1

Progression and Continuity in Learning Science

Chapter overview

Understanding progression and continuity in science learning is a prerequisite for thinking about how and why pupils do or do not move forward in their learning at transitions. Continuity and progression are considered in terms of conceptual and procedural knowledge and understanding of science. 'From → to' statements help the reader understand progression steps as they affect Key Stage 2 (KS2) and Key Stage 3 (KS3) pupils. The two areas of knowledge and understanding of science are linked by a model explaining continuity and progression in each and as part of a 'spiral' curriculum.

Continuity and progression are cornerstones of education, essential in understanding the construction of schooling in most countries. *Progression* describes pupils' personal journeys through education and ways in which they acquire, hone, apply and develop their skills, knowledge and understanding in increasingly challenging situations. *Continuity* is concerned with ways in which the education system structures experience and provides sufficient challenge and progress for pupils in a recognizable curricular landscape. The introduction of a national curriculum in the UK from 1989 was an opportunity to provide this landscape, with its spiral structure of age-related programmes of study, each providing assumed amounts of continuity and progression in demand through consistent and recognizable areas of experience (called 'attainment targets'). Unfortunately pupils' personal journeys through education are often more disjointed and discontinuous than this curriculum model assumes or can assure. There are major points of disjunction when pupils transfer from one programme of instruction to another, particularly when

this transfer involves a change of school. How and why these disjunctions occur in learning science, and strategies that can be used to minimize if not eradicate these disjunctions and the setbacks in learning that result, are key subjects of this book. Before I consider where disjunctions commonly occur and why (in the next chapter), it is important to explore what the terms 'continuity' and 'progression' mean. This is fundamental to an understanding of transitions in learning science.

Continuity

I find landscape analogies useful when thinking about continuity. Thus continuity provides a safe and recognizable map for the personal journeys that individual learners make across it. Similarly, we can think of the subjects of the curriculum, history, geography, science, English, mathematics, and so an as recognizable landmarks, and the programmes of study and schemes of work as towns and villages, communities of knowledge and experiences if you like to be visited, each with optional routes between them. To extend my analogy to include progression, these journeys can be both forwards and backwards, uphill or downhill, thereby representing progression in moving forwards as well as the setbacks of regression. Explaining the ups and downs of progression/regression is an important point to which I return in the next chapter.

In working with primary student teachers at Bretton Hall College of the University of Leeds, my colleague Roy Phipps produced a summary of what he saw as the main points associated with continuity in learning science. I think this deals well with what we need to understand at this stage.

Continuity:

1 is about the nature of experiences pupils are offered
2 implies a consistency in aims, values and expectations
3 relies on good teacher–teacher relationships and communication
4 should require teachers and schools receiving pupils from another class or key stage to give attention to the learning children have already received
5 is facilitated in the UK National Curriculum through programmes of study carrying similar titles across all key stages and though a common language and scheme for assessment (see the Glossary for definitions of National Curriculum terms).

These tenets associated with the concept of continuity sound very fine and are certainly in sympathy with the intentions of the National Curriculum as it existed in the early 1990s, but we will see throughout this book that many of them are much less assured, in pupils' experience, than we might assume.

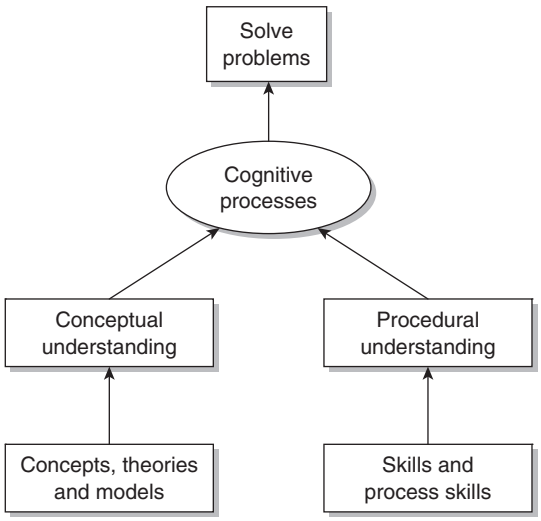

Figure 1.1 A model for school science (based on Gott and Duggan, 1995: 25)

