UNIT 4.1 PLANNING FOR PROGRESSION IN SCIENCE

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INTRODUCTION

What is unique to learning science is that the learner comes across strange ideas that defy experiences of everyday life and common sense. Invisible charges drift through wires, invisible forces hold matter together, the massive trunks of oak trees are made up of building blocks that come predominantly from the apparently immaterial air, balls moving upwards have only a downward force acting on them, the invisible products of a combustion engine have a greater mass than the petrol that is burned, electrical impulses constantly surge through our body. Electrons, atoms, cells, fields, neurones are the invisible or microscopic stuff of nature. Osmosis, entropy change, and radiation are some of the processes that have to become real so that they have an explanatory power. Pupils can only start to understand these things, if they are constructed on the back of experience and knowledge they already have.

Progression 'describes the personal journey an individual pupil makes in moving through the educational system.' (Asoko and Squires, 1998: 175). To understand how pupils' learning of science is structured you need to understand progression. But what is involved in this personal journey? Do pupils move from simple to more complex ideas? Is there a pattern in the way all pupils progress which might help us organise their learning more systematically? How personal is the journey – what is the role of teachers? This chapter attempts to address these questions and to identify ways in which you can help pupils progress in their understanding of science.

OBJECTIVES
By the end of this unit you should be:
- able to describe examples of progression
- aware of the complexity of progression
- able to start planning for progression
- able to identify the kinds of activities that enable progression.

DESCRIBING PROGRESSION

Imagine a two-year-old at bath time playing with bath toys. Playing is hopefully a pleasurable experience for this infant although she is unlikely to make any distinction between toys which float and those which sink. Even if an adult intervenes and tries to draw the child's attention to these distinctions they are likely to go unremarked. When the child is a little older, say four or five, she starts to categorise objects by certain properties, such as shape, size, colour, soft and hard. She begins to notice that shells, coins and pebbles sink to the bottom of the bath but other objects like polystyrene toys don't, even if they are pushed down – they bob back up to the surface. This might prompt the child, possibly with the support of a helpful older person, to see what happens when a further range of objects are dropped into the water, all of which might be characterised as 'floaters' or 'sinkers'. Once the child has had a range of experiences and has been able to talk about them, she might be able to generalise that 'sinkers' have attributes different from those of 'floaters' and to predict what happens when an object is dropped in water. According to the experiences from which the child generalises, ‘sinkers’ might be heavy, hard, compact, lacking air. It does not matter at this stage whether these generalisations are correct or not; the point about generalisations is that there are exceptions which might prompt the child to rethink the basis of her reasoning. Contradictions, for example a hard heavy object like a boat that floats, might generate further trials either in the bathtub or, by this time, at primary school. The child might see what happens when she tries to submerge in water a bottle filled with air and then filled with water.

By this time the child’s earlier generalisations are becoming refined, and through guided observations, the data collected is more directed. She begins to test certain things out – for example, to find out what happens when the bottle is half-filled with water. As well as being able to predict with some accuracy whether objects float or sink she might notice now that water seems able to ‘push up’ on an object. She develops a language, with support, where the scientific meanings are very specific, that an object *weighs* less in water than it does in air, that there are *forces* acting on the object, that the upward force acting on the object is called *upthrust*. She begins to test whether the same objects float or sink when placed in different liquids and ask why some objects which sink in fresh water float in salty water. To test her ideas she begins to make measurements, to use equipment to make the measurements (for example a measuring cylinder to find out the volume occupied by the object in water), to record her data, make inferences and test these inferences further.

Of course, this is an idealised case. We have assumed that all the ideas follow on one from another, that the child does have baths in her early years, and has bath toys (some only have showers or don’t always have the time to play), and that there’s a helpful older other person who intervenes appropriately and knows the right kinds of questions to ask. Some children may have very particular experiences, interest in boats, for example, from an early age, while others might not have seen natural watercourses. Whatever the circumstance of the child, the elaboration of one idea depends on an earlier idea. For example, a child cannot generalise about floating and sinking until she can recognise the difference and has thought about explanations for the differences. Children may go through these stages at different times and at different rates but the point is that all children go through the earlier stages. What we have described is progression, the child's developing ability to make increasing sense of the world, in this case floating and sinking. This developing ability can be mapped through a number of different routes:

- an increasing sophistication of explanations, from the everyday to using scientific explanations (these objects float while these sink to how ships float when they weigh thousands of tonnes). This also includes argumentation in using relevant data and warrants to support claims (Simon and Maloney, 2007).

