Session 1

A systematic approach to teaching particle theory

Objectives

- To explain why particle theory is a key scientific idea
- To explain that the yearly teaching objectives set out progression in developing an understanding of particle theory
- To relate the yearly teaching objectives to a teaching methodology

Resources

For tutor

Slides 1.0–1.8, 1.10

Framework for teaching science: Years 7, 8 and 9

Spare copies of the yearly teaching objectives for particles

Audio clip on CD-ROM, and player

Popcorn

Polythene food bags

Popcorn maker

For participants

Handouts 1.2, 1.5, 1.7, 1.8 and 1.9

Evaluation form

Participants should bring:

Framework for teaching science: Years 7, 8 and 9

Session outline

45 minutes

Introduction Considering the whole unit	Talk Whole group	5 minutes
Developing an understanding of particle theory Considering progression in the curriculum	Talk, task A, audio clip Whole group, pairs	20 minutes
A strategy for using models Using a four-stage method to teach models of particles	Talk, demonstration Whole group	15 minutes
Plenary Identifying an improvement to make to teaching	Reflection, talk Individuals, pairs	5 minutes

© Crown copyright 2003

Using only part of the session

In this brief session there is no scope for reducing content as all sections are essential. However, if the day gets off to a late start and you are trying to recoup some time you may be able to make a few minutes' efficiency savings in the first two sections or by combining the plenary from this session with that at the end of session 2.

Introduction **5 minutes**

Slide 1.0

Have **slide 1.0** on display at the beginning of the session.

Session 1	**Slide 1.0**
A systematic approach to teaching particle theory	

Welcome participants to the training and deal with any domestic or administrative matters. Say that the pre-unit task that they have completed will be needed in session 2.

Slide 1.1

Show **slide 1.1**, which outlines the four sessions in the unit, and explain the programme for the day. (If the unit is being organised into a format that is not a one-day course, use a modified version of slide 1.1 and explain the structure of the unit.)

Introduction	**Slide 1.1**
Session 1	A systematic approach to teaching particle theory
Session 2	Using the key scientific idea of particles to explain physical events: Year 7
Session 3	Teaching about different kinds and sizes of particles: Year 8
Session 4	Using particle theory to improve understanding of chemical reactions: Year 9

Slide 1.2

Handout 1.2

Show **slide 1.2**, which gives the objectives for the unit as a whole and is reprinted as **handout 1.2**. Go through both slides to ensure that all participants are well briefed on the day ahead and how it is structured.

© Crown copyright 2003

Objectives for the unit **Slide 1.2**

- To explain how the yearly teaching objectives set out progression in developing an understanding of particle theory, and to relate this to a teaching methodology
- To introduce and evaluate some of the models appropriate to teaching particles at Key Stage 3
- To illustrate an approach to using the particle theory in teaching about some observed phenomena
- To apply an understanding of particle theory in teaching Key Stage 3 science, including ideas and evidence and contemporary science issues
- To suggest a range of practical work and other teaching and learning activities relating to particle theory appropriate to Key Stage 3
- To enhance participants' knowledge and understanding of the key scientific idea of particles
- To determine priorities and actions for follow-up in school

Draw their attention to the evaluation form, which they will use regularly throughout the day, and handout 4.16 (follow-up actions), to which they may also wish to refer during the day.

Also draw their attention to handout 4.18, which lists the publications and websites referred to in the unit and will save them writing them down each time a resource is encountered during the day.

Developing an understanding of particle theory

20 minutes

Slide 1.3

Show **slide 1.3** and explain the objectives for this session.

Developing an understanding of particle theory **Slide 1.3a**

Objectives for session 1

- To explain why particle theory is a key scientific idea
- To explain that the yearly teaching objectives set out progression in developing an understanding of particle theory
- To relate the yearly teaching objectives to a teaching methodology

Developing an understanding of particle theory **Slide 1.3b**

By the end of this session participants should:

- know that an understanding of particles is fundamental to learning science
- be aware of the yearly teaching objectives for particles and the progression within them
- know that models for particles need to be taught explicitly and that pupils regularly need to apply these to explain their observations
- know there is a four-stage method for using models in teaching about particles
- have identified one significant change they will make to their teaching

© Crown copyright 2003

Say that:

