Newton's understanding of forces and motion

Critical teaching ideas - Science Continuum F to 10
Level: Moving towards level 10

Student everyday experiences

It is very difficult to tell with the naked eye if an object is accelerating (e.g. a ball flying through the air), and so students do not tend to think of motion in terms of whether it is accelerated or not. Accelerated motion is also a difficult concept for students because it occurs when an object changes either speed or direction or both.

Students are familiar with objects accelerating from rest or braking, e.g. a car speeding up or to a lesser extent slowing down at the traffic lights.

However, it is much more difficult to determine if an object already moving is changing its speed unless the change is dramatic. Students seldom identify a car turning a corner at constant speed as accelerating because their common understanding requires the object to be changing speed to be accelerating.

Even senior students regularly confuse 'acceleration' and 'speed', for example thinking that if speed is increasing then acceleration is also increasing.

(See Champagne Klopfer & Anderson, 1980 and Trowbridge & McDermott, 1981 and Loughran Berry & Mulhall, 2006).

Students often have a set of "intuitive rules" that seem to explain everyday examples of motion (See the teaching ideas on Forces and motion at the lower levels). These rules appear to work when students ignore friction and air resistance; friction and air resistance are generally not seen by students as - involving forces (See Mitchell, 2007).

A common view that persists at this level is that a moving object must have a force acting on it in the direction of motion, with some students also strongly believing that this force is being used up if the object is slowing down. This may be partly a terminology problem: what students label as a force in these situations is similar to what scientists call 'momentum'.

(See Champagne Klopfer & Anderson, 1980; Gunstone & Watts, 1985; Gunstone Mulhall & McKittrick, 2007; Osborne & Freyberg, 1985)

Students often struggle to grasp the concept of net force, and often think it is an extra force in addition to the actual forces on an object. (See Gunstone Mulhall & McKittrick, 2007)

The scientific view

The net force is the combined effect (the sum) of the real forces acting on the object. Net force is a valuable construct that has no separate existence of its own, unlike the real forces acting on the object, i.e. it is not an additional force. (Gunstone Mulhall & McKittrick, 2007)

While the net force on an object is zero, its speed and direction of motion remain unchanged (and stationary objects remain stationary). (Newton's first law of motion).

When there is a net force on an object, it causes the object to accelerate in the direction of the net force; this is not the same as the direction of the motion unless the object is going in a straight line. The magnitude of the net force on the object is the product of its mass and its acceleration (Newton's second law).

Critical teaching ideas

- An object accelerates when its speed changes or its direction of motion changes or both.
- Changes in an object's speed are continuous even though in some situations it may appear to be almost instantaneous (e.g. a golf ball when hit by a golf club, car collisions).
- The net force on an object is the combined effect (i.e. the sum) of all the pushing and pulling forces actually acting on the object.
- If the forces pushing or pulling on an object are not balanced, i.e. a net force acts, then the object will accelerate in the direction of the net force .

(See Loughran Berry Mulhall, 2006; Gunstone Mulhall & McKittrick, 2007)

The list of ideas about forces and motion below, are each covered in greater detail in the sequence of teaching ideas introduced at the lower levels.

Objects that are accelerating may be changing speed or their direction of motion, or both.

A net force on an object changes its motion – the greater the net force, the greater the acceleration. More massive objects require bigger net forces to accelerate the same amount as less massive objects.

A force is described by using the format 'force of A on B' and drawing an arrow to show the direction of the force, e.g. the weight of a book is the 'force of Earth on the book'. It can be represented diagrammatically by an arrow drawn through the centre of the book directed downwards towards the earth.

It is important for students to have a sound qualitative understanding of the ideas of Newton's second law before mathematics is introduced. Students need exposure to situations that require verbal explanations about the forces involved before they are exposed to quantitative work involving formulae (See McDermott, 1997).

A simple mathematical relationship exists between the mass of an object, the net force on the object and its acceleration. The acceleration of an object is directly proportional to the net force and indirectly proportional to the object's mass ($a = F/m$).

