*Physics > Big idea PFM: Forces and motion > Topic PFM2: Moving by force*

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| **Key concept (age 11-14)** |
| **PFM2.2: Motion graphs** |

**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 helps to develop the big idea by building on clear and accurate descriptions of motion, in order to develop an understanding of how these can be represented on distance-time graphs so that more detailed analysis of changing motion is made possible.

****The conceptual progression starts by checking understanding of how to read values from the axes of a graph. It then supports the development of describing simple relationships between the axes such as those represented by straight lines in order to enable understanding of how distance-time graphs represent motion in real situations.

**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: Motion graphs**

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| **Learning focus** | Information about the motion of an object can be summarised on a distance-time graph: the plot shows the object’s distance from the start at a given time and the slope (gradient) at that point shows its speed. | | | | |
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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** | | | | |
| Read values of distance or time off the axes of a distance-time graph for a plotted point  **P** | Describe the changes to an object represented by a move from one point on a distance-time graph to another | Describe motion of an object represented by straight lines on a distance-time graph | Explain how a distance-time graph shows the changing position of an object | Explain how a distance-time graph shows the changing speed of an object  **B** |
|  |  |  |  |  |  |
| **Diagnostic questions** | Off the line | Plot story | Line story | Where’s Sally? | The speed of Dwight |
|  |  | Two slopes |  |  |
|  |  |  |  |  |  |
| **Response**  **activities** | Plot the line | Speedy graphs | | | |

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

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| **Off the line** | **Plot story** | **Line story** | **Two slopes** | **Where’s Sally?** |
|  |  |  |  |  |
| Linking ideas | Simple multiple choice | Simple multiple choice | Two-tier multiple choice | Confidence grid |
| **The speed of Dwight** | **Plot the line** | **Speedy graphs** | |  |
|  |  |  | |  |
| Simple multiple choice | Application and practice | Application and practice - practical | |  |

**What’s the science story?**

Information on the motion of an object can be summarised in a distance-time graph (showing the distance the object has travelled from its starting point at a given time). The slope (or gradient) of the graph at a given time indicates the speed of the object at that time.

**What does the research say?**

Before developing an understanding of dynamical principles, such as Newton’s Laws of motion, students need to be comfortable in describing and representing motion. They need to be able to describe motion appropriately using written descriptions, graphical representations and numerical formulations, for example, speed = distance ÷ time. Reflection and discussion are recognised as critically important for developing these competencies, requiring time and carefully designed tasks for the purpose. (Driver et al., 1994)

It is common for students to view motion graphs as pictures that link to existing physical knowledge of a situation. (Lingefjard and Farahani, 2018; Stump, 1999; Brasell, 1987; Clement, 1986) For example Clement (1986) found that 28% of 12- to 14-year-olds (n=25) drew an up-hills and down-hills picture of a cycle route when asked to draw a speed-distance graph. Likewise Lingefjard and Farahani (2018) found that 35% of 18-year-olds (n=17) interpreted distance-time graphs intuitively as if they were pictures, with more of them starting off this way before correcting themselves.

Often text books (and teachers) put great attention on the procedures for plotting graphs and calculating gradients, rather than developing understanding of relationships that a graph shows (Stump, 1999). It can be more constructive to concentrate on the latter, which involves teaching:

* understanding of how to read information directly from a graph, interpreting each axis individually
* how to describe simple relationships between the axes such as those represented by straight lines
* how to interpret a graph, linking what it represents to a real situation (Friel, Curcio and Bright, 2001; Lingefjard and Farahani, 2018)

When interpreting graphs students must be able to determine which features of a graph correspond to particular physical concepts. With distance-time graphs there is often confusion between the slope (speed) and height (distance) of a graph (Clement, 1986; McDermott, Rosenquist and van Zee, 1987). One strategy to overcome this is to use motion sensors and data-loggers to plot real-time graphs of motion. Students can practise predicting the shape of graph for different descriptions of motion and also reproduce the shape of given graphs by moving in front of a motion sensor. A study of 17- to 18-year-olds (n=75) showed this approach significantly improved students ability to interpret distance-time graphs (Brasell, 1987).

There are several possible explanations that may explain why real-time graphing of motion improves learning: it allows students to process information about the event and the graph simultaneously; the dynamic display of the data-logger focuses attention on one feature at a time; and frequent repetition of graphing events supports consolidation. Further investigation by Brasell (1987) suggests even a short delay of 20-30 seconds between observing a motion and seeing a graph limited students ability to link aspects of motion to features on a graph.

In the progression toolkit ‘motion graphs’, the focus is placed on comprehending distance-time graphs rather than in drawing them. The essential skill of reading values from each axis of a distance-time graph is checked, before focusing on interpreting motions represented on the graph by plots and straight lines. Several diagnostic questions investigate aspects of misunderstanding caused by intuitive interpretation of graphs, with responses suggested that direct students to more structured and effective ways of reading them. Practical work helps students to develop and consolidate their understanding of how the relationship between distance and time of real motions is represented on a graph. This will enable some students to interpret position, speed and acceleration on more complex distance-time graphs.

**Guidance notes**

In mathematics students will study scales, plotting graphs and drawing lines of best fit. For many students at age 11-14 these skills are well developed and for others they are not. There is not usually sufficient time in science lessons to teach these skills as comprehensively as they are in maths lessons. For these reasons it is more productive in science lessons to focus on comprehending graphs and linking what they represent to real situations. This will complement the construction and analytical skills that students are developing in their maths lessons.

**References**

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