Teaching Science

Exploring the Issues

Ken Appleton

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Ken Appleton

ABOUT THE AUTHOR

Ken Appleton has been involved in science education for over twenty-five years as a teacher, curriculum officer, and lecturer. Besides his teaching qualifications, he has a science degree, a masters in curriculum evaluation, and a Ph D in science education. He has published nationally and internationally in journals such as *Research in Science Education, Science Education, International Journal of Science Education,* and *Journal of Research in Science Teaching*. His research interests include cognitive change, learning theory, teacher education, and teaching strategies in science. He is currently a lecturer in the Faculty of Education, Central Queensland University.

INTRODUCTION

What This Book is About

Teaching science: Exploring the issues provides a comprehensive program for teachers and intending teachers to acquaint themselves with the principles of teaching science in schools, and apply these to their own circumstances. It is activity-based, and provides a set of basic information about each of the key issues. In line with the constructivist emphasis in the book, it encourages you to construct personal meaning from the information obtained, and provides specific structures to support this process. Of course, no book can stand alone in doing this. It very much needs the additional support of colleagues in discussion, other information sources, and opportunities to try to develop ideas in practice. Unless these are available and used, the support structures provided may be of little value.

The purpose of the book is to present you an opportunity to consider the main issues that impinge upon the teaching of science in formal educational settings from early childhood to secondary school. It is intended that this be more than just a body of knowledge to be learnt for assessment purposes, but that it become a part of your own teaching practice. The text therefore provides a summary of information about the respective issues, to save you the exhausting task of finding it all personally, and learning project suggestions to help you consider whether and how this information might be applied to your own situation. The book would serve the purposes of both preservice and inservice science education courses focusing on science education curriculum and pedagogy.

Science is usually taught from early childhood settings to senior high school. However, the basic issues in teaching science remain the same. How those issues are responded to and put into practice varies with the different areas of schooling. This book explores the range of issues important to the teaching of science, and looks at their application in each area of schooling: early childhood, primary, and secondary. In particular, it encourages you to make personal application of each issue to your own area of teaching interest. The current emphasis on constructivism in the science education literature is reflected throughout the book, in both the content and presentation. In particular, it includes learning projects for you to work through, which will help you make personal sense of the information contained in the body of text. It also includes some references to other sources of information to supplement what is contained in the book.

The book begins with a selection of stories told by teachers from each area of schooling. While these are composite stories told by imaginary people, they represent the many stories I have heard from teachers as I work with them. Teachers have also consistently mentioned to me problems they have in teaching science. Some of these have been highlighted by classroom research as well. These are looked at in the second chapter, so you can be looking for ways of addressing the problem areas as you proceed through the remainder of the book. Each of the issues impinging on science education are examined in turn, before the practical aspects of implementing the emergent science program are considered. You should examine each idea in turn to decide to what extent they are relevant, and which aspects you believe should become part of your own teaching philosophy and repertoire. A key outcome for you should therefore be the identification and articulation of a belief system for teaching science in your sector of schooling which is embedded in practice.

I should make a further comment about what I have called the constructivist principles underlying this book. In drafting the book, I have had to address the problematic issue of how to use these principles in a print form, when so many of them depend upon social interaction and the social context of the learning. Firstly, the constructivist principles that I subscribe to are drawn from a combination of cognitive and social constructivism. In terms of cognitive constructivism, I have therefore endeavoured to provide a basic source of information on the key issues, and learning projects which are designed to help you use and apply the information to your own situation. These projects are marked with a question mark, suggesting the importance to your learning of reflection and asking questions. The first project in each chapter asks you to clarify what you already know on the topic, so you can more clearly build upon that, and decide what you need to pursue further.

Secondly, drawing upon aspects of social constructivism, I have provided some suggested group discussion projects which are designed to help you work toward some consensus in your group about the ideas. These are indicated with a light bulb, implying that bright ideas can emerge from group deliberations. It is in this social arena that a print form is particularly limiting, and so I cannot emphasise enough the importance of engaging in discussion with others about the information you are examining. The role of an instructor is also crucial.

Thirdly, the organisation of the book has been structured to try to provide a scaffold or structure for your learning. The scaffold is a basic framework for you and your instructor to use, to the extent that you find it helpful. You or your instructor may wish to reorganise the structure to meet your own needs.

To an instructor who might use this book as a text, I suggest that classwork incorporate two key aspects at least. The first is a time for small group and whole group discussion on issues raised in the text. The suggested projects for groups could be used as an organising feature. The second is the need to make as much of what is in the book concrete and embedded in practice. That is, the teaching techniques, strategies and approaches should ideally be explored in practice, with actual science experiences planned for the students. The choice of these is often best left to the instructor, which is why I have not included them as part of the text. For students studying via distance education, I have written a set of materials which can be used in conjunction with the text.

As you examine each of the issues raised in the book, I encourage you to explore how they relate to you and your own teaching situation. Together, the issues will help you frame a belief system for the teaching of science, and working through those ideas will assist you in exploring pedagogies consistent with that belief system.