Progression in learning science

In considering progression in science learning, I think it is important to look at two interrelated areas: *procedural* and *conceptual* understanding. This idea derives from a model proposed for learning science where *cognitive processes* required to solve problems, whether they be purely practical or about reaching new levels of understanding ideas about the world, draw on two distinct but interacting sets of knowledge, both of which have to be taught (Gott and Duggan, 1995) (see Figure 1.1). *Conceptual understanding* requires learners to draw on the known facts, laws and theories of science, and models that have been devised to help explain these, to reach progressively more sophisticated levels of understanding of how the world works. *Procedural understanding* requires 'thinking behind the doing' (Gott and Dugan, 1995: 26). In this way science, like any other subject, has a set of unique procedures that come into play, for example, when planning and designing tests of the reliability and validity of evidence to support an idea or hypothesis, and deciding what measurements are needed to collect data. Other procedural knowledge is drawn upon to decide how best to represent data and what patterns or new ideas emerge from analysis. The National Curriculum was constructed with progression in both of these areas of knowledge and understanding in mind, though the chopping and changing of documentation from one version of the curriculum to the next over the past 20 years has meant that the progression lines are often hard to see. An aim of this chapter is to clarify these lines of progression.

Progression in conceptual understanding

The spiral curriculum

Most commentators on the evolution of the school curriculum and its design acknowledge the influence of Jerome Bruner (b. 1915). Bruner realized that construction of knowledge relies on a continual process through which learners develop complexity of thinking by integrating new experiences, observations and knowledge with what they already know and have experienced. According to Bruner the child already possesses some sort of mental templates for interpreting the world, new experiences are matched against these and, eventually, the templates develop and change to accommodate new ways of thinking about the world (Bruner, 1966).

In his classic text, *The Process of Education*, Bruner proposed a 'spiral curriculum' through which to accommodate, 'the great issues and values that society deems worthy of the continual concern of its members' (Bruner, 1960: 2). Bruner described the principle behind the spiral curriculum in the following way:

> I was struck by the fact that successful efforts to teach highly structured bodies of knowledge like mathematics, physical science and even the field of history often took the form of a metaphoric spiral in which at some simple level a set of ideas or operations are introduced in a rather intuitive way and, once mastered in that spirit, were then revisited and reconstructed in a more formal or operational way, then being connected with other knowledge, the mastery at this stage then being carried one step higher to a new level of formal or operational rigour and to a broader level of abstraction and comprehensiveness. The end stage of this process was the eventual mastery of the connectivity and structure of a large body of knowledge … (Bruner, 1960: 3–4)

We can see from this that Bruner drew heavily on the idea of developmental stages identified by Jean Piaget (see Gardner, 2001). For Bruner it was not only a question of what intellectual capacities already existed in the minds of children at different developmental stages but also how step-by-step changes in the abilities to interpret and rethink information and experiences are used. In this way Bruner was thinking about the *cognitive structures* that might develop through revisiting areas of experience and knowledge, and how children might lay on new layers of knowledge and new interpretations to develop their thinking about phenomena and concepts met before. In science learning, this 'layering' process of thinking resonates with many examples taught in the school curriculum. Table 1.1 is one illustration of this.

Reflection

Try drawing up tables showing progression for concepts associated with other phenomena, such as switching on an electric light or an apple decaying.

Table 1.1 'Layers' of thinking about evaporation (of a puddle)

Observations and explanations	'Layer' of thinking
Puddles disappear	Basic experience of a phenomenon
Puddles disappear faster when it is windy	Link between cause and effect
When puddles disappear the water evaporates	Early conceptual thinking
Puddles disappear faster when it is windy because the air above them does not get saturated with water vapour	Conceptual development linking cause and effect
Washing on a line also dries faster on a windy day for the same reason	Application of the concept to provide explanations for other phenomena (generalization)

