*Physics > Big idea PMA: Matter > Topic PMA2: Floating and sinking*

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| **Key concept (age 11-14)** |
| **PMA2.1: Floating, sinking and density** |

**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 an understanding of the properties an object has that enable it to float, to develop a general principle that can be used to determine how well something will float.

****The conceptual progression starts by checking understanding of what is meant by floating. It then supports the development of a qualitative understanding of density in order to enable understanding of why the density of an object and the density of the fluid it is in, both affect how well it floats.

**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: Floating, sinking and density**

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| **Learning focus** | An object that is surrounded by a fluid (liquid and/or gas) floats if its overall density is less than the density of the fluid. | | | | |
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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 objects that are floating.  **P** | Describe how the mass and volume of an object affect how well it floats. | Describe how the shape of an object affects how well it floats. | Explain how the density of an object determines how well it floats. | Explain how the density of a liquid (or gas) determines how well objects float in it.  **B** |
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| **Diagnostic questions** | Iceberg | Building bricks | Flipping iceberg | Block float | Density column |
| Fruit and veg |
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| **Response**  **activities** | Submarines | Block work | Buoyancy | | Grape expectations |
| Clay boat | |

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

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| **Iceberg** | **Building bricks** | **Fruit and veg** | **Flipping iceberg** | **Block float** |
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| Simple multiple choice | Confidence grid | Simple multiple choice | Simple multiple choice | Confidence grid |
| **Density column** | **Submarines** | **Block work** | **Buoyancy** | **Clay boat** |
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| Confidence grid | Application and practice - problem | Clarifying - demonstration | Predict, explain; observe, explain  PEOE | Application and practice - practical |

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| **Grape expectations** |  |  |  |  |
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| Predict, explain; observe, explain  PEOE |  |  |  |  |
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**What’s the science story?**

The density of a substance is a measure of how heavy it is for its size. The density of a substance is defined as: mass of a sample divided by its volume. Density is a characteristic property of a substance.

A compact solid object (i.e. one that is not boat-shaped or hollow) floats in a liquid if its density is lower than that of the liquid.

If an object is wholly or partly immersed in a fluid, its apparent weight (as measured by a spring balance) is less than in air. The fluid exerts an upthrust on the object, so the net downward force acting on it is smaller (zero, if it floats). The upthrust is equal to the weight of fluid that the object displaces. An object made of a material less dense than the liquid displaces its own weight of liquid when only partly immersed. So it floats. An object made of a material that is more dense than the liquid will float if its shape means that it will displace its own weight of liquid before it becomes completely immersed (e.g. if it is cup- or boat-shaped, or hollow).

Most solids and liquids (and all gases) expand continuously as their temperature is raised. The behaviour of water is anomalous; when a block of ice melts, the volume of the liquid water is less than the volume of the ice. The water continues to contract as its temperature rises from 0oC to 4oC, and then begins to expand steadily.

**What does the research say?**

It is not always obvious to students whether or not an object is floating in a liquid. A survey of 7-14 year olds by Biddulph and Osborne (1984) that is reported by Driver et al. (1994) and Allen (2014), found that most students were only confident that a floating object was floating when a large proportion of the object was visible above the surface of a liquid. When only a small proportion of a floating object was visible above the surface, some students described it as both floating *and* sinking. Others suggested the object was starting to sink and that it would slowly go down. Many students did not recognise that objects could float at all if they were completely submerged. Objects such as fish or submarines *can* float underwater.

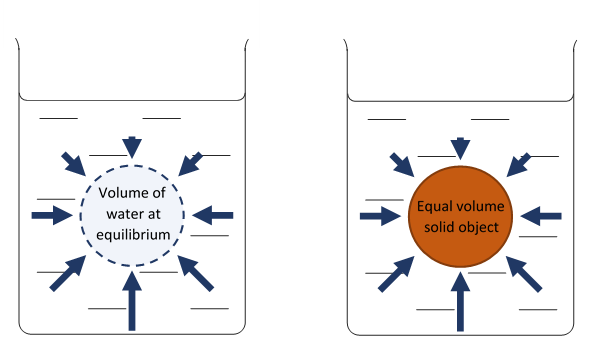
In a study of 13-14 year olds (n=120), Ȕnal and Coştu (2005) found that about half of students thought that the main factor influencing whether an object floated or not was its weight or mass. It is quite common for young children to think all light objects float, and all heavy objects sink (Allen, 2014). In Ȕnal and Coştu’s study many students identified the volume of an object as also playing a part in whether or not an object floated, but approximately 40% had difficulties in describing density and in comparing the densities of different objects. A surprising finding was that over half of students thought that increasing the volume of liquid in a container would make objects float more easily. Biddulph and Osborne (1984) found that up to 35% of 11- to 12-year-olds held this view.