1

Stories about Teaching Science

I have spoken to hundreds of teachers over the years. Many have interesting stories to tell about their personal professional journey in teaching science. I have selected a few stories to include here. You may find that some parts of these stories strike a chord with you. The first is the story told by Joan, a preschool teacher:

> *I've been teaching in preschools for about fifteen years. I run an integrated program, so I never used to think about science at all. I would just choose a theme and web the plan of activities that fitted in. I suppose some of the experiences I planned were science, like when I did some cooking, grew some seeds, and some children brought in pets. But I never planned for it specially as a subject. I realise now that I tended to avoid anything too much like science unless it was plants and animals and stuff like that because I wasn't too sure about it. I usually fell back onto themes I had tried before so I knew they worked, and what other preschool teachers said were good ideas.*
>
> *We used to have an advisor who dropped in a few times a year with some ideas to share. On one of the her visits a few years ago, she told us about some new project on effective teaching and learning. She had a video of some preschool kids pulling apart torches and making bulbs light up. It was still all integrated, but I could see there was a lot of science learning going on from what the kids were saying. It started me thinking about what I was doing, and I wondered if I could do something like that. The children looked like they were really into it. I was a bit nervous about it, but the advisor encouraged me and came along for the first few sessions just in case. I got the children to bring along some old torches and managed to find some wires and things. The primary school was a help there. I just left the torches out on a table for a few days for them to tinker with, and then scheduled an activity with the bulbs and batteries. I was careful to try to guide their thinking like I had seen in the video. I don't know if I did a very good job but the kids loved it and seemed to learn a lot too.*

> *That seemed to be a turning point for me. I realised that I had been avoiding science, and the children had been missing out. At first it was a conscious effort for me to deliberately plan science into my webs. I also found I had to read up a bit on some things I didn't know about. I found that a good idea was to invite some body in who worked in the field we were exploring. Like, after a few sessions with the batteries and bulbs, I invited an electrician in to answer the children's questions. He was one of the fathers, so knew how to speak to them. He was wonderful. Now I wouldn't be without some science in my program. I've found I enjoy it now I've lost my fear of tackling it. I'm still learning a lot of course, but I'm finding it an interesting challenge.*

Sally is a primary teacher. She has been teaching for four years now. Hers is a fascinating story:

> *I hated science. At high school it was boring and didn't make much sense to me. I did biology in Year 12 but only because I felt I had to. It was a disaster! So when I did my teaching course at uni I avoided science as much as I could. I had to do a bit. It was different and interesting, which surprised me. But I could see science wasn't a big deal in schools, so didn't change my way of thinking much. When I graduated, jobs were a bit hard to find. I finally got an offer, but the school was trying something new: they were having all their science taught by a specialist, and I was to be it! Well I wanted the job, so gritted my teeth and took it. I was packing death the first few days. I had a room with some gear in it, and that was all. Luckily there was a teacher on staff who gave me a few pointers. I spent days before school started organising gear and trying out activities. Once we started, though, I found it wasn't such a big problem. The kids loved it. They really got into the activities and worked on ideas. I remembered some stuff about misconceptions and how to teach science from my uni science course, so tried some of those ideas. It was a real buzz to see the kids working on ideas and actually learning something. You could see it all sort of coming together for them.*
>
> *After the first few months, I wasn't so nervous, and started to realise how much I didn't know. It was still taking me ages to prepare because I had to find good activities, get the gear organised, and try them all myself. I wasn't going to risk giving them an activity that I hadn't tried — I*

wanted to make sure it all worked the way I expected it to. I was also having to read up on the science I had avoided all my life. I found it was best to admit to the kids if I didn't know something, and try to find out with them. A few other teachers helped me, and for some topics, I invited somebody who knew a lot about the topic in to talk to the kids. I always made sure that we had worked through a lot of ideas first, and the kids had a list of questions they wanted answered. One time I used a high school teacher, another time a scientist, anyone I could find who could help. I even used a Year 12 student once.

By the end of the first year, I surprised myself: I wanted to stay as the specialist, rather than be a general class teacher. I went to some inservice programs on science teaching. Some of the things I vaguely recalled from uni, like how kids learn science, were suddenly real and important. I also found I was watching all the science shows on TV, and even visited the science centre when on holidays. Science had never been so interesting. Two years ago I plucked up enough courage to enroll in a part time science course at uni. I'm enjoying it too, and finding it so interesting. I suppose they haven't changed the way they do things, I've changed. I can cope with it now.

The story told by Julian, a secondary teacher, is a bit of a contrast to Sally's. But he too, found himself reexamining what he was doing:

Ever since I was a young teenager, I wanted to be a science teacher. I was always interested in science as a child. But what started me off really was in the last year of primary school, I had to give a lecturette on a topic of my choosing. I was really keen to do a good job, and chose nuclear submarines. This was in the early 60s, so they were fairly new. An article in a boys' magazine triggered my interest. I scoured books and encyclopedias to find out what I could, wrestling with the ideas of nuclear fission, heat transfer, and steam turbines. My lecturette went over fairly well, but my interest in the topic continued. At high school, I found a lot of the work familiar and became successful in it, especially chemistry. I also continued my habit of wrestling with ideas until I understood them. Of course learning stuff off for exams was a pain. I did chemistry and physics at Year 12, and went on to a science degree in chemistry at uni.