- Particle theory is an important explanatory idea in science and it is explicitly taught for the first time at Key Stage 3.
- Pupils need to be taught explicitly about **consensus models** of particle theory and, importantly, how these can be **used to explain phenomena**.
- Understanding particle theory doesn't happen in one step. Throughout the science curriculum, from secondary school to university, ever more sophisticated views of particle theory develop to explain wider ranges of phenomena.
- At Key Stage 3 we seek to develop models of particle theory that are '**good enough**' in a step-wise fashion.
- The yearly teaching objectives set out clearly the progression expected.
- Although many pupils will not be capable of fully abstract ideas about particles early in their Key Stage 3 career, it is important that these ideas are carefully introduced from Year 7 if the pupils are to have developed sufficient understanding by the end of Year 9.

T

Additional guidance

Many pupils start Key Stage 3 unable to handle abstract concepts and this cognitive ability develops during these three years. It is necessary for teaching, particularly in Year 7, to be sensitive to this and to use supportive visual and physical models. Many pupils will not be able to form a fully abstract model of particles immediately but the yearly teaching objectives are based on an evolving understanding of particles across the three years. Teachers will need to adapt and differentiate their teaching according to the cognitive abilities of the pupils in their class.

Slide 1.4

At this point ask participants to look at the yearly teaching objectives for particles on page 28 of the Framework and show **slide 1.4**.

Understanding particle theory — Slide 1.4

For pupils to understand the particle theory properly we need to:

- teach a simple model
- challenge pupils to use the model to explain what they observe

Say that:

- The yearly teaching objectives expect that pupils are **explicitly taught** a simple model of particle theory **early in Year 7**. They are then expected to **use this model to explain** a range of phenomena.
- Year 7 pupils should be challenged to use their developing understanding to explain things they observe. This may require a change in the way we teach and question pupils. When pupils study expansion we need to be asking questions such as '*what do you know about particles that can help us explain why heating has led to expansion?*'

© Crown copyright 2003

- At some point, of course, the simple model becomes not good enough and a more sophisticated model is needed.

Talk teachers through the yearly teaching objectives for particles, showing them how they are constructed with this last point in mind. Point out the structure which expects, firstly, teaching the model then, secondly, asking pupils to use it to explain ideas. Point out where the model has to become more sophisticated because the simple model has broken down.

Task A

10 minutes

Slide 1.5

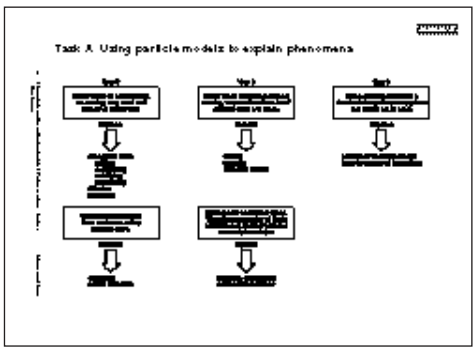
Show **slide 1.5**.

Task A Using particle models to explain phenomena **Slide 1.5**

- Find handout 1.5.
- Add your suggestions of other phenomena that pupils could explain with the models used in each year group.

Handout 1.5

Ask participants to look at **handout 1.5** and invite them, in pairs, to annotate and add any other phenomena they think pupils could attempt to explain with the model they are taught in each year group. Tell them that they can annotate with specific examples (e.g. collapsing can) if they wish.



The purpose of this task is to help teachers consider the opportunities that arise in the classroom and in the content of what they teach to help pupils develop a better understanding of particle theory. Some phenomena not listed are: air pressure (e.g. why cans collapse), viscosity. After 5 minutes draw the task to a close by sharing some of the ideas. How you do this will depend on the size of the group. One good way is to ask pairs to form fours (or even sixes), share ideas within each group and then give brief feedback.

Audio clip

Say that we are about to listen to an **audio clip** of Sir Harry Kroto talking about using models in his scientific research and in science generally. This helps to reinforce the importance of models in developing scientific understanding. Play the audio clip.

© Crown copyright 2003

T

Additional guidance

This is the same audio clip used in the Misconceptions in Key Stage 3 science *CPD unit. It lasts about three and a half minutes.*

Slide 1.6

Show **slide 1.6** to conclude this section.