The progression in the explanations provided in Table 1.1 seems logical to us (as adults and teachers) and so might seem relatively unproblematic to teach. But this is because we are seeing through the lens of adulthood and from our informed vantage point at the top of the 'layered learning cake'. I have often found that, for the child, explanations can seem counter-intuitive and odd, often clashing with naive (but to the child much more logical and useful) reasoning. For example, it is often more obvious to a child that water in a puddle merely soaks away into the ground rather than parts of it (molecules that are invisible) leaving the surface to enter air. Thus, linking cause and effect requires rationalization based on evidence that challenges existing ideas and moves thinking on. The mental effort of doing this is significant. This is where the skill of the teacher comes in. In my own teaching for example found that those naive, intuitive ideas could be challenged by evaporating bowls of water, some with impermeable plastic bases and some covered by clear plastic trapping re-condensed vapour as liquid water. Research, however, indicates that such one-off experiences are often not enough to permanently shift thinking to new levels (Driver et al., 1985; Osborne and Freyburg, 1985). I see learning science like a slowly constructed jigsaw. In some lessons and through some experiences more of the pieces fall into place; at worst some pieces already there are lost or do not seem to fit the picture anymore. The teacher's job is to draw on her or his tool kit of experience and knowledge about children and teaching to decide what experiences and learning tools are most likely to move thinking in more fruitful directions. Some call this crucial professional knowledge – pedagogical content knowledge (PCK) – and providing or enhancing it is effectively the basis of much that we do in initial teacher training (ITT) and continuing professional development (CPD) of teachers.

Steps and leaps in understanding

In a very useful handbook for science teachers published by the Association for Science Education (ASE), Asoko and Squires (1998: 178) refer to different amounts of *cognitive effort* required by pupils to reach new layers of understanding.

Modest leaps in understanding These require relatively small steps linking experience and new knowledge, and extending it in limited ways. For example, experience that some metals conduct electricity and others do not could be extended by showing that electricity is conducted to different extents in the metals that do conduct. When studying the distribution of plants on a field, pupils might learn that different areas contain different collections of plants. This experience could be extended to discover that occurrence and distribution of plants might be linked to an environmental factor such as the amount of water available or a human factor such as the amount of trampling by feet.

Major leaps in understanding These require a shift from observation and description of phenomena and simple linking of cause and effect to explanations requiring more abstract thinking, often through the application of advanced ideas or conceptual models. For example, the layer of thinking requiring an explanation of rates of evaporation in terms of the relative saturation of air with water, referred to in Table 1.1, requires thinking about evaporation in terms of a model of particles and how they are arranged and move. The teacher's PCK here relies on judging how much abstraction from the model is needed to help pupils shift their ideas without them losing contact with the explanations that have been perfectly satisfactory (and of value to them) so far.

Constructing frameworks of understanding These are sometimes referred to as the 'big ideas' or 'key ideas' of science (Millar et al., 2001). There are frameworks, ways of thinking, that have helped scientists make sense of concepts, models and theories and can be applied in several contexts and across different scientific disciplines. For example the framework of thinking called 'energy' unifies ideas about what forms energy takes and what happens to it as it is transferred around various systems. The framework holds equally true for, and is helpful in understanding, what happens in physical systems such as heat transfer, in chemical reactions and for studying 'flows' of energy in ecosystems. These frameworks are what Bruner envisaged when he wrote about 'broader levels of abstraction and comprehensiveness' and the 'connectivity and structure of a larger body of knowledge' (Bruner, 1960: 3–4). Part of the teachers' PCK required here is to realize the value of consistency and unity of language in teaching. One issue in teaching about energy ideas in secondary schools has been that teachers, often in separate and distinct departments dealing with biology, physics and chemistry, have used the supposedly unifying

framework of 'energy inconsistently'. The same terms or ideas are used to mean quite different things in different lessons. This was something that a move to integrated or combined science teaching in the 1980s was supposed to have addressed. For example in one scheme, Suffolk Coordinated Science, it was recommended that 'a common language and use of conceptual models should be used by teachers from all disciplines when teaching about energy' (Dobson, 1987: 90–7). Dobson even set out how the framework of ideas should be developed and progressed across the age range taught (1987: 14–16).

