

Acknowledgements

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The extract on handout 2.3, page 55, is from *Access and engagement in science: Teaching pupils for whom English is an additional language* (DfES 0610/2002).

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Overview

This pack contains the materials, background notes and guidance for the training unit *Strengthening teaching and learning of forces in Key Stage 3 science*. As the Key Stage 3 science consultant or tutor you will use these materials as part of the Key Stage 3 National Strategy for Science.

The unit is intended for all science teachers who have identified a need to develop their own teaching of the key scientific idea of forces. It is part of a suite of units focusing on the key scientific ideas in Key Stage 3 science. This unit develops further the initial ideas about the teaching of forces that were introduced briefly in the unit *Misconceptions in Key Stage 3 science* and provided as a follow-up task for that unit.

The unit has been structured so that it can be delivered flexibly and adapted to suit the needs of the participants. It includes teaching and assessment materials developed by York University as part of the Evidence-informed Practice in Science Education (EPSE) Research Network. The diagnostic questions in this pack may be copied for use in schools participating in the training associated with this unit only.

This unit includes follow-up work of two sorts:

- that principally to be used by the participant to develop their own teaching;
- that which they can use to disseminate and develop some of the ideas from the unit with colleagues in the department.

Unit objectives

- To consider how diagnostic questions can be used to identify what pupils know and identify areas for development
- To identify what pupils have been taught in Key Stages 1 and 2
- To explore the use of 'force arrows' as a teaching model
- To explore some of the forces that are difficult to visualise
- To identify pupils' ideas and common misconceptions about forces and motion
- To illustrate the use of diagnostic questions in the development of pupils' understanding of forces and motion
- To develop a procedure and rules for analysing motion and identifying the forces acting
- To apply these rules to a range of simple examples of linear motion

Outline programme

Session 1	What do pupils know about forces and the use of 'force arrows'?	90 minutes
Session 2	Visualisation of forces and their effects	60 minutes
Session 3	What do pupils know about forces and motion?	75 minutes
Session 4	Teaching and learning about forces and motion	95 minutes

Synopsis

Session 1 What do pupils know about forces and the use of ‘force arrows’?

This first session explores how participants can use diagnostic questions. These are introduced as a way of establishing what pupils know and understand through a series of progressively more challenging questions based on everyday situations. Participants then look at ‘force arrows’ as a teaching model. Attention is paid to where the arrow should be placed on a diagram and whether it is used to represent just the direction of the force or both its magnitude and direction. The aspects of forces pupils have studied in Key Stages 1 and 2 are considered, as are the ways in which Year 7 teachers can build on these. The session finishes by asking participants to reflect on the physicist’s way of thinking about a ‘perfect’ or ‘ideal’ world compared to pupils’ and adults’ real everyday experiences.

Session 2 Visualisation of forces and their effects

The emphasis of this session is on how pupils can learn about forces that are difficult to visualise. Participants are alerted to ways in which pupils can identify and indicate the existence of these forces and the ways in which they affect moving objects. Gravity, tension and friction are all considered, through a circus of classroom activities. The idea that forces arise from an interaction between two objects and so always come in pairs is introduced. The opportunity for pupils to use creative writing to demonstrate their understanding of the contrasts between the real world and the ideal one of the physicist is also included.

Session 3 What do pupils know about forces and motion?

The purpose of this session is to make clear the many misconceptions pupils have about the way in which motion and forces are interrelated. The obstacles these present to pupils’ progression are illustrated through the development of a progression map for forces, drawing on the yearly teaching objectives. Through discussion, ways of overcoming some of these obstacles are identified. There is also an opportunity to see how the *Ideas and evidence* aspect of Scientific enquiry (Sc1) is exemplified, for forces, through the historical development of ideas about motion under the effect of gravity. The use of diagnostic questions to help pupils develop their understanding of forces and motion is also included in this session.

Session 4 Teaching and learning about forces and motion

This final session introduces a procedure and rules for analysing motion and identifying the forces acting. Participants are provided with a range of activities to test this procedure, sharing some ideas they have brought from their own department.

They will also consider how they will use the diagnostic questions in their departments and, in the plenary, identify follow-up actions in school.