Teaching activities

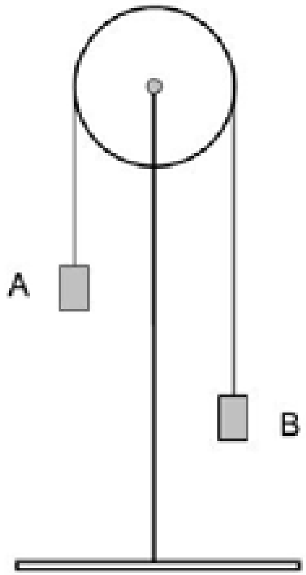
Students should use the format ‘force of A on B’ to identify the agent and receiver of a force in various situations, and use an arrow to represent the force’s direction. They can then be asked to identify all the actual forces and the net force on objects in a wide range of motion contexts (e.g. a ball rolling along a table; a ball that was rolling on a table but is now stopped; a ball thrown up in the air that is moving upwards (or downwards; a skate board rider moving down a gently sloping path who is moving at a constant speed).

In particular, the role of friction needs to be explored because it has such a huge influence on the observed motion of everyday objects (See Friction is a force).

Encourage students to identify phenomena not explained by the (currently presented) scientific model or idea.
The teacher can suggest to students who hold the belief that moving objects have a force on (or in) them that keeps the objects moving that what they are thinking of when using the word ‘force’ in this way is actually what scientists call momentum, (See Osborne & Freyberg,1985). This approach encourages students to substitute their existing incorrect understanding of the term for a new term where their understanding is correct.

Research suggests that the specific context of moving in a horizontal direction (e.g. on a bicycle or roller skates) is one where students can successfully use their everyday experiences to develop scientific understandings of motion (See Palmer, 1997). For other teaching activities, see Car restraints.

Open up discussion via a shared experience.
POE (Predict-Observe-Explain). Powerful understandings can be developed about balanced and unbalanced forces using a bicycle wheel mounted as a pulley, with a bucket of sand hanging from either side. After students respond to each question below, they observe what happens and then explain their observation:



1. With one bucket (A) higher than other (B), and both stationary, ask students which weigh more.
2. With A pulled down so it is level with B, ask students to predict what will happen when you let go of A.
3. Return to (1) and ask for student predictions about the effect of adding a small weight to B – will either side move, how far, etc?
4. The same as (3) but with a much heavier weight (so it will cause movement). Ask students whether B’s speed is same at two widely separated points in its path.
5. Explore the effects of adding and subtracting large and small weights while the buckets are moving.

(See Loughran Berry & Mulhall, 2006)

Promote reflection on and clarification of existing ideas.
Road safety is again a topic where students can explore the issues associated with mass and

speed of vehicles involved in car accidents and how these may influence the injuries inflicted on passengers.

Encourage students to think of the advantages of introducing light weight vehicles and the disadvantages of being involved in collisions with much heavier trucks.

Promote reflection on how student ideas have changed

Students can look for examples in films and cartoons where Newton's laws are not obeyed. The 'Coyote and the Road Runner' cartoons use frequent scenes where students' alternative conceptions are displayed. Identify situations and discuss these in class.

Collect evidence/data for analysis

Links to technology: Data loggers can be used to record and graph students' movement and the motion of other objects. Search for software programs that can analyse video (or digitally recorded) motion.

Further resources

Science related interactive learning objects can be found on the FUSE Teacher Resources page. To access the interactive learning object below, teachers must login to FUSE and search by Learning Resource ID:

- **Accelerate** - Pilot a spaceship between planets. Use Newton's second law of motion to work out the acceleration needed in a series of challenges. Drive at a constant acceleration, then make adjustments for cargo and friction. Examine velocity-time line graphs showing acceleration as the gradient. This learning object is a combination of three learning objects in the same series.
  Learning Resource ID: UM9P74
- **It's a drag** – Students investigate the braking efficiency of cars and trucks. They test stopping distances under controlled conditions and compare effects of vehicle type, speed, tyres, road surface and weather conditions.
  Learning Resource ID: W2XXLR