Developing pupils' models	**Slide 1.6**
We should not make assumptions that pupils see things as we do.	
We need to help pupils visualise ideas.	
We need to build pupils' pictures of the world step by step.	
One model cannot explain everything; models sometimes break down.	

Say that we need to help pupils develop their understanding of how the particle model can help them explain what they see. We need to take every opportunity to get them to apply what they know in suggesting explanations of the world.

A strategy for using models

15 minutes

Say that:

- Creating models is a major way in which scientific understanding advances.
- When teaching pupils about particle models it is important to help them develop an understanding that this is so.
- Pupils need opportunities to explore models and to create their own, to appreciate how models are used in science.

Slide 1.7

Handout 1.7

Show **slide 1.7** and ask participants to look at **handout 1.7** (which is an expanded version of the slide).

A strategy for using models and analogies	**Slide 1.7**
Using models and analogies as a teaching approach	
(The four-stage method)	
• Teach the model explicitly.	
• Test the model by applying it.	
• Challenge the model.	
• Increase sophistication if necessary.	

Talk participants through the handout, pointing out that this is a teaching approach that we can consider to have four stages. The stages are unlikely to happen all in one lesson, but we need to use this approach if we are to teach pupils about particles in an effective way. You might like to ask participants to discuss this with each other briefly.

© Crown copyright 2003

Slide 1.8

Show **slide 1.8**, which is expanded in **handout 1.8**.

Handout 1.8

Encouraging pupils to identify the strengths and weaknesses in a model Slide 1.8

Discuss the model and encourage pupils to:

- identify what each part represents;
- think about the strengths and weaknesses; what it can explain, what it cannot explain;
- suggest improvements for the model.

Provide models created by others that are problematic and encourage pupils to:

- identify limitations of the model;
- consider what misconceptions it might generate.

Say that:

- An important element of teaching using models and analogies in this way is the role pupils play in developing their own understanding.
- Discussing with pupils the merits of a model, or an analogy, helps them to realise that models and analogies are the ways we often visualise science. They are only models and one model cannot give the whole picture.
- Encouraging critical thought develops pupils' ability to reason and helps them to appreciate that modelling is a useful way of thinking.
- Discussing strengths and limitations of models or analogies helps pupils make good progress in developing their understanding.
- Constructive criticism of their own and other people's models can be motivating.

Illustrate this methodology by the use of a physical model with many limitations. If you have a popcorn maker available use it to prepare some popcorn as participants watch. If not, use pre-popped corn. Use popcorn in a transparent polythene bag to model the particles in a solid, a liquid and a gas. Refer to slide 1.8 and ask participants to identify some of the strengths and limitations of this model, as might be done with a Year 7 class. Take suggestions, but there is no need to record these on a flipchart.

T

Additional guidance

Strengths of this model may include:

- *use of a relatively familiar material;*
- *the popcorn maker animates the particles in a manner similar to the particles in a liquid or gas;*
- *it engages pupils' interest.*

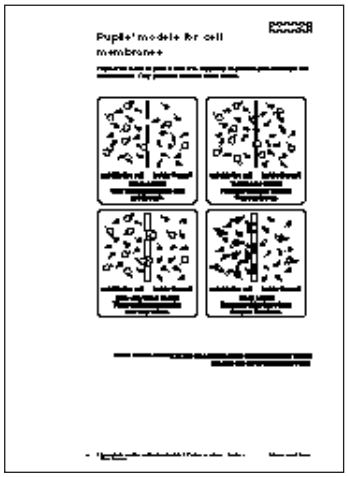
© Crown copyright 2003

Limitations of the model include:

- *the particles have irregular shape and size;*
- *the grains expand when heated, suggesting particles expand.*

Handout 1.9

Next ask participants to look at **handout 1.9**.



Say that:

- This was part of a teaching programme for Year 9. Pupils were being taught that the simple visking tubing model was insufficient to explain how particles pass through a cell membrane.
- They were challenged to develop their own models that explained how this might occur.
- The ideas generated fell into four main camps.
- The outcomes were used to discuss the merits of each model. This helped move pupils to a consensus view of a preferred model, but the teacher made it explicit that no one model gave the whole picture.

Plenary **5 minutes**

Ask each participant to work individually. They should write down one thing they are likely to do differently as a result of this session and reflect on why they will do this. After 1 minute ask them to join with a partner. They should share their selected change and their reason for this with the partner.