After my education course I started teaching in high schools. I think I just taught the way I had been taught: going through the text book, doing problems, and organising labs to back up the text. Not that I had much say. The subject master seemed to plan the work program. After a few years I was asked about the text books, but that was all. I went on that way for years. What caused me to change? I decided to go for a subject master position. To get it I had to show that I was innovative and energetic, so I looked around for something to pick up and run with. I started reading the Science Teachers Journal, and found an article about students having misconceptions, even after being taught a topic. It had some ideas about how to find out what misconceptions they have, so I tried it out and got quite a shock. I had just finished doing light with a good Year 9 class, and just couldn't believe all the things they still had screwed up. Well things went on from there. I read more, did an upgrading course in science ed at uni, and tried a lot of ideas about teaching science to try to make what I was doing more effective. It did allow me to achieve my initial aim of getting my subject master position, but by then I was really into the whole deal of understanding the learning process and how to teach science better.

Through my uni upgrading science ed course, I became involved in a research project which involved me with the uni science ed staff and had me trying out some different ideas, this time with some observers in the classroom. I began to be aware of a whole stack of things I had not ever considered before. Like including bits about the history of science, and teaching the students to be metacognitive in their work. I heard about the PEEL work and read some of their stuff. I'm still going, even though the research project has finished. I'm even thinking of starting my masters in science ed. Just looking back at the way I used to teach, I can't believe I used to do that to kids. I must have turned them off in droves! I know I survived that sort of teaching, but I had taught myself how to learn, regardless. I want to make sure that I do the best for my kids from now on.

I have told you these stories because each of these teachers found that their professional career took a turn when something triggered them to reexamine what they were doing in their science program. But notice that they each had a similar reaction to the stimulus. They followed up with a reflective and critical look at their own teaching, sought other ideas about teaching science, decided what was useful and practicable, and tried them out in their own situations. This is just what Bereiter and Scardamalia (1993) claimed people do to become experts in a particular domain, but they called it "progressive problem solving." In reading these stories, I hope you see a bit of yourself, perhaps now, perhaps some time in the future. I trust you can set your sights on becoming an expert teacher who teaches science well, or even an expert teacher of science. Bereiter and Scardamalia (1993) pointed out that formally learned knowledge is of little use in problem solving unless it also becomes part of a person's informal knowledge; what the person knows about the world and how it works. If you treat this book only as a source for gaining formal knowledge then both you and I will be disappointed, for it will serve you poorly in your quest to become a competent teacher of science. On the other hand, if you approach what is in this book as a resource for stimulating your own reflection on how you teach science, treating each new thing as a problem to resolve in your own teaching situation, you will find many stimulating rewards, and I will be well satisfied.

Learning Project 1

What is your own story of science learning and teaching so far? Jot down some of the main characteristics and events that you can recall.

You may also have noticed that I have included stereotypical genders for the teachers from each area of schooling, that is, female early childhood and primary teachers, and a male secondary teacher. Read through the stories again, but this time imagine each being told by a different gender. Has this altered your perception of the story told?

In a group share aspects of your story that you feel comfortable about making public. Also discuss the effect of reversing the gender of the teachers telling the stories has on their impact.

In the next chapter I want to point out some things of which you may or may not be aware, which are potential problem areas in teaching science, and which may provide a stimulus for you to begin that problem solving process.

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2

Some Common Problems in Teaching and Learning Science

What This Chapter Asks You To Do

During this chapter you will:

- Identify problem areas you are aware of in teaching and learning science.
- Consider ways of exploring students' ideas about science topics, and try them with some students.
- Reflect on your own science teaching and/or learning to identify problem areas such as those outlined in this chapter.

Teaching can be a challenging job. Teaching science can be especially challenging, perhaps more so for some people than for others. Experienced teachers can readily identify particular aspects of teaching science which they know have potential traps or difficulties. Research in classrooms has also revealed a lot about the sorts of things that can happen in science classes which become problematic for the teacher, learner, or both. In this chapter we will look at some of these things. As you progress through later chapters, you should be able to decide how to avoid or reduce the problems.

Before reading any further, you should take a moment to do Learning Project 2. This will prompt you to recall areas of difficulty in your own learning and teaching of science.

Learning Project 2

In your own schooling and perhaps even tertiary study, you may well have had some personal difficulties in learning science. Jot these down.

In the teaching experience you have had so far, and/or your reading, you may be aware of problem areas in science teaching and learning — things that can go wrong, things to watch out for, things to make sure you do and so on. Jot these down.

Are there any similarities between your two lists?

In your group share experiences which highlight problem areas in teaching and learning science. Make a priority list of problem areas which your group would want to address as you work through this book.

Students Get Some Funny Ideas

People who have worked with students for several years, can usually recall some way-out comments made in class or assessments. We wonder where on earth they could have found those ideas. This happens at all ages. In younger students it is cute, but in older students we start to get concerned. The same concerns emerged among several groups of researchers in different parts of the world, when their research in science classrooms (such as that of the Learning in Science Projects, University of Wailcato, Hamilton, New Zealand) began to reveal that there was a serious problem which schooling did not seem to be addressing, and in fact seemed to cause greater problems for some students. I will recount just a few instances of what they found.