From → to statements

In an effort to address some of the complexities of conceptual progression discussed, research and development teams at York felt that teachers would benefit from seeing progression in terms of statements showing clear lines of development (NCC, 1991; Qualter et al., 1990). These so-called 'from → to' statements had previously been prominent in guidance connected with the development of procedural knowledge (knowledge associated with practical science) associated with an attainment target devoted to the 'Exploration of Science'. This attainment target was considered at the time it was introduced in 1989 to represent a different and more open-ended model of practical science than had previously been taught and thus outside the experience of most practising teachers. By the late 1990s, guidance associated with the introduction of a national curriculum for initial teacher training combined some of these statements about procedural knowledge with others on conceptual development (DfEE and TTA, 1998a; 1998b). I have provided some of this in Text Box 1.1 as I think it summarises quite well it some of the most important aspects of progression in school science.

Reflection

The examples of progression shown in Text Box 1.1 could be mapped against schemes of work to see how they are accounted for. This might be a useful activity for student teachers.

Progression in the 'process skills' of science

What are process skills?

Procedural understanding, as conceived in Gott and Dugan's model (see Figure 1.1), deals with learning of what Harlen has called *process skills* (Harlen, 1997). It is important to understand what we mean by 'process skills' as these will be referred to throughout this book. Science educators often use the terms 'skills' and 'processes' to define important aspects that can be recognized when pupils carry out practical work in science, but the

Text Box 1.1

Progression considered at primary school level (adapted from Teacher Training Agency, 2000a)

- **from** using everyday language **to** an increasingly precise use of technical and scientific vocabulary, notation and symbols
- **from** personal scientific knowledge in a few areas **to** understanding in a wider range of areas and of links between areas
- **from** describing events and phenomena **to** explaining events and phenomena
- **from** explaining phenomena in terms of their own ideas **to** explaining phenomena in terms of accepted scientific ideas or models
- **from** participating in practical science activities **to** building increasingly abstract models of real situations
- **from** unstructured exploration **to** more systematic investigation of a question
- **from** using simple drawings, diagrams and charts to represent and communicate scientific information **to** using more conventional diagrams and graphs.

Progression considered at secondary school level (adapted from Teacher Training Agency, 2000b)

To aid planning and to ensure that trainees know how pupils are progressing in science, **trainees must be taught the importance of ensuring that pupils aged 11–19 progress:**

- **from** understanding of accepted scientific knowledge in a few areas **to** understanding in a wide range of areas including, where relevant, the links between areas
- **from** describing events and simple phenomena **to** explaining events and more complex phenomena
- **from** explaining phenomena in terms of their own ideas **to** explaining phenomena in terms of accepted scientific ideas or models
- **from** a study of observable phenomena **to** increasing use of formal and generalized ideas
- **from** an essentially qualitative view of phenomena **to**, where appropriate, a more quantitative and mathematical view
- **from** seeing science as a school activity **to** an understanding of the nature and impact of scientific and technological activity beyond the classroom
- **from** experiment and investigation involving simple scientific ideas **to** those in which
  - more complex scientific ideas may be drawn upon
  - more than one variable may be pertinent
  - decisions have to be made about strategies and instruments for data collection
  - data is interpreted and evaluated in terms of strengths and limitations

- **from** accepting models and theories uncritically **to** recognizing how new evidence may require modifications to be made
- **from** simple drawings, diagrams and charts representing scientific information or data **to** diagrams and graphs which use scientific conventions
- **from** using a limited range of scientific language, notation and symbols **to** using an extended technical vocabulary and standard notation and symbols routinely, appropriately and correctly.

terms are often confused. So what is the difference between *skills* and *processes*?

Skills describe small-scale or short-term actions, decisions or routines that underpin practical work.

Processes are sets of procedures that deal with the *thinking* and *decision-making* about how to deploy skills. In this way processes link to what are sometimes described as 'thinking skills'.