Slide 1.10

Show **slide 1.10** and run through the expected outcomes with participants.

© Crown copyright 2003

Plenary for session 1 **Slide 1.10a**

Objectives for session 1

- To explain why particle theory is a key scientific idea
- To explain that the yearly teaching objectives set out progression in developing an understanding of particle theory
- To relate the yearly teaching objectives to a teaching methodology

Plenary for session 1 **Slide 1.10b**

By the end of this session participants should:

- know that an understanding of particles is fundamental to learning science
- be aware of the yearly teaching objectives for particles and the progression within them
- know that models for particles need to be taught explicitly and that pupils regularly need to apply these to explain their observations
- know there is a four-stage method for using models in teaching about particles
- have identified one significant change they will make to their teaching

Ask them to complete session 1 on their evaluation form.

Finish this introductory session by saying that the next three sessions focus on one year at a time and explore the ways in which we can incorporate this approach, with others, into our teaching. This will help pupils to develop progressively a good understanding of particle theory and to be able to use it to explain what they observe.

T

Additional guidance

Some teachers may wish to know where this advice about methods of teaching has come from. You can say that it is based on substantial research both internationally and within the UK. One specific project that led to the development of these ideas involved the University of Reading, Hampshire and Southampton LEAs and approximately 20 schools. In addition, the Royal Society of Chemistry, the Association for Science Education and the University of York have helped in formulating this approach.

© Crown copyright 2003

Objectives for the unit

- To explain how the yearly teaching objectives set out progression in developing an understanding of particle theory, and to relate this to a teaching methodology
- To introduce and evaluate some of the models appropriate to teaching particles at Key Stage 3
- To illustrate an approach to using the particle theory in teaching about some observed phenomena
- To apply an understanding of particle theory in teaching Key Stage 3 science, including ideas and evidence and contemporary science issues
- To suggest a range of practical work and other teaching and learning activities relating to particle theory appropriate to Key Stage 3
- To enhance participants' knowledge and understanding of the key scientific idea of particles
- To determine priorities and actions for follow-up in school

© Crown copyright 2003

Task A Using particle models to explain phenomena

Year 7

Matter made of particles that are moving, very small and broadly of similar size.

Explains

changes of state:
- melting
- evaporating
- solidifying
- condensing

diffusion
expansion

When particles interact there are forces acting between them.

Explains

dissolving
crystal formation

Year 8

Matter made of particles that are moving, very small and can be of different sizes and mass.

Explains

density
osmosis
Brownian motion

Particles are of different types. There is a set number of kinds of atoms and all other particles are made from these.

Explains

elements, compounds and chemical change

Year 9

When particles interact in a chemical change they swap places in a limited set of ways.

Explains

patterns of chemical change
mass is conserved in reactions

© Crown copyright 2003

Using models as a teaching approach

Purpose

To help pupils to:

- visualise abstract or complex ideas and understand the consensus models;
- understand the nature of modelling as a tool for creative thought and explaining phenomena.

Stage 1

Teach the model explicitly. Show which part relates to which, making sure pupils understand it and 'picture' it; or ask pupils to develop their own model to explain a particular phenomenon.

Stage 2

Test the model by applying it. Pupils practise using the model by attempting to explain a limited range of simple phenomena, so exploring the model's strengths and limitations.

Stage 3

Challenge the model. Provide some phenomena that the model cannot explain, so that pupils see the limitations of the model. Evaluate the model, exploring what it can explain and what it cannot.

Stage 4

Increase sophistication if necessary. Explore with pupils the development of a better model or provide a more sophisticated model. Test it out on the new phenomena, exploring what it can explain and suggest its likely limitations.

These stages may take place in one lesson or more likely over a period of time. A lesson may focus on just one stage or part of a stage.

© Crown copyright 2003

Encouraging pupils to identify the strengths and weaknesses in a model

Discuss the model and encourage pupils to:

- identify what each part represents;
- think about the strengths and weaknesses; what it can explain, what it cannot explain;
- suggest improvements for the model, or analogy.

Provide models created by others that are problematic and encourage pupils to:

- identify limitations of the model;
- consider what misconceptions it might generate.

