*Physics > Big idea PSL: Sound, light and waves> Topic PSL4: Waves*

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| **Key concept (age 11-14)** |
| **PSL4.1: Waves on water and ropes** |

**What’s the big idea?**

A big idea in physics is waves because it is the key to explaining how energy can be transferred from one object to another object by radiation, even when the objects are not touching. Waves carry information that can be detected by humans or manufactured detectors. Understanding waves helps us to communicate, explore the universe, and transfer energy to where we want it.

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

This key concept helps to develop the big idea by building on the idea that ‘particles’ in a transverse wave move only at right angles to the direction of the wave, in order to develop the understanding that waves transfer energy, but not substance.

****The conceptual progression starts by checking understanding that the medium through which a transverse wave is travelling does not move forward with the wave. It then supports the development of ideas about how particles move in a transverse wave in order to propagate the wave. This concept leads to an understanding of why amplitude and frequency do not affect the speed of a transverse wave, and of why they do affect the rate at which transverse waves can transfer energy.

**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: Waves on water and ropes**

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| **Learning focus** | A transverse wave travelling across the surface of water (or along a rope) transfers energy, as particles of water (or rope) are successively made to vibrate at right angles to the direction in which the wave travels. | | | | |
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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** | | | | |
| Recognise that as a transverse wave travels forward, the medium through which it travels does not.  **P** | Describe the movement of each ‘particle’ of a transverse wave as the wave moves forward. | Explain how movement of each ‘particle’ of a transverse wave causes a perturbation to move forward. | Compare the speed of transverse waves that have different amplitudes or frequencies to each other and are moving through a common medium. | Compare the amount of energy transferred by transverse waves that have different amplitudes or frequencies to each other and are moving through a common medium.  **B** |
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| **Diagnostic questions** | A moving wave | Part of a moving wave | Rope wave | Faster waves | Energy from a wave |
|  |  |  |  |  |  |
| **Response**  **activities** | Making waves | | |  |  |
|  |  | Ripples on a pond | | | |

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

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| **A moving wave** | **Part of a moving wave** | **Rope wave** | **Faster waves** | **Energy from a wave** |
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| Simple multiple choice | Confidence grid | Confidence grid | Two-tier multiple choice | Two-tier multiple choice |
| **Making waves** | **Ripples on a pond** |  |  |  |
|  |  |  |  |  |
| Critiquing a representation | Talking heads |  |  |  |

**What’s the science story?**

Ripples on water surfaces and waves on ropes are described as transverse waves. As a transverse wave travels across the surface of water or along a rope, water particles or bits of rope vibrate at right angles to the direction the wave travels in. As a wave travels this can be seen by observing a cork bobbing up and down on the surface of water, or a mark on a piece of rope moving from side to side.

The number of pulses produced each second (and hence the number passing any given point as the wave passes) is the frequency of a wave. The higher the frequency, the more quickly energy is transferred by the wave. Energy also transfers more quickly if each ripple or vibration is larger (has a bigger amplitude).

Neither frequency nor amplitude change the speed of a wave. Speed of a wave depends only on the medium through which the wave is travelling.

**What does the research say?**

When waves move through a medium students often describe the movement of some entity (perhaps mass, matter or force) through the medium. The scientific explanation involves no such movement. A wave moves forwards when a perturbation passes through a medium, and after it has passed the material of the medium returns to its original position. This is what distinguishes the motion of a wave from the motion of an object. (Fazio et al., 2008)

The motion of waves is hard for students to understand because waves form from large numbers of small scale events, such as the up and down movement of water particles in a water wave that are quite different to the form and motion of the wave (Caleon and Subramaniam, 2010). This is seen clearly when spectators in a sports stadium stand up and sit down in sequence to produce a *Mexican wave* moving around the stadium. In a mechanical wave the disturbance of one particle has a direct effect on the particles around it, causing them to move and progressively pass on the disturbance to adjoining particles. This process transfers energy through a medium, but without the transfer of any bulk substance.

The speed of a mechanical wave depends on the properties of the medium it is passing through and is independent of the wave’s frequency or the size of disturbance (amplitude). In a study of senior high school students (n=324), Tongchai et al (2011) found that fewer than 10% of students held the correct scientific view and that over 70% held the common misunderstanding that wave speed depends on frequency. Wittmann, Steinberg and Redish (1999) found similar results: that over 70% of students enrolled onto a university physics course (n=92) thought the speed of a wave along a rope was affected by the way in which a hand moved to set the wave off.

In Wittmann, Steinberg and Redish’s study (1999), some students explained that waves set off with a bigger amplitude moved faster because they had been given more energy or more force. It should be noticed that in a string any sideways force that produces the wave is not pushing along the direction of the wave and so does not accelerate the wave in the forwards direction. Any extra energy is observed by the greater side-to-side movement of the string as the wave progresses. A few of the other students had the misunderstanding that waves with smaller amplitudes travelled faster. The reason they gave was that the smaller pulses could slip more easily through the medium. This is an example of students thinking of the wave as a moving ‘object’, rather than as a perturbation moving through a medium.

**Guidance notes**

This key concept develops understanding of how ‘particles’ in transverse waves interact with adjoining ‘particles’ to transfer energy through a medium without any ‘object’ moving through the medium. From the research it appears that students are quite good at labelling waves and properties of waves, but often their understanding of what these terms mean differs from the scientific understanding – and these misunderstandings need to be teased out and challenged in order to build that scientific understanding.

**References**

Caleon, I. and Subramaniam, R. (2010). Development and Application of a Three-Tier Diagnostic Test to Assess Secondary Students' Understanding of Waves. *International Journal of Science Education,* 32:7**,** 939-961.

Fazio, C., et al. (2008). Modelling Mechanical Wave Propogation: Guidelines and experimentation of a teaching-learning sequence. *International Journal of Science Education,* 30:11**,** 1491-1530.

Tongchai, A., et al. (2011). Consistency of students' conceptions of wave propogation: Findings from a conceptual survey in mechanical waves. *Physical Review Special Topics Physics Education Research,* 7(2)**,** 11.

Wittmann, M. C., Steinberg, R. N. and Redish, E. F. (1999). Making Sense of How Students Make Sense of Mechanical Waves. *The Physics Teacher,* 37**,** 15-21.