- moving from hands-on activities in familiar situations to applying ideas in less familiar contexts (observing things floating and sinking in a bath to testing ideas using laboratory equipment such as a measuring cylinder or 'Eureka' can).

- terminology becomes more precise and scientific ('water seems to be pushing on my hand' to 'water is exerting a force on my hand and my hand is exerting a force on the water).

- moving from qualitative to quantitative explanations (these objects float, these objects float in liquids above a certain density).

- developing practical and mathematical skills to underpin understanding.

- developing of procedural skills (making simple observations, planning experiments to test hypotheses, using models as ideas).

Task 4.1.1 Describing progression in different topics
Find another context or topic, for example photosynthesis, chemical reactions or light. Map the main stages in progression from Key Stage 1 to Key Stage 5 using about four main stages. For example, the more detailed account about floating and sinking above can be mapped:

Some objects float, others sink
Light objects seem to float while heavy objects sink
Objects denser than water sink, objects which are less dense float

Whether objects float or sink depends on whether the force acting downwards is greater than the force acting upwards.

THEORISING PROGRESSION

From the previous section you would have a sense of progression of a moving forward from simple everyday ideas to more complex situations or to contexts requiring abstract concepts to explain them. Progression in all these situations may require the use of new scientific terminology and procedural concepts. But as a teacher you need to know how to enable and recognise this progression. Progression presupposes development, i.e. that, with maturity, the child can assimilate more experiences. Piaget produced the most widely recognised explanation of cognitive development as development through a number of age-related stages. In these stages knowledge is actively generated as the learner explores her world. In the first years of life the child understands the world through her senses and moves on to begin to categorise and describe objects through their characteristics. These first stages are known as the sensory-motor and pre-operational stages, respectively (see Burton, 2009) and correspond to the child's playing followed by categorising and classifying as described for floating and sinking in the previous section.

Two further stages were recognised by Piaget, the concrete operational and the formal operational. As the child moves from the stage of concrete operations to formal operations she moves from a manipulation (both mental and physical) of specific experience to generalising and to logical, mathematical reasoning about events not seen. For example, pupils working at the concrete operational stage may be able to measure the time period of a pendulum and show that it is dependent on the length of the pendulum; the longer the pendulum the slower the time period. If presented with the challenge of finding the effect of length and mass of the bob of a pendulum have on the time period, pupils unaided may not be able to separate and control the two variables until they are working at the stage of formal operations. Furthermore, until they have progressed to this higher stage they may not recognise the shortcomings of their approach and the validity, or otherwise, of their conclusions.

Piaget argued that children progress from one stage to the next as they encounter cognitive conflict and have to assimilate new explanatory models and more complex thinking. Although Donaldson has pointed to problems in Piaget's theory – because research shows that children can manipulate more complex variables than Piaget originally supposed – this was not a repudiation of the basis of general stage theory (Donaldson, 1978). (It is worth noting that there have been cogent critiques of the basis of developmental psychology from social constructivist (O'Loughlin, 1992) and feminist perspectives (Burman, 2008).) Intelligible and fruitful learning experiences assist this progression (Posner *et al*., 1982), hence the teacher has to be aware of the appropriate point to present material and explanations which will advance understanding.

The picture so far is one of the child constructing knowledge of the world about her with occasional facilitation by the teacher. However, the child lives in, and partakes of, a social world in which she is interpreting diverse forms of communication, mainly through talk (Vygotsky, 1978). The child, her peers and teachers generate meanings by interpreting what is said and co-construct new meanings together. The teacher, responding to detailed knowledge of the child's cognitive and social development, presents learning experiences which are beyond what the child already understands but gives enough support to move on to a 'higher rung of the ladder.', a process teachers call 'scaffolding'. For further discussion of scaffolding see Wood (1998).