Main messages

You will find it helpful to know the main messages from this unit as you start your preparation. A similar version is also provided for participants as part of the main messages leaflet included with each participant's pack.

- Forces is a key scientific idea which is taught in all key stages. Pupils starting Key Stage 3 have already had substantial experience of thinking about forces in the science they have studied in primary school.
- There are a number of common misconceptions that pupils can hold about forces. For example, that if there is motion there is a force acting and/or that stationary objects have no forces acting on them. An awareness of pupils' misconceptions and the appropriate use of teaching models can help overcome these.
- It is important that teaching of forces as a key scientific idea is started early on in Year 7 in a way that is made explicit to pupils and which explicitly builds on work they have done in primary school.
- The yearly teaching objectives set out a progression in the key idea of forces that should be taught in Year 7, Year 8 and Year 9.
- Diagnostic questions are a powerful way of finding out what pupils' ideas are, identifying misconceptions and providing evidence of pupils' knowledge and understanding.
- The value of such questions is significantly enhanced when diagnostic assessment is used to provide feedback to pupils about their understanding of key ideas, rather than just giving them a mark or grade. This leads to better motivation and better learning, in both the short-term and the longer-term.
- An understanding of forces and how they affect motion requires pupils to imagine a 'perfect' or 'ideal' world. This provides a significant conceptual challenge for pupils which needs to be supported by carefully structured teaching.
- The teaching model of using arrows to represent forces requires a simplification of many quite complex situations. The arrow is often used to represent both direction and magnitude of the force; these two aspects need to be described carefully.
- Forces, due to gravity, tension, friction and reaction (in particular) are difficult to visualise. Pupils need to learn how to visualise the forces acting even though only their effects can be observed.
- Pupils' understanding of the way forces affect motion can be developed by the application of a procedure and rules for analysing motion and identifying the forces acting.

Preparing for the unit

Flexibility in organising this unit

This unit has been written with flexibility in mind, to allow it to be organised and delivered in several ways. The organisation will depend upon local factors, such as whether the LEA has already provided subject-specific training. Many aspects of this unit would be suitable for further follow-up work through local networks of teachers.

One-day unit

It is preferable to deliver this unit as a one-day course. It could be organised in several ways. Here are two sample programmes.

9.00	Session 1	9.15	Session 1
10.30	Coffee	10.45	Coffee
10.45	Session 2	11.00	Session 2
11.45	Session 3	12.00	Lunch
13.00	Lunch	13.00	Session 3
14.00	Session 4	14.15	Session 4
15.35	Tea (and administration of follow-up tasks)	15.50	Tea (and administration of follow-up tasks)

Both these examples offer tea at the end of session 4, prior to departure, which may provide some time for you to negotiate support visits.

Two half-day courses

The unit will split into two equal courses in the following way.

First half-day

90 minutes	Session 1
60 minutes	Session 2
10 minutes	Plenary

Second half-day

10 minutes	Recap on first half day
75 minutes	Session 3
95 minutes	Session 4

There is an extra plenary at the end of the first half-day to allow time for an inter-session task to be set.

Twilight courses

This unit is also suited to the creation of a series of twilight courses that could be run for a whole science department or a group of teachers. There are several ways in which twilight courses could be structured, depending upon the prior experience of the participants. Physical science teachers in the department could be asked to assist with tuition of some sessions. One possible model is:

Twilight A	Session 1
Twilight B	Session 2
Twilight C	Session 3
Twilight D	Session 4

Middle school courses

This unit is suitable for use with all science teachers of Key Stage 3 pupils, whether the middle school is deemed as primary or secondary. Forces as a key scientific idea is first introduced in Key Stages 1 and 2. By the end of a unit on forces taught in Year 7, such as *Forces and their effects* or the *Solar system and beyond*, many pupils should be working at level 5, some will be working at level 6 and almost all should be working at level 4 at least.

Sharing presentation with a colleague

During this unit, you may wish to draw upon examples of good practice from your local schools. If you do not feel confident about the whole content of the unit, draw on the expertise of a fellow consultant, leading science teacher and/or advanced skills teacher. However, do not delegate the whole unit to a specialist, as there is some strength in being able to say to the participants that you too were less than confident before attending training!