A commonly used technique to find out students' understanding of aspects of science is an interview, which can focus on ideas and labels like plants or animals, and events like melting ice or a ball rolling down a slope (Osborne & Gilbert, 1980). Interviews have usually been held one-to-one, but can be conducted with a small group of students. The interview technique used in the research projects can be adapted for use in classrooms.

The interview technique

The purpose of interviewing a student or group of students is to discover their ideas about a particular event, object, phenomenon, or word. **A** researcher usually tries to document and report this information, but a teacher would use it for diagnostic purposes as a basis for further teaching. The interview starts with a stimulus, such as some pictures, some materials, or an activity. It is sometimes convenient to record the interview for later analysis.

Since the interview is a valuable technique for learning how to probe students' ideas, I have included detailed instructions here. The following set of instructions for conducting an interview is based on the "event" of lighting a torch bulb using a battery, bulb and wires. It is described here as a one-to-one interview, but can easily be modified for a group interview.

When you introduce the topic to the student, produce the battery, bulb and one wire, and ask the student to make the bulb light. Allow the student several minutes to try to get the bulb to light. Do not intervene, but take note of the ways the student tries to light the bulb – what parts of the bulb and battery the student attaches wires to. If after a few minutes the student has no success, or if she/he gives up, offer to give a clue. Very quickly connect the bulb so that it flashes on, then give it back to the student. Do not leave it connected for close inspection. Encourage the student to keep trying. Only as a last resort should you show him/her how to do it. If conducting a group interview, give others in the group an opportunity to light the bulb as well.

Once the student has lit the bulb, ask, "When the bulb is lit, is there an electric current in the wire, do you think?" For a group, give each participant an opportunity to answer. They will usually respond affirmatively, so ask, "Which way do you think the electric current is moving in the wire?" Encourage the student to explain his/her answer more fully, and ask questions to clarify what the student means.

Repeat this whole exercise, but this time using two wires. The student should be able to make the bulb light fairly quickly this time. Again ask about current movement in the wires. If a different answer from the first is given, gently draw the discrepancy to the student's attention. Do this as a person who is puzzled by a problem, rather than as some one who has caught another out. Clarify whether the student has changed his/her mind, or whether the situations are now perceived as different.

The interview may be extended by exploring other instances of circuits, such as in a torch, or household wiring.

Some general principles for the interview:

- The interview should be conducted on the basis of a friendly discussion between an adult and a child, where the adult is genuinely interested in the child's ideas. It is imperative that you do not "play teacher." The first step is to establish some rapport with the student, and put him/her at ease by discussing something of interest to the student.

- When the student is at ease, explain that you are interested in children's ideas about different things, and that you would like the student to explain her/his ideas about the topic. Emphasise that it is not a test, and that there are no right or wrong answers. If you are using a tape recorder (advisable, as it is hard to listen, question, and write answers at the same time), explain how poor your memory is and how you do not want to miss anything the student says. Say, "So that I don't miss anything you say, I'd like to tape it. If you say anything you might be worried about, we will wipe it before we finish. Is that all right?" If there is no dissent, turn on the recorder and forget about it. If the student objects, do not use the recorder.

- At this point, introduce the focus for the discussion with a comment like, "To help us, I've brought along ...", and take out the focus materials. Keep them hidden until you need them!

- Set the purpose of the activity, which will vary with the topic. In the case of the circuits, ask, "Do you think you can get the bulb to light?" Record the student's actions and responses.

- If the student says something that is unclear to you, ask for further clarification. You need to probe the student's understanding of the phenomenon — do not accept answers superficially: probe! It often helps to pretend that you are uncertain as to what the answer might be too. If at any stage you criticise or reject an answer, or reveal that you think the answer is wrong, or attempt to explain the "right" answer without the student asking for your opinion, it is unlikely that you will get much more from the student, apart from what she or he considers are "safe" answers normally given to teachers.

- The interview should take a maximum of thirty minutes. Thank the student when you are finished.

Electric circuits

Current flow in an electric circuit has been investigated in a wide range of settings from early childhood to university, usually using a version of the interview described above, or using surveys. Students' answers tend to fit one of the four ideas, or models, outlined below (see Figure 2.1).

Model **A** is very common with students who have lit the bulb with only one wire and do not recognise the direct contact of bulb to battery as comprising a "wire." It is also a common explanation for the operation of a torch. If students notice that a second wire is necessary, it is often explained away as a "safety wire." However, continued experience by students causes them to see the necessity of two wires.

Model B therefore becomes very popular. The "clashing currents" idea, as it is often called, apparently explains why the bulb lights, the need for two wires, and why the battery goes flat. This model was also suggested by Ampere, who lived some 200 years ago, and was an early pioneer of work on electricity. The unit of electrical current, amperes, is named after him.

Model ***C***, the diminished current model, reflects the idea often suggested by a teacher that the current moves in a circle, or circuit, from the battery, through the wire to the bulb, and through the other wire back to the battery. The perceived loss of current in the bulb is not usually mentioned by teachers, but is logical to the students because it explains how the bulb is lit, and why the battery goes flat.