A third explanatory model is that of the child as information processor. The mind acts to transform the information it receives but care needs to be paid to the capacity of the processor at any one time. Information overload inhibits learning and too little information results in lack of stimulation. Knowledge of how much information the child can process is crucial to effective teaching and learning (Kempa, 1992; Burton, 2009).

All three models of learning come under what is broadly termed 'constructivist' theory, because the learners are seen as actively constructing their knowledge. In the UK there have been two particular developments in teaching related to progression in science based on constructivist theory, one is the Children's Learning in Science Project (CLISP) and the other is the Cognitive Acceleration in Science project (CASE). The Children's Learning in Science Project (CLISP) takes as its basic assumption that many children have conceptions about scientific phenomena that are different from the scientifically accepted explanations (Driver *et al.*, 1994). Thus, for example, younger children and some older children think that when you add a substance to a beaker of water and the substance dissolves, the mass of the beaker and water stays the same, clearly contravening the principle of the conservation of mass. You can't see it so it's not there. Many examples of children's everyday thinking have been identified, and a few are given below:

- heavier objects fall faster than light ones
- electric current is used up as it passes through a circuit
- whales are fish
- plants get all their food from the soil
- when fossil fuels burn there is no product.

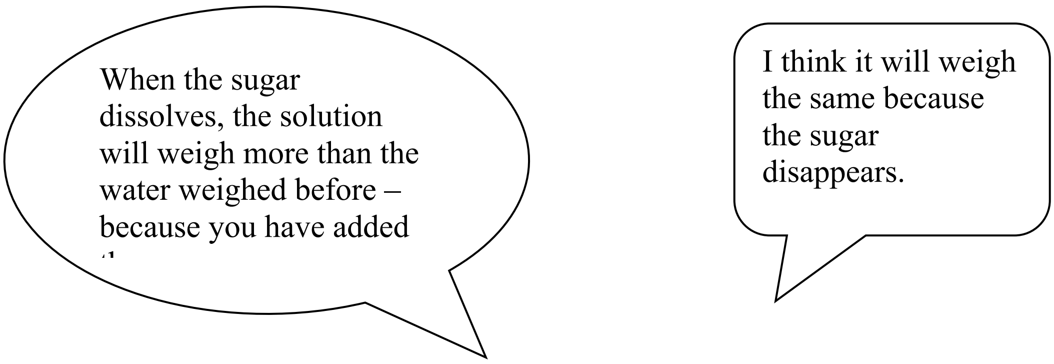
Research into children's conceptions about scientific phenomena began in the 1980s, largely influenced by research work in New Zealand (Osborne and Freyberg, 1985). Since then, many articles have been written about children's explanations of events across the science curriculum. These explanations have been termed 'prior conceptions', 'misconceptions' or 'alternative frameworks' according to the viewpoint of the author. 'Prior conceptions' suggest that children have conceptions about nature before they are inducted into the accepted framework of science. 'Misconceptions' implies that children's ideas are often mistaken and need challenging and changing as they begin to understand correct scientific explanations. When children have 'alternative frameworks' the emphasis is that children have another way of explaining the world that is coherent to them and that science is another explanatory framework.

If children do have conceptions that do not accord with the accepted scientific explanation, how can teachers help them to understand something that challenges their way of thinking, particularly when many scientific explanations are counter-intuitive? Under normal circumstances we don't see the gases produced when fuels burn so how can they be recognised as products? When an object rests on a table how can the table be pushing up with an equal and opposite force? A table is a static object which doesn't appear to be doing anything let alone exerting a force when an object is put on it. A whale lives in the sea and looks like a fish so it is a fish. Mammals are hairy and live on land. It just doesn't make sense to say a whale is a mammal.

