'I'm tired because I have run out of energy' or 'I can run very fast because I have a lot of energy'

- health – ‘exercise is good for you because it builds up your energy’, ‘when we run out of energy we need medicines and vitamins’
- food and fuels – some objects contain a lot of energy that can be used up to help us move about and to make other things happen

The most common misunderstanding students have about energy is that, like food or a fuel, it gets used up. This misunderstanding is hard to transfer. In a study of students aged 12-14. Duit (1981) found that, even after teaching, very few students use ideas of the conservation of energy to explain their predictions about unfamiliar events. He suggested that the students preferred to use instead ideas they had gained through everyday experience. Millar (2011) also notes that students often think of electricity as a fuel, perhaps from their experience of batteries ‘running out’.

When talking about energy students tend to use science terms loosely: Driver et al. (1994) describe evidence from several researchers that students often confuse ideas of energy with ideas of force, work or power and may use the terms interchangeably. Rogers (2018) emphasises the importance of teachers modelling accurate use of science terms and advises giving students opportunities to practise using language precisely to help them develop an accurate model of what is happening.

Generally people think of energy as a substance, with flow and conservation analogous to that of matter. Although not scientifically correct this is considered an acceptable analogy (Millar, 2011). When explaining how energy is transferred, Tracy (2014) recommends that we focus on describing the processes and mechanisms involved. He suggests that trying to identify the ‘energy’ in each step is just a labelling exercise that can get in the way of a clear understanding of what is happening.

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).

Millar (2005) suggests that to make sense of the *law of conservation of energy*, students need to know that in almost every event there is some heating, whether desired or not, and a consequential increase in the heat store of the surroundings. Identifying how friction and drag cause heating introduces students to the idea of dissipation of energy. Describing how energy is dissipated in a range of examples can support understanding of the idea of conservation of energy.

The first progression toolkit for *energy stores and transfers* introduces the idea that an energy store is necessary for something to happen in order to allow students to identify different types of energy store. Observing a range of practical examples gives students the opportunity to identify changes between the amount of energy in initial energy store(s) and in final energy store(s). Opportunity to describe transfers of energy between energy stores, using precise language, allows students to consolidate their learning through practise and application. Representing energy transfers with Sankey diagrams also reinforces learning and introduces thinking necessary to understand the law of conservation of energy.

The second progression toolkit for *energy stores and transfers* engages students in thinking about how energy is transferred between energy stores. Observing events that transfer energy give students the opportunity to describe some of the processes and mechanisms involved. Using examples with friction and drag introduces the idea of heating by doing work. Discussion around a range of examples can be used to explore ideas about heating and the dissipation of energy. Understanding dissipation is necessary to making sense of the law of conservation of energy, which is covered more fully in the topic *PMA1: Heating and cooling*.

Guidance notes

Energy is just about impossible to explain and often definitions given in text books are wrong. For example 'energy makes things happen' is not right. It may be best not to give a definition, but perhaps the best we could do is 'energy stores are necessary for something to happen'.

Students understanding of energy will evolve over time. At this stage it is important to present a useful model that students can use to develop their thinking and which is not misleading in any significant way. The 'energy stores' and 'energy pathways' model that is used in the BEST materials achieves this. In this introductory key concept, students identify a range of different energy stores and observe whether the energy in each energy store increases or decreases. They also describe the mechanisms and processes that moves energy from one store to another. Later in their learning, they will be able to carry out meaningful measurements and use equations to calculate the quantity of energy in each store, and their descriptions of the mechanisms and processes for transferring energy become more sophisticated. The methods for describing energy qualitatively at this stage of learning, correlate with the steps necessary in carrying out a useful quantitative energy analysis in later studies.

As a teacher it is easy to 'slip up' and use talk about energy in everyday terms: 'energy use', 'energy consumption', 'using energy' or 'consuming energy'. This is largely unavoidable, so being upfront about the challenge of describing energy is helpful. Perhaps challenge your students to spot your mistakes and throw in a few deliberate mistakes. Correcting these together offers good scaffolding for students in developing their own way of talking about energy scientifically.

Using the very precise language of energy stores and pathways can feel quite clunky and cumbersome, and for this reason it is unlikely that it will become a common way of talking about energy. At the early stages of thinking about energy however, consistent use of this language supports students in developing a clear scientific understanding of energy.

A summary of the BEST approach to teaching energy can be found on the Best Evidence Science Teaching landing page which is on the STEM Learning website (Fairhurst, 2018).

References

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