Model D, the equal current model, also reflects the circuit idea, but the key difference is the idea that the amount of current is the same in all parts of the circuit. This does not make sense to many students, as it does not explain why the bulb lights, or why the battery goes flat. Yet this model is preferred by scientists.

Learning Project 3

Before reading on, decide what the outcomes of these interviews tell you. If you have ever taught about electric circuits, batteries and bulbs, or a related topic, or had difficulties learning about them, can you see anything from your own experience which is similar? Does this problem seem similar to one of the points you listed in Learning Project 2?

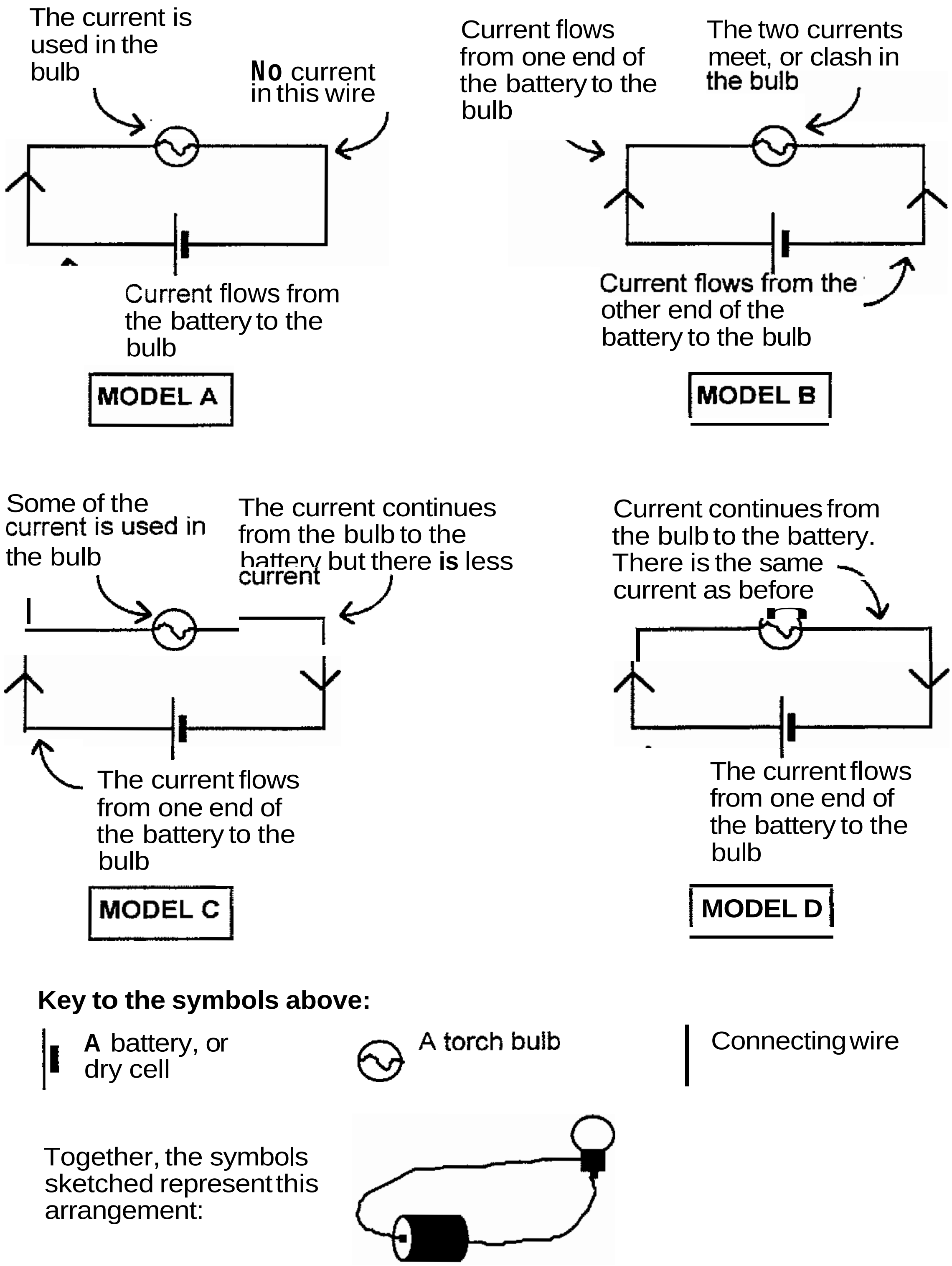

Figure 2.1 The four common ideas about current flow in a circuit

What we learn from these interviews

What do these interview findings reveal about students' thinking? It shows a confusion in many students' minds between electric current and the energy carried by the current. Scientists think of electric current as a flow of electrons through a conductor which provides a clear pathway from one end, or terminal, of the current source (such as a battery), to the other end. Along the way it may pass through something like a .bulb, heating coil, or motor. The electrons are visualised as moving from one atom in the conducting material to the next, pushing other electrons along. **As** an analogy, picture a row of standing dominoes collapsing as a string as the first one falls. With this movement of electrons, there is some associated energy which has its origin in the current source (such as the battery). In some conductors, a portion of this energy may be converted to other forms of energy such as light and/or heat. This happens in a bulb. Even though the electrons lose some energy, they still continue on their journey back to the current source. A useful analogy for this process is the idea of petrol tankers (electrons) leaving the storage depot (battery) full of petrol (energy), and travelling along a highway (wire) to the city (bulb). There the petrol is unloaded, and the tankers return to the depot via a different route (second wire). It is natural that, intuitively, students tend not to distinguish between current and energy since they are both abstract terms not readily seen. Yet in our teaching of electric circuits, this distinction is often not clearly made, nor do we help students get beyond the intuitively illogical notion of Model D. Research into teaching about circuits has also revealed that just telling the students that Model D is correct does not necessarily help them make personal sense of it. Models B and C remain the most common views (35 to 50% of students) from primary years up into Year 10. Only in senior high school physics majors do we find that the number of students holding the scientific view increases towards 80% (Cosgrove & Osborne, **1983).**

The students' choice of model often changes with the situation. It is very common for them to choose Model **A** when only one wire is used. This seems to be related to the fact that the students can see only one wire, and therefore only one wire is considered necessary. When two wires are used, students tend to select one of Models B, C or D. When discussing a torch, students again tend to use Model A, because the only direct connections they see are the chain of batteries touching the bulb; the metal torch body is not considered **as** a "wire." Linked to this reasoning is the idea that one battery, either the furtherest from the bulb, or the closest, will go flat first because the current from that battery is used up first. The analogy in the student's mind seems to be a picture of physical quantities of current filling the batteries, much as water fills a jug. This is a very reasonable comparison, based on the students' experience and intuition.

Poor **teaching?** My first reaction when hearing about this was that the teachers must have been doing a poor job; they were not getting the message across clearly! Or there was something wrong with the curriculum. But across so many countries, so many teachers have been involved, that this cannot be the reason. The problem must go deeper. This was emphasised to me some years ago when, as part of an inservice program, I organised for the participating teachers to interview some Year Nine students from a local school. Their teacher tried to tell me it would not be highly successful since he had just finished a unit on electric circuits, and the students had done well on the test. He was both embarrassed and humbled when he saw the tallied results of the interviews, which fitted exactly the research reports of proportions for the number of students holding each model, that is, over two thirds of the class held either Model B or Model C views.