The challenge for the CLISP project was to provide a strategy, based on constructivist principles, which allows teachers to support pupils through these transitions in their thinking. To plan the learning tasks it is important to know what ideas pupils do have and how dissimilar they are to the accepted scientific ideas. Much of this information can now be accessed from the literature but the starting point is to provide opportunities for pupils to make their own ideas explicit (Driver *et al.*, 1985). Two stages are involved when children make their ideas explicit; the first is 'orientation' – setting the scene – where pupils are given stimulus material relating to the topic, recording what they already know; the next is to induce cognitive conflict by introducing students to discrepant events which may promote 'restructuring.' of ideas. In doing so the teacher is promoting in the learner an awareness that there is a difference between their ideas and the scientific idea and that there is a strategy for bridging the difference. Socratic questioning can be used where the teacher helps pupils to identify inconsistencies in their thinking. The last stage is that pupils try out these new ideas in a variety of contexts involving ‘application’ of ideas and they finally ‘review’ what they have learned. This strategy is by no means watertight because pupils have experiences which are consistent with their commonsense thinking and teachers are often exasperated to learn that pupils repeat their original conceptions when there was every reason to suppose they had assimilated the new scientific ideas. Think about the way people often say ‘close the door or you’ll let the cold in’ rather than ‘close the door otherwise the temperature gradient will mean that there will be a flow of heat from indoors to outdoors’. Everyday language is not very well suited to school science concepts. That is why these ideas are periodically revisited in different contexts. An example of this type of strategy is discussed in Task 4.1.2.

Task 4.1.2 Understanding conservation of matter
Context: Pupils are given a situation in which they are asked to choose between two possible explanations of an event; see Figure 4.1.1. In Figure 4.1.1 pupils have to decide whether the mass of the system changes or remains the same. This situation provides orientation by introducing a context and provides the second stage, elicitation, by asking questions. The third stage provides a situation where pupils are asked to carry out tasks which may challenge their preconceptions.
Your task: Go through this problem yourself identifying:

- concepts pupils might already hold (Driver *et al*., 1994; Driver *et al*., 1985)
- the scientifically acceptable conception
- how the tasks might help restructure pupils’ thinking about the topic
- how you might run this activity in a Key Stage 3 classroom.



What do you think? How could you find out who is right?

Figure 4.1.1 An orientation exercise

The CASE project has the aim of helping pupils to progress faster in their thinking skills by promoting cognitive conflict and through reflecting on their own thinking. The theoretical model for CASE is based on the learning theories of both Piaget and Vygotsky (see Burton, 2009). As we have seen in Piaget's work, children move through a sequence of stages as their understanding about the world develops. In Piaget's model the child interacts with the environment where new stimuli are *assimilated* into the child's mental model. Where the child's cognitive structure has expanded so she becomes aware of discrepancies, there is cognitive conflict and the cognitive structure shifts to *accommodate* the new stimuli. The processes of *assimilation* and *accommodation* are intrinsic to Piaget's theory. For Vygotsky, the role of a peer or teacher (which he calls an 'other') is crucial in enabling a child to complete a task successfully. Here the teacher becomes a mediator in framing the task in such a way that the learner can make the necessary jump to success.

The CASE materials are based on the 'five pillar teaching model', which are stages in enabling progression (Adey and Yates, 2001). These pillars are listed below.

1. *Concrete preparation:* pupils become familiar with the practical context of the task and the relevant terminology. The teacher and pupils develop a shared language through questioning and group work.
2. *Cognitive conflict:* pupils are led towards observations which occasion surprise and do not meet their expectations. The conditions have to be right for cognitive conflict

to occur. Some children may simply not be ready for it, very able children may be able to assimilate and accommodate new observations with relative ease.

3. *Construction:* the pupil actively puts bits of information together to build new
    a. knowledge and make it her own.
4. *Metacognition:* the pupil not only solves a problem but can articulate how it was solved and can therefore use their thinking skills much more flexibly.
5. *Bridging:* applying the skills they have learned to a variety of contexts. – for examples of bridging strategies, see Shayer and Gamble (2001).