Carrying out a *process* while doing practical work relies on knowing and being able to deploy a number of *skills*. For example if you ask a pupil to find the warmest location in the classroom this involves the *process* of measurement which requires the pupil to think about *what* to measure, *where* to measure and *how* to measure. In carrying out the measurement of temperature, a number of *skills* are used: choosing a thermometer with an appropriate range for the task, manipulating the thermometer in a way that will provide an accurate measure and then taking a reading against the instrument's scale. For most of the time in this book we can say that 'process skills' are broadly equivalent to 'processes'.

In the training associated with the development of bridging work in the STAY project we found that having a list of 'process skills' was useful because it helped teachers focus on the elements of practical work that are essential to a particular (transition) task in hand. This helps in planning, that is, deciding what your objectives for practical work are, and in assessing, that is, deciding how you will judge pupil outcomes in relation to specific process skills rather than trying to assess many different outcomes at the same time.

The *process skills* of scientific enquiry are:

- Raising questions
- Planning
- Predicting
- Measuring
- Observing
- Recording and communicating
- Interpreting evidence
- Drawing conclusions
- Explaining
- Evaluating evidence (adapted from Harlen, 1997; Harlen and Jelly, 1997).

In a project developing partnership teaching in primary schools (funded by the AZSTT) in Barnsley, Wakefield and York, I found that understanding process skills helped teachers disentangle what pupils were doing in science practical work and to plan more effectively to develop particular, targeted process skills (Crebbin, 2001). Teachers told me that they found teaching practical work (Attainment Target 1 of the National Curriculum) difficult because they assumed pupils should be involved in most if not all process skills in one practical lesson so making it hard for them to identify pupils' problems and provide appropriate support. In many ways this was a case of seeing the process skills *wood* through the *forest* of scientific enquiry. I think that one of the reasons there has been so much confusion about what is to be taught and how it is to be assessed is because of the many changes in emphasis in Attainment Target 1 in the four revisions of the National Curriculum for science between its inception in 1989 and the version in use today (Braund, 1996). So, sorting out what is the real progression in process skills seemed a necessary step forward in any work as transitions.

Process skills are fundamental in developing understanding of phenomena and concepts and in testing out theory as Gott and Duggan's model (Figure 1.1) implies. For example, the ability to consider and question evidence is vital if pupils are to accept or disregard conflicting ideas. This is essential in helping pupils develop new understanding by moving away from naive assumptions, for example, about dissolving, to a more sophisticated understanding of what is involved.

In the past it was often assumed that process skills would be learned integrally, that is, that merely carrying out practical tasks was enough for pupils to develop an understanding and that further practice would embed skills and hone performance. Current thinking is that, just as with the rest of science, *process skills have to be taught.* The AKSIS (ASE and Kings College Science Investigations in Schools) materials contain resources that help teachers develop pupils' process skills through direct teaching (see, for example, Goldsworthy, et al., 2000; Watson and Wood Robinson, 1998). The aim of these materials is to encourage specific teaching of process skills rather than allow pupils to discover how to improve on these through the often busy and less structured learning environment of open-ended practical work.

Mapping progression in science process skills

The first version of the National Curriculum for science (DES/WO, 1989) included an entire attainment target ('Exploration of Science') devoted to development of procedural understanding, though that phrase was not used at the time. The mere existence of any part associated with practical science, especially one carrying a weighting in teaching and testing of 50 per cent at Key Stage 1 and 40 per cent at Key Stage 2, was a triumph in the face of adversity. At the time I was working for the Assessment of Performance Unit at the University of Leeds and I know that members of Her Majesty's Inspectorate

(HMI) involved in negotiations on the National Curriculum came under enormous pressure to slim down the overambitious document produced by the Science Working Group (SWG) in 1988 (DES/WO, 1988b). The SWG recommended 22 attainment target areas in the programmes of study, five of which referred to practical experience (Braund, 1996; Graham, 1993). Fearing that practical experience might be lost from the National Curriculum altogether, HMI turned to the researchers from the Assessment of Performance Unit (APU) in Science based at Kings College London and the University of Leeds who had researched performance in most of the process skills identified by Harlen at ages 11, 13 and 15 over a period of 10 years (Archenhold, 1988; Russell, 1998; Schofield, 1989). Thus what appeared in the 1989 programmes of study, and especially in criteria for assessing outcomes of practical work at least had some sound foundation in research (DES/WO, 1989). In my view these assessment criteria represented the clearest progression for investigative work that the National Curriculum has ever contained. The need to slim down weighty and unworkable documentation during the 1990s meant that at each revision these progression lines became less distinct.