Paik et al. (2017) describe a learning progression for buoyancy that begins with the basic concepts of weight and volume, before starting to develop the scientific concepts of density and buoyancy. In their progression, the density of an object is introduced as the object being *heavy (or light) for its size*. This working definition of density allows students to develop understanding of how volume and weight combine to give an object its buoyancy, and provides descriptive tools that help explain why boat-shaped objects (that are filled with air) are more buoyant than other more compact shapes. This idea is also linked to the understanding that buoyancy increases as the volume of liquid (or gas) displaced increases. Buoyancy is defined as the resultant upward force of the liquid (or gas) around an object, on the object.

When an object sinks in a liquid, Cepni and Şahin (2012) found that most 13- to 14-year-olds (n=48) did not think that the object had buoyancy. In some cases students labelled the buoyancy of a sinking object as downward: they thought that the liquid was pushing it downward. Conversely some students may think that a floating object has no weight (Allen, 2014). Buoyancy always acts vertically upward; the resultant force is determined by comparing the force of the water pushing the object up, with the force of gravity pulling the object down.

It is appropriate to teach students how to calculate buoyancy only after they have developed a good qualitative understanding how it works (Gao et al., 2018). Students can use a displacement can to measure the weight of water displaced by an object and compare this to the weight of the object. Buoyancy is equal to the weight of the water (or other fluid) displaced. Objects that float displace their own weight of water. If the weight an object is greater than the weight of the water that the object displaces, then the object will sink. In other words: if an object is less dense than the liquid (or gas) that it is placed in it will float; if it is denser it will sink.

**Guidance notes**

This key concept focuses on developing an understanding of why it is necessary to consider both mass and volume at the same time when determining whether or not an object will float. It is necessary for students to have this foundation if they are to appreciate the significance of measuring mass and volume, at a later stage of their studies, in order to calculate density.

**Why does buoyancy equal the weight of water displaced?**

The reason why buoyancy is equal to the weight of water displaced arises from the fact that fluid pressure increases with depth. This idea is covered in the BEST concept: PMA2.2 Pressure in fluids. When a ‘ball of water’ is suspended in water the differences in pressure produce a resultant upward force on the ‘ball of water’ which exactly equals its weight. If the ‘ball of water’ is swapped for a solid ball, exactly the same pressure differences remain and the upwards force is the same – which is equal to the weight of the water the solid ball has replaced (Nave).

**Ice and water**

Substances that have a higher density than others may have individual particles that have more mass, and/or the particles may be packed more closely together. In the case of ice and water, the particles in each are the same, which means that the particles in solid ice are further apart than the particles in liquid water. This is contrary to what students will have been taught about the separation of particles in solids and liquids. The fact that ice is commonly seen to float on water may need some explanation for observant and thoughtful students. The reason particles are further apart in ice than in water is because H2O molecules are polar. As water freezes, electric charges in the H2O molecules orientate them to form a lattice that increases the space between each one.

**References**

Allen, M. (2014). *Misconceptions in Primary Science, 2nd* ednBerkshire, UK: Open University Press.

Biddulph, F. and Osborne, R. (1984). Pupils' ideas about floating and sinking. *Australian Science Education Research Association Conference.* Melbourne.

Cepni, S. and Sahin, C. (2012). Effect of different teaching methods and techniques embedded in the 5E instructional model on students' learning about buoyancy force. *Eurasian Journal of Physics and Chemistry Education,* 4(2)**,** 97-127.

Driver, R., et al. (1994). *Making Sense of Secondary Science: Research into Children's Ideas,* London, UK: Routledge.

Gao, Y., et al. (2018). Developing a Learning Progression of Buoyancy to Model Conceptual Change: A Latent Class and Rule Space Model Analysis. *Research in Science Education*.

Nave, C. R. *HyperPhysics, Buoyancy* [Online]. Georgia State University, USA. Available at: <http://230nsc1.phy-astr.gsu.edu/hbase/pbuoy.html> [Accessed October 2019].

Paik, S.-H., et al. (2017). Developing a Four-level Learning Progression and Assessment for the Concept of Buoyancy. *Eurasia journal of mathematics, science and technology education,* 13(8)**,** 4965-4986.

Unal, S. and Costu, B. (2005). Problematic issue for students: Does it sink or float? *Asia-Pacific Forum on Science Learning and Teaching,* 6(1)**,** Article 3.