Activities across all five stages encourage children towards formal operational thinking through such characteristic reasoning programmes as classification, probability, control of variables, equilibrium, proportionality. The CASE project is aimed at developing scientific reasoning skills. Although CASE uses content and context to realise its objectives the approach is not specifically designed to widen factual knowledge. Pupils may move more quickly through the Piagetian stages as a result of exposure to CASE activities but not all pupils may reach the level of formal operational thinking, or jump stages, such as from pre-operational thinking to formal operational thinking. Research shows that progress through CASE activities transfers across to progress in other subjects such as English and mathematics (Adey and Shayer, 1994).

As well as the main cognitive elements in progression, you should take into consideration other factors that may influence progression. Pupils:

- have different motivations
- learn in different ways

- learn at different rates
- have had different experiences
- have different language skills to help them
- have different emotional responses to the topic.

PLANNING FOR PROGRESSION

To support progression in learning in all your pupils you should consider the following points:

a. What is it that you want the pupils to know, understand and do, i.e. to have learned, in this topic by the end of the course, module or lesson?

b. What is it that the pupils know, understand and can do at the start of the topic?

c. What sequence of learning activities will help pupils progress from their present understanding to the objective?

d. How will you know when pupils have reached where you want them to go?

e. Remember that pupils are individuals and will need a range of strategies to support learning.

One way to think about planning for progression is to consider points a. to e. in turn.

What do you want pupils to learn? Learning objectives and outcomes

What you want pupils to have learned by the end of an activity, lesson or topic is known as the learning objective. An objective at Key Stage 3, for example, could be ‘pupils understand that chemical reactions can either be exothermic or endothermic’ or ‘pupils know how flowers help a plant to reproduce'. But stating objectives in this way begs a further question: How do you, as the teacher, *know* when pupils have achieved these objectives? How can you *tell* a pupil knows or understands something? To answer these questions, the pupils have to provide evidence of their understanding or knowledge. You need 'doing' words that describe this evidence, for example 'sort these reactions into exothermic and endothermic', 'label the male and female parts of the flower', 'explain the differences between exothermic and endothermic reactions', 'draw what happens when pollen travels from one flower to another'. Statements like these are called learning outcomes, i.e. objectives that can be assessed. Outcomes contain terms like: *explain, design a poster, sort out, discuss, interpret, use the model to show (use the particle model to show the differences between solids and liquids)*. Finding out if pupils do understand the differences between exothermic and endothermic reactions, they could:

- describe what happens in terms of temperature change in exothermic and endothermic reactions
- complete schematic diagrams showing where heat is being gained and lost interpret data from an experiment to show that a reaction is exothermic or endothermic
- identify the thermicity of a reaction from an energy diagram
- suggest ways of finding out how exothermic or endothermic a reaction is.

Most outcomes and objectives will only be partly achieved. Pupil A may answer a homework question by describing an exothermic reaction as one that gives out heat and an endothermic reaction as one that takes in heat. Pupil B might respond. 'Exothermic reactions such as the burning of a candle and the reaction of magnesium with acid lose heat to the surroundings. We can tell it is an exothermic reaction because the temperature of the surroundings rises as a result of the reaction. If we put a thermometer in the reaction mixture of magnesium and acid, the temperature rises until the reaction is complete.….' Clearly, pupil B has been able to meet the outcome more precisely than pupil A. You could therefore help pupil A to progress by giving a short exercise to help them identify instances of exothermic reactions and see if they can report what happens in terms of temperature change (see Unit 6.1 Assessment for Learning). Pupil B can be superseded by pupil C who relates the temperature change to particle motion. Thus there are opportunities for progression within a particular outcome.

Some teachers identify several levels of learning outcomes to cater for different levels of achievement in the class. They might state their outcomes as follows:

- All pupils will be able to recall that heat is lost to the surroundings in exothermic reactions and that heat is gained from the surroundings in endothermic reactions.
- Some pupils will be able to identify exothermic and endothermic reactions and to state what happens to the surrounding temperatures.
- A few pupils will be able to translate energy diagrams into exothermic and endothermic reactions.