To fill the gap in guidance on progression in process skills in Attainment Target 1 and provide something more useful for teachers in planning for progression, the project team at York working on the second of the science transition projects (the North Yorkshire AstraZeneca Science Pedagogy and Progression [NYASPP] project) devised sets of from → to statements for most of the process skills identified by Harlen (1997). These are provided as Text Box 1.2. While I do not claim these statements are a full picture of progression routes within each process skill across the age range of the National Curriculum, I think they do provide an important guide relevant to the KS2 → KS3 transfer discussed in this book.

Reflection

Compare pairs of practical activities used in similar content areas either side of the KS2/3 transfer to see if progression in relevant process skills is in line with that recommended in Text Box 1.2.

Another device have we used to help teachers understand progression in procedural understanding in specific process skills is to provide extracts from pupils' work and to order these as progression from least to most developed. In training associated with transition projects at York we used this to look at progression in one key area of Attainment Target 1, *considering and evaluating evidence*. This area was chosen as it received increased emphasis in the 2000 revision of the National Curriculum for science and had received much less attention in teaching compared with aspects such as 'fair testing' and planning of investigations (Goldsworthy et al., 2000). To help think about progression in this area we identified five sub-themes:

Text Box 1.2

From → to statements for seven of the process skills identified by Harlen (1997)

Observation		
Describing objects, phenomena and events in some detail.	→	Justifying why, and saying how, observations are made.
Understanding that human senses sometimes need assistance.	→	Choosing appropriate aids to make observations.
Making repeated observations to check results.	→	Linking quality and quantity of observations to 'concepts of evidence'.
Measurement		
Measurements of basic quantities (mass, length, time, volume, temperature).	→	Repeated and accurate measures of basic *and* derived quantities (for example, velocity/rate).
Choosing equipment suitable for the type of measure to be made.	→	Choosing the appropriate measuring range of a piece of equipment.
Reading major scale divisions.	→	Reading minor scale divisions.
Predicting		
Making a statement of based on limited expectation scientific reasoning.	→	Justifying predictions in terms of science ideas.
Giving some idea of the sequence, order or magnitude of events or effects.	→	Using evidence to give reasoned predictions of the sequence, order or magnitude of events or effects.
Planning		
Identifying some effect factors and realising that one has to be changed while others are controlled.	→	Identifying most of the key factors that might have an effect. Selecting factors to control.
Recording and communicating (graphs)		
Realizing when line graphs and bar graphs should be used. Constructing graphs with some help.	→	Constructing line graphs.
Beginning to decide on axes and scales for graphs.	→	Choosing appropriate axes and scales for graphs.

Interpreting evidence

Recognizing simple trends and patterns in results.	→	Describing detailed patterns in results, for example, changes over time.

Evaluating evidence

Knowing when some results don't fit the pattern and beginning to wonder why.	→	Identifying and explaining anomalous results.
Realizing that single results might not occur again.	→	Linking reliability of findings to the spread of readings.
Beginning to reflect on experimental design.	→	Linking reliability to experimental design where appropriate.

Source: Braund, et al., 2004: 2–3

1 Seeking patterns and describing relationships in results.
2 Identifying and explaining anomalous results.
3 Appreciating and explaining the degree of reliability in findings.
4 Relating predictions to outcomes and suggesting scope for further enquiry.
5 Explaining findings in terms of existing or developing scientific knowledge and understanding.

The mixed-up pupils' responses for sub-themes relate to a specific investigation, the effect on bubble-blowing of mixing varying amounts of bubble mixture and glycerine. An example of one of these mixed-up, response sort activities, for the sub-theme, 'seeking patterns and describing relationships', is provided in Text Box 1.3.