My next reaction was that this must be an isolated case. Electric circuits is an abstract idea, and so is particularly hard for students to grasp. Surely this sort of thing would happen for only abstract concepts! Alas, the research reveals a very different picture.

Is it an animal?

This was the focus of another interview and later follow-up surveys using pictures of animals and nonanimals as a stimulus (Bell, 1980). The students were asked, “The way you think about an animal, is this a picture of an animal?” If the answer was positive, the next question was, “What is there about it that makes it an animal for you?” A similar question was asked for the negative response. The findings showed that only the large, furry, four-legged beasts such as cows, horses and sheep were considered animals by most students. Creatures like whales, worms, spiders, and flies were not thought of as animals by a lot of students. It would also be reasonable to assume that the more schooling students have, the more their responses would correspond to the scientific classification of animals. For example, the classification of “people” as animals shows this trend. However, Bell’s research has shown that students’ performance in classifying worms, spiders and the like gets worse as their age increases, until some improvements begin to appear in the junior high school.

So this shows that not only do many students seem to hold ideas about animals which are different from the scientific ideas, but that somehow schooling makes the situation worse. When we look at the reasons students give for their classifications, we can see that part of the problem has its origins in language usage. For instance, flies are not considered animals because they are insects; and whales are mammals, not animals. In some shops signs banning animals are displayed.

An even worse situation can occur. If the teacher is not aware of this problem and teaches something new based on the scientific notion of animals, students’ learning in the new area can be impaired. For example, teachers often introduce the ecological terms “producers” and “consumers” by explaining that they are plants and animals respectively. It is not surprising then, to find that students tend to think of consumers as cows, sheep and the like, but not worms and grasshoppers (Osborne & Freyberg, 1985).

Some conclusions

From a huge bank of research data, the researchers doing this work drew several conclusions. The first was that students have their own ideas about many things, even before they are taught them formally. These have been labelled “misconceptions” or “alternative frameworks,” because they often differ from the scientific ideas. However, I prefer to call them “preconceptions” or “existing ideas.”

It seems that these ideas are developed intuitively from the students' everyday experiences. They may also be based on fragments of experiences from school, or from the media. Some of these ideas are so firmly rooted in experience that students find alternative ideas like the scientific explanation do not male sense, so that their ideas are not readily changed. However, some ideas are not strongly held, and the scientific ideas can be developed readily. Unfortunately, if the teacher tries to go onto new work which is based on existing ideas that differ from the scientific ones, the students are likely to experience difficulty and may indeed develop misconceptions about the new area being taught.

Clearly this research has revealed a major problem area in the learning of science. Two issues captivated the researchers' attention:

- What theory of learning can explain how these preconceptions form and persist?
- What can we as teachers do about it?

The answers to these issues are still being sought, but much progress has been made. You will discover that you can find answers for yourself as you work through the later sections in this book.