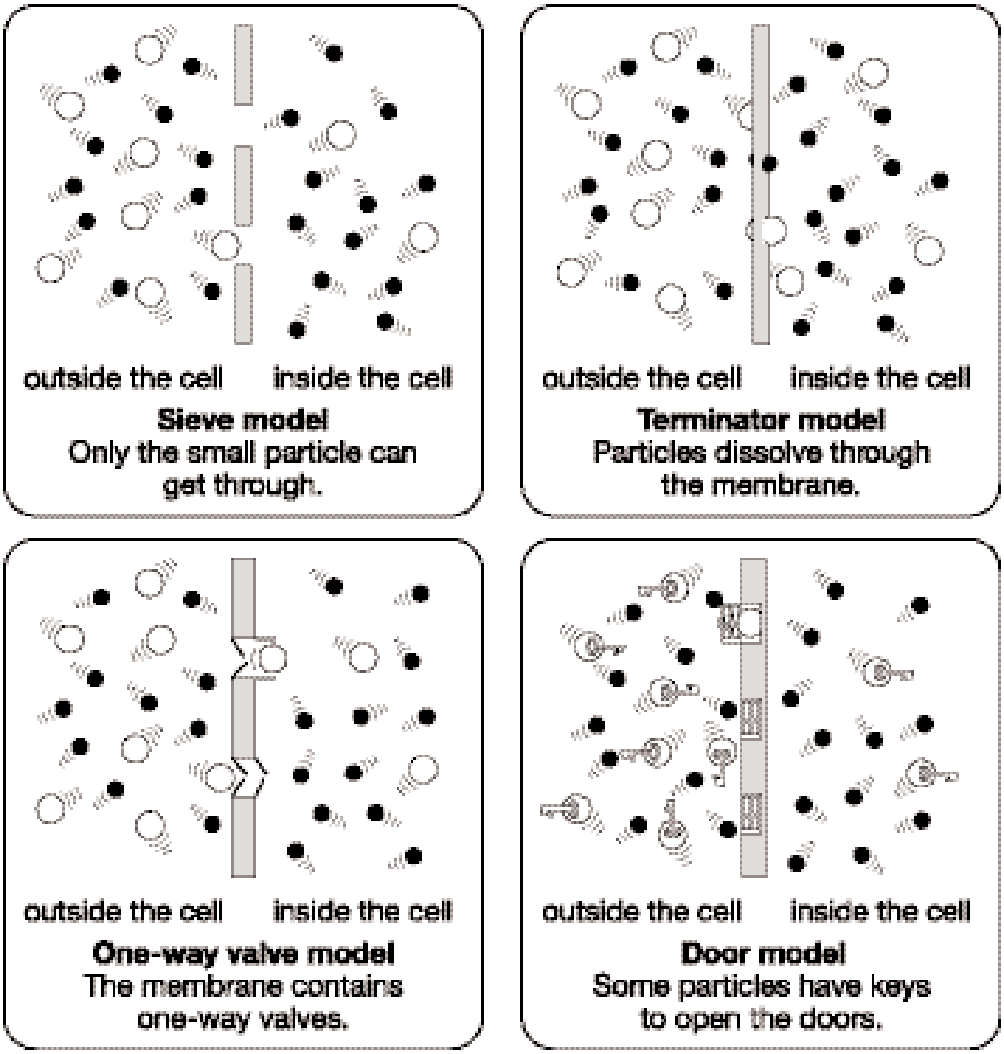
When using models and analogies in this way in teaching it is essential to engage pupils in discussion and analysis in order to maximise their learning.

- Discussing the merits of a model, or an analogy, helps pupils to realise that these models are the ways we often visualise science. Discussion should help pupils realise that no one model can give the whole picture.
- Encouraging critical thought develops pupils' ability to reason and helps them to appreciate that modelling is a useful way of thinking, wider than just science.
- Discussing strengths and limitations of models or analogies helps pupils make good progress in developing their understanding.
- Giving and receiving constructive criticism of a model can be motivating for pupils as well as helping to develop their understanding of the model.

© Crown copyright 2003

Pupils' models for cell membranes

Pupils were asked to picture what was happening as particles passed through the cell membrane. They generated four alternative models.



Source: Matthew Newberry, as part of a continuing models and modelling project involving Hampshire LEA and the University of Reading

© Crown copyright 2003