In this activity sophisticated responses describe the relationship between the length of time bubbles last and the amount of glycerine in the mixture. The order of increasing progression from undeveloped reasoning to the most sophisticated response is $2 \rightarrow 1 \rightarrow 3 \rightarrow 5 \rightarrow 4$. Response 4 is the most precise and developed one because it identifies that the bubbles last longer as the amount of glycerine is increased but only up to a certain point. Beyond this the length of time bubbles last actually decreases. Responses can be given out as cards but printing them onto acetate sheets, and cutting up the statements so they are separated, makes it easier for groups to feedback their views of progression. Participants place pieces of acetate in their chosen order onto a blank overhead projector transparency and write notes alongside these showing reasoning behind their choices. An interactive whiteboard could be used to achieve the same outcome. The activity has been used successfully with a variety of participants including teachers, advisers, consultants and student teachers.

Text Box 1.3

Mixed-up statements for the sub-theme of considering and evaluating evidence, 'Seeking patterns and describing relationships in results'

1
The results show it was best when we added some glycerine to the bubble mixture.

2
When we added glycerine the results were different to the results with just the bubble mixture on its own.

3
The bubbles became better and better as we added more and more glycerine to the bubble mixture.

4
With more glycerine in the bubble mixture the bubbles lasted longer – until we got to 2.5 cm^3. After that the bubble didn't last as long.

Source: Braund and Driver, 2005b, unit 5: 1–6

Integrating progression in procedural and conceptual understanding in science

In this chapter I have put forward the idea that progression in science learning can be viewed in two dimensions, one associated with the learning and understanding of concepts and the other with procedural understanding required to solve problems through practical activity. There is a danger, however in assuming these are distinct areas of knowledge separated in teaching. It is my view that to divorce practical experience from the concepts it is designed to illuminate is a dangerous fallacy. The notion of concept-free practical activity has little credibility. In the 1980s a

number of teaching schemes such as Science in Process (ILEA, 1987) and Warwick Process Based Science (Screen, 1986) promoted science teaching in the early years of secondary school that purported to be concerned mainly with development and application of 'processes' rather than advancing knowledge and understanding of science. Indeed, the second of these schemes treated processes as if they could be taught in a hierarchical way, observation followed by measurement, followed by prediction, followed by planning investigations, hypothesising and so on. This led to a division among science educators, some of whom argued that hiring off process from content was dangerously artificial and others who claimed it was a perfectly valid way of introducing the study of science and more engaging for pupils. This so called 'processes versus content' debate culminated in a series of critiques of the process-led approach that also began to re-examine the very purposes of science education (see, for example, Hodson, 1988; Millar and Driver, 1987).

While it is beyond the scope of this chapter, and probably a distraction for me to go further into the debate on processes versus concepts, it is worth considering one attempt to integrate the two areas of scientific knowledge and so to provide a view of how this fits Bruner's notion of the spiral curriculum. In 1990 my APU colleagues based at Kings College, London, put together a book about progression in science explorations, drawing from over a decade of APU's large-scale research (Qualter et al., 1990). In this book a model was proposed showing the relationship between procedural knowledge (which they called 'Exploration of Science') and conceptual knowledge (which they called 'Knowledge an Understanding'). This model is provided as Figure 1.2.

In Qualter et al.'s model the solid and dotted lines represent the two areas of learning science as four turns of a double spiral; each turn representing one of the key stages of the National Curriculum. Thus the double spiral model reminds us that procedures and concepts are revisited in each key stage. The two parallel spirals are linked by 'blobs' representing investigations (today we might call these 'practical experiences'). Each 'experiential blob' has associated letters 'p' and 'c' alluding to the fact that the level of the concept underpinning each investigation and the procedures necessary to carry it out progress in terms of demand and complexity in line with the content of the programmes of study for each key stage (Qualter et al., 1990: 48). My APU colleagues drew on research work showing progression in the demand and complexity of scientific investigations and added this to the x and y axes of their model. As in Gott and Duggan's approach, the model reminds us that scientific investigations and, more broadly, practical experiences provide a matrix or 'glue' that helps pupils to make sense of scientific ideas and to test the robustness of the theories and evidence on which they are based. In modern National Curriculum parlance this provides an essential part of authenticating scientific activity as part of what is now called 'how science works'.