Task 4.1.3 Identifying three learning outcomes for one objective

Take the following objectives and break each one down into three outcomes, i.e. what all, some and a few pupils can do:

- plan an investigation to find out the best anti-acid remedy
- understand that light can travel through a vacuum but sound cannot
- know that habitats support a variety of plants and animals that are interdependent.

What is it that pupils know, understand and can do at the start of the topic?

To help pupils to meet learning objectives you must have some idea of where the pupils are starting from. There are at least two reasons for this .– pupils may have done much of the topic before and may become bored going over old ground. Secondly, you may assume knowledge which the pupils don.'t have and if this is the case they may become quickly disaffected. Of course, pupils won.'t all be starting from the same point so you need a means of finding out what pupils do and don.'t know before starting a topic. The list below gives guidance on how you can find the relevant information.

1. Pupils ought to have covered something of the topic at Key Stages 1 and 2 if you are starting at Key Stage 3. Starting at Key Stage 4, there ought to have been some coverage at Key Stages 2 and 3. Find out from the National Curriculum what they are likely to have covered.

2. Ask more experienced teachers who can tell you about the kinds of things pupils know well and what gaps in knowledge to look out for.

3. Acquaint yourself with the literature on children's ideas (Driver *et al.*, 1994; Driver *et al.*, 1985) so you can anticipate ideas pupils may bring to the topic.

4. Use diagnostic tasks and starter activities to find out what pupils know. These activities can be given at the beginning of a topic. They should be:

- short
- easy to administer
- engaging for the pupil
- able to give you the information you want
- quick to mark.

What sequence of learning activities helps pupils to progress from their present understanding to the next learning objective?

Starter activities and diagnostic tasks not only tell you what pupils already know and don't know, they also reveal a wide range of understandings within the classroom. The instruction and learning opportunities you give pupils within the lesson must then have two characteristics:

- offer sufficient challenge for all the pupils
- allow the pupils to develop scientific ideas, skills, terminology etc. (this is likely to involve active instruction).

Whether you are teaching in a setted, streamed or mixed-ability class there are always differences in knowledge and understanding, although the range of knowledge and understanding may be (but not necessarily) narrower in a streamed or setted class. Differences need not necessarily be vertical, i.e. one pupil knows more than another; they may simply be different and have knowledge in different types of context. Because all pupils are different there is a tendency to think that the best way out would be to give each pupil individualised work. This approach is clearly impossible and probably undesirable; pupils can learn from each other so devising activities for them which encourage discussion and exchange of ideas assists progression.

You need to ensure that you are starting from the appropriate level for those pupils who have clear misconceptions and that you are setting a sufficient challenge for those pupils who have clear understandings. Most departments have a bank of activities which you can adapt for your own purposes. You can support the lower attainers by giving them guided help. Suppose you ask pupils to explain how condensation appears on the outside of a cold, stoppered conical flask, which contains ice (a can taken out of the fridge rapidly gains condensation). Some pupils say that the water seeped through the flask. You might want to help them by showing them a flask containing water where condensation doesn't appear on the outside of the flask, or dyeing the ice red and demonstrating that the water on the outside is colourless.

Don't expect pupils to accept your explanations immediately because you are challenging beliefs they might hold quite strongly. When pupils come to realise that the explanations they have held up to now contradict new explanations which they are beginning to own intellectually, we call this situation cognitive conflict. Resolution of this cognitive conflict can take some time and needs reinforcement; this is why you need to revisit concepts and widen experience. Some pupils will need help to reinforce the concept to help them progress. For others you will need to ensure that they have sufficient challenge. Pupils are progressing through the topic but there are opportunities at various stages for reinforcement for some pupils and extra challenge for others.

Teachers rightly want to ensure that all their pupils are challenged but it is important not to be too ambitious and to devise too many activities. As a starting point, try the approaches listed below:

- For each idea taught, devise three or four distinct activities, all of which underpin the understanding of the idea. For example, one activity might involve a short practical
- exercise such as finding out how quickly different liquids evaporate, another discussing a concept cartoon, a third answering questions on a short written piece and finally analysing a piece of data from a website.
- Devise an activity which all pupils can do but at different levels. For example, it might be answering questions on a piece of data, or a short extract from a video, where successive questions become more demanding.
- Ask pupils to plan an investigation where you set different demands.