Learning Project 4

You should now read about other research about students' preconceptions. There is a lot available, but look at a few. For example, try:

Driver, R., Guesne, E., & Tiberghien, A. (1985). *Children's ideas in science*. Milton Keynes: Open University.

Osborne, R. & Freyberg, P. (1985). *Learning in science*. Auckland, New Zealand: Heinemann.

You will find it invaluable if you take some time to explore this area of students' preconceptions for yourself. Use the interview technique, but tailor it to suit the age group you will work with. Also choose a topic area, perhaps one of the ones you have read about, and interview one or two students whom you have access to. Compare your findings to those you have read about.

Is there a problem with some curriculum materials? Look at some of the materials used as resource materials in science for your sector of schooling, such as a teachers' guide, student texts, or activity ideas. Is any indication given of possible preconceptions? Are any preconceptions, either preexisting, or developing during the lesson, likely to be dealt with from the work outlined in the curriculum?

In your group share and discuss the findings from your own investigations of students' preconceptions in the topic areas you were able to investigate. How would you say these preconceptions might be formed?

If you looked at curriculum materials, discuss the extent to which they indicated the likelihood of preconceptions and how to deal with them. How important do you think it is for curriculum materials to include this sort of information?

Practical Work in Science

Practical work in science goes under various terms such as investigations, activities, experiments, and laboratory work. I will mostly use the generic term "practical work." There are several problems which have been expressed about practical work.

The purpose of practical work

There are a few aspects of this which both research and practice have shown to be problematic. The first arose from the Learning in Science Project work mentioned earlier. The researchers explored what students were making of practical work which they were engaged in. Their findings confirmed the intuitive feeling that many teachers have felt, that all was not well. I recall setting a Year Five class a science activity to do, with the instructions set out on activity sheets. After going through the instructions with the whole class, I set them to work and moved quickly from group to group to ensure they were getting started properly. I found one group, after 10 minutes, had still not commenced the activity — they were "playing" with the equipment, which happened to be a pair of powerful bar magnets. They were engrossed in experiencing the feelings of attraction and repulsion between the magnets. Another group spent 15 minutes doing something not in the instructions, but they excitedly told me how they had tested the two magnets to see which was strongest.

Since this was the first time most of the students had ever handled strong magnets, perhaps I should have anticipated that there would have been some distractions from my set task. But the important thing to note is that these students set their own purpose for the activity, which was different from mine. The first group wanted to experience the new force. The second group wanted to see how strong the force was. Too bad that I wanted them to see what objects would be picked up by the magnets, and classify them. A third group did get onto that, but never got much past picking up long trains of paper clips. Their purpose was apparently to make the longest paper clip train.

Osborne and Freyberg (1985) noticed the same sort of problem, but also found some variations of it. For example, they recounted the story of two lower secondary students working from a laboratory manual (pp. 72-73). They had progressed to the third instruction for the experiment they were conducting, but could not recall what the instruction was without rereading it, and had no idea what the experiment was about. Later, when the same students were heating a yellow solid, their explanation of what they were doing was merely in terms of the steps they were following in the laboratory manual. They had no idea why they were doing it, what might happen, or what the purpose of the activity was.

Clearly neither student had any clear idea about what they were doing and why. The purpose they seemed to have devised was to follow the instructions, to get to the end. So, even though activity and laboratory work is considered very important in science, students are frequently not aware of the purposes for doing the activities and the reasons for doing them in particular ways. This may even occur after the teacher has carefully explained the activity and the reasons for doing it.

Teacher-student interaction

Fleer (1992) identified a different problem with practical work. Her focus was in an early childhood setting, where she looked at the type of interaction between the teacher and students. We have all experienced the difficulty of leading students through an activity, and explaining aspects of it, but in the end finding that not all have really picked up the ideas we wanted them to. Fleer found the outcome was highly dependent on how the teacher went about this. The teachers she observed were trying to lead their early childhood students to build a circuit and reach a scientifically consistent conclusion about current flow from their work with torches and batteries and bulbs. The teachers all used the same activities and teaching approach to the topic, but the type of interaction that they engaged the students in seemed to determine the quality of the understandings reached by the students. The form of discourse which forced the students to think about what they were doing and why, seemed to be most effective. Fleer noted that the teacher who continually intervened to focus the students' thinking and model the complete circuit at times when the they were receptive to this, achieved the best cognitive gains in the students. They were able to make complete circuits and explain the movement of electricity along the circuit.

Discovery learning

Driver (1983) has looked at the classroom outcomes of what is commonly called discovery learning, a common strategy used in practical work. Before proceeding, however, it may help to clarify the term, since it often used in different ways. The term seems to have much of its origins in Bruner's (1961) discussion of discovery learning, and an adaptation of what he advocated has emerged as a common practice in science teaching. In this, the teacher chooses a set of first-hand experiences which are all related to the same scientific principle, such as "Air exerts a pressure." The students conduct each practical experience in turn, and are expected to work out the scientific principles inductively.[1] For example, students might be given several activities involving air pressure, and be expected to induce

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[1]Induction is the process of arriving at a generalisation from several instances of one event. If you met several people with purple hair who were also wearing a purple jacket, you might induce the general conclusion that people with purple hair wear purple jackets. Induction may be contrasted to deduction.

the existence of air pressure. The teacher would probably expect to have to help the students work this out. In practice, such help frequently takes the form of the teacher telling the students the answer he/she was expecting, asking leading questions to .provide clues about the expected answer, writing the correct results and conclusions on the chalkboard, or referring students to a book which contains the answers. Teachers have resorted to these tactics because they have found that many students are not able to arrive at the expected conclusions just from doing the designated activities. Driver has confirmed the difficulties associated with the inductive version of discovery for many science lessons.