Preparing yourself

You may need to refresh your memory of the notes and guidance provided in the tutor's notes for the LEA launch of the science strand under the following sub-headings.

- Some tips on using your tutor's notes
- Preparing for Units: practical arrangements

For convenience, the resources needed for each session are listed in the appendix.

Other preparations consist of making sure you are familiar with:

- *Framework for teaching science: Years 7, 8 and 9*, particularly the section on forces;
- *Science: a scheme of work for Key Stage 3* (the DfES/QCA exemplar scheme of work for science, henceforth called the 'QCA scheme of work');
- these notes (including the tasks for participants), slides and handouts;
- the diagnostic question materials. There are five question sets included:
 - Identifying forces
 - The link between force and motion
 - Friction
 - Gravity and freefall
 - Forces in pairs: Newton's third law

Each question set has an introductory section which provides details of the focus of that group of questions and guidance about the challenges to pupils' learning in this aspect of forces. You are also provided with a set of answers. You need to understand the questions and the pattern of the groupings within the questions. You also need to be familiar with the introductory sections and the answers so you can show participants where guidance about the underlying ideas can be found as well as the correct answers. Part of your role in this unit is to support participants to develop greater understanding of the science ideas contained within the guidance materials. In some sessions, participants are asked to complete the

diagnostic questions before referring to the introductions (see session 3). In other sessions the participants will use the guidance at the same time as the questions (session 4).

For session 2 you will need to have a section of a spring mattress or a block of high density foam, a piece of cushion flooring and a piece of hardwood flooring. Each should be large enough for a participant to stand on.

Writing to schools before this unit

You will need to prepare and send to schools in advance a programme based on the outline of the unit, tailoring times of sessions to suit your local circumstances. Send a map of how to get to the venue and include a contact telephone number for the venue that delegates can use.

There are some brief pre-unit tasks for this unit, including reading materials as well as diagnostic activities to use with pupils, and a range of possible post-unit activities, some of which may require your support. You will need to explain the brief pre-unit tasks and enclose copies of the relevant reading material and diagnostic question sheets. Master copies of these materials are included in the appendix on pages 106–114.

You may also want to prepare and send a list of participants' names and their schools to those who are attending.

You may need to ask participants to bring with them a copy of the *Framework for teaching science: years 7, 8 and 9*. This depends upon the number of copies of the Framework available to you at the venue.

Pre-unit tasks

Before attending this unit.

- Each participant should read *Introduction to forces* and read the section on forces as a key scientific idea in the *Framework for teaching science: Years 7, 8 and 9* (pages 19 – 20). They should also familiarise themselves with the yearly teaching objectives (page 29) for forces (Pre-unit task 1).
- Each participant should use the forces diagnostic questions (Pre-unit task 2) with at least one group of Year 7 pupils in order to diagnose issues relating to pupils' understanding of forces. If possible, a similar diagnosis should be carried out with a group of Year 6 pupils.
- Each participant should review the activities currently used in their department to teach about forces at Key Stage 3. They should select one of these activities and bring the necessary resources to enable the other participants to try out this activity during session 4. As part of this review, they should discuss with colleagues useful websites, teaching analogies and illustrations that are used in the teaching of forces. They should bring the details of these with them on the day in order to share ideas and information with the other participants.
- Each participant should locate and bring a copy of a departmental version of the forces map developed from the Progression unit if it was completed and/or bring a copy of sections from their Key Stage 3 departmental scheme of work relating to the topic of forces.

Evaluation

At the beginning of each unit, you should give participants copies of the evaluation form. You will find a copy of this at the back of these tutor's notes. A copy is also included as the first page of the participant's notes. An electronic version in Word is provided in the CD-ROM and may be adapted to reflect your delivery of the unit.

Collect the completed sheets at the end of the unit. You will need to read them and to summarise the data on the tutor's evaluation form also included at the back of this booklet. This will be collected as part of the monitoring and evaluation of the Key Stage 3 National Strategy.

As well as an evaluation sheet for participants, there is one included for you, as the tutor. Complete this after completion of the unit and your analysis of the participant evaluation sheets. Please return to:

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