Task 4.1.4 Planning differentiated investigations

If we take the example of evaporation, the following tasks could be set:

- Find out the order in which these four liquids evaporate. You will need a measuring cylinder, stopwatch and evaporating basin. Start off with the same volume of each liquid.
- Plan an experiment to show how surface area of a liquid influences the rate of evaporation.

How do you know when pupils have reached where you want them to go?

Pupils provide evidence of outcomes in the work they produce such as written exercises, drawings and analysis of practical work, but much of pupils' understanding is ephemeral, captured quickly in off-the-cuff remarks or contributing something to a discussion when they are not aware of being watched. It is important for the progress of individual pupils that you are able to record the necessary information. While you cannot record the progress in a single lesson of each and every pupil, focus on a sample of three pupils for each lesson and make any notes on points that they appear to have understood or that they find difficulty with. An example of how you can do this is given in Figure 4.1.2. These notes should then be transferred to the register where you keep pupil records.

Self-assessment is another way in which pupils can keep a record of their own progress. When the teacher makes explicit to pupils the stages in their learning the pupils can check how well they have understood each stage. This helps both the pupils and the teacher. Helping the pupil to develop the skills needed for self-assessment is discussed in Unit 6.1.

Remember that pupils are individuals and will need a range of strategies to support learning.

Selecting teaching strategies to meet needs of individuals is explored in detail in Unit 4.4.

Context: Comparing the rates of marble chips dissolving in acid.

	Group 1 John, Paul and Mary	Group 2 Laura, Pamjit and Anwar
Making predictions	Paul could with reasons. John and Mary struggled.	Laura/Pamjit, good predictions but not sure why.
Devising procedure	All gave good response, but John not sure why.	Laura and Pamjit OK. Anwar only understood when told.

Figure 4.1.2 Keeping notes of pupils' progress

SUMMARY AND KEY POINTS

This chapter has discussed the ways in which progression may be described and the theories that underpin such discussion. Children do not always progress in the same way and effective teaching has to maintain a balance between challenge and support, pitching the work at just the right level of demand to encourage participation and success. The keys to enabling progression are two-fold: a sound knowledge of the topic in hand and a sound knowledge and understanding of the pupils in your class. The first can be prepared for; the second develops over time, with increasing confidence and trust developing between you and your pupils. The main thrust of this chapter has focused on planning for progression and suggested the kinds of activities that you can try out in the classroom. The *Key Stage 3 Strategy for Science* (DCSF, 2009a) has many useful ideas which complement the material in this unit.

FURTHER READING

Harrison, C., Simon, S. and Watson, R. (2000) ‘Progression and differentiation’, in Monk, M. and Osborne, J. (Eds) *Good Practice in Science Teaching. What Research Has to Say.* Buckingham: Open University Press.

This examination of progression draws on research literature and helps the reader tease out several meanings of ‘progression’ that are appropriate to different contexts.

Jarman, R. (2000) ‘Between the idea and the reality falls the shadow’, in Sears, J. and Sorensen, P. (2000) *Issues in Science Teaching*. London: RoutledgeFalmer.

Ruth Jarman addresses continuity and progression across Key Stage 2 and 3 and raises important issues about acknowledging what prior learning pupils have and how that can be assessed and recognised.

Johnson, P. (2002) ‘Progression in children’s understanding of a “basic” particle theory: a longitudinal study’, in Amos, S. and Boohan, R. (eds) *Teaching Science in Secondary Schools: A Reader*. London: RoutledgeFalmer for the Open University, pp. 236–49.

This is a report of a longitudinal study into secondary pupils’ (aged 11–14) understanding of particle theory. Useful examples of strategies for discussing ideas with pupils and the types of understanding pupils’ display at different levels of progression.

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