An example which she cites is the common activity where students are asked to draw the magnetic field about a magnet, after they have seen the patterns formed when iron filings are sprinkled onto paper, under which is a strong magnet. The students are usually asked to draw what they see, but tend not to draw what we normally recognise as the stylised view of a pattern of magnetic lines of force from pole to pole of the magnet. They draw two prickly bunches of filings with a few scattered lines between them. Only after instruction about the lines of force and how to represent them in a drawing do the students' drawings resemble those of scientific convention (see Figure 2.2).

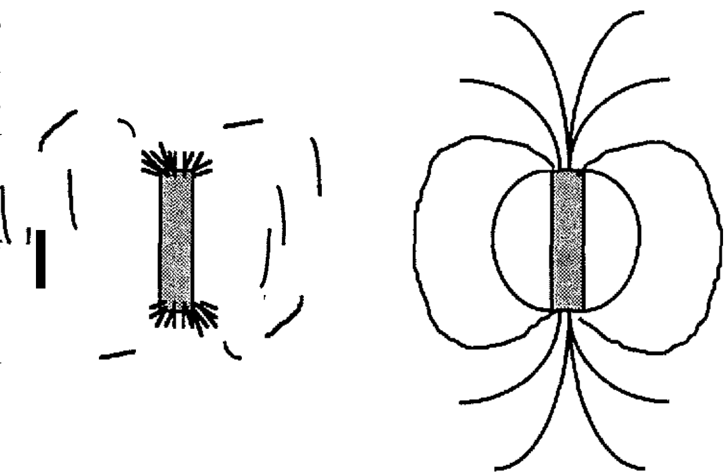

Figure 2.2 Comparison of drawings of magnetic lines of force

Many conclusions that we expect students to reach inductively following this notion of discovery may simply be unavailable to the students. Indeed it may have taken scientists hundreds of years to reach those conclusions. That is, the students.really need to know about the principle concerned to be able to recognise it. I experienced this problem with a Year Six group. I gave the students a series of activities which were all (supposedly) examples of air pressure in action. I then asked them to explain the principle behind the activities, expecting them to talk about the weight of air, or air pressure. They tried, but all I received were wilder and wilder guesses. I began to give clues to help them. Finally one student advanced, "Would it have anything to do with air pressure?" He had seen one of the activities they had done, described in a book under the heading "Air Pressure," and made a guess. Once the term was mentioned, it was evident that a lot of the students knew something about air pressure already, but they had not linked what they knew to the activities they had done. They certainly had not induced any conclusions about air pressure.

What were the problems? Obviously the earlier point about the students not understanding the purpose of the activities is pertinent. I had also pretended that they knew nothing about air pressure already (the notion of their minds being an "empty slate"). I expected them to somehow make an intuitive jump and perceive an abstract principle in activities which were spectacular in themselves. Yet even those who did know something of air pressure could not recognise the principle in operation. When the situation became desperate, I began a subtle process of telling, by giving them clues. They responded by trying to guess the "right" answer. In my experience, this is what many teachers do. We give students an activity, and ask for conclusions. If the desired ones are not forthcoming, we embark on a game where the students guess our answer, and we provide clues. We may finally have to tell them our answer, which is usually then recorded by the students in some way. A common term applied to this style of teaching is "guided discovery," used most frequently in early childhood settings and primary schools, but also in some junior high school programs. However, it is really a sort of game; a way of telling students when we do not want to tell them.

Experience for experience-sake

Some primary and early childhood teachers have taken a different way out of the dilemma. They put emphasis on the hands on experience as an end in itself, and do not worry about conclusions the students reach, as long as they conclude something. Doing the activity becomes the goal of the science lesson. Successful completion of the exercise is seen by both teacher and students as achieving success in science. This is often done in the belief that students learn best from hands on work, and a hope that incorrect ideas will be modified later by more experience. But the research into students' preconceptions is showing that this is not necessarily happening.

Safety

With an increasingly litigious society, safety has come to the forefront of teachers' minds. Of course the welfare of students has always been a priority, but now there is the overtone of litigation. Engaging students in science practical work with equipment or field trips therefore presents a problem for many teachers, for these are seen to increase the possibility of something going wrong. It does not have to be so, as long as adequate measures are taken, just as they need to be taken for any classroom activity. For some early childhood and primary teachers, uncertainty about the science and potential hazards is a particular difficulty. For secondary teachers, ignorance of hazards can occur just the same, but complacency can be an even more serious problem. I have included only a brief section on safety in this book, since most education systems have their own documents. You should consult these yourself