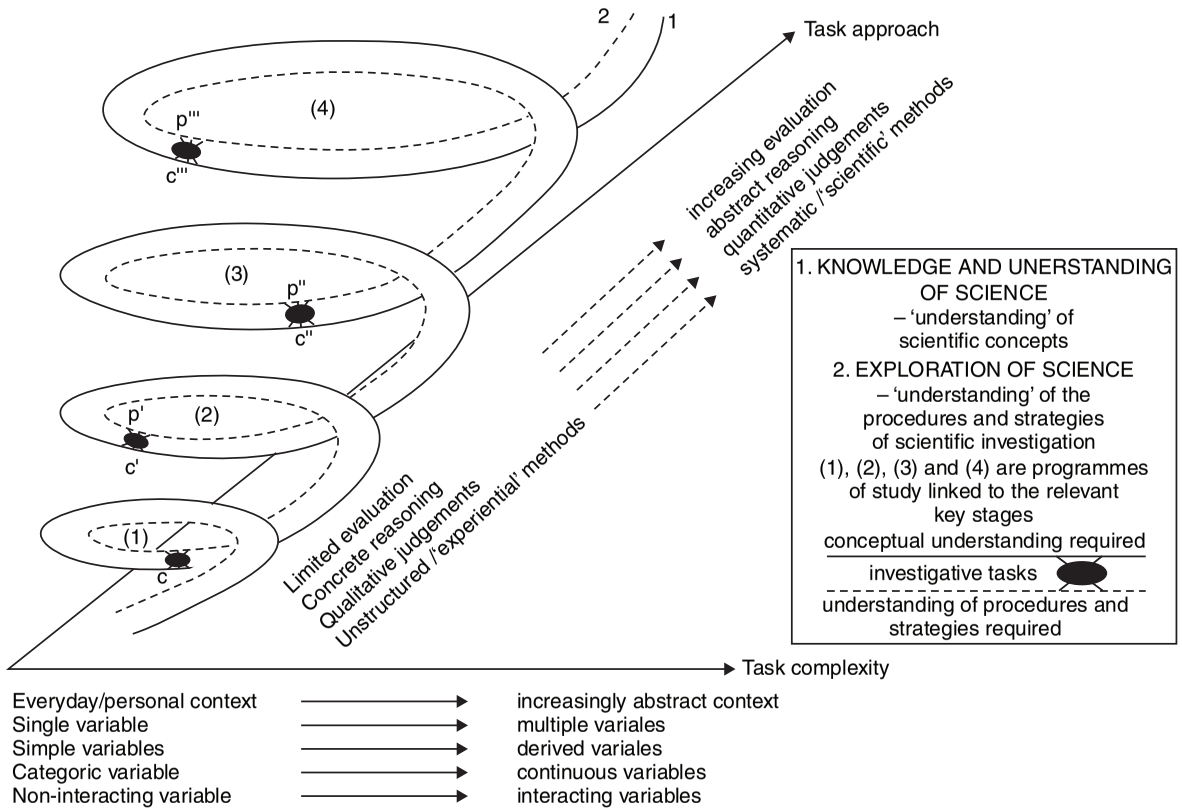

Figure 1.2 An integrated model of progression in science

Source: (Qualter et al., 1990: 48)

Summary

In this chapter the importance of continuity and progression in a spiral curriculum model providing pupils with opportunities to build competence in procedural understanding to develop and refine understanding of scientific concepts has been discussed. Successive revisions of the National Curriculum have made progression lines in procedural understanding less clear and so methods to improve on this have been included. *Conceptual* and *procedural* areas of science combine to help pupils build progressively new levels of thinking.

Suggested actions

- Use from → to statements to clarify progression lines when planning schemes of work and sequences of lessons, and in liaison meetings with teachers in alternate key stages.
- Try using mixed-up statements of pupils' work to help others clarify lines of progression in procedural or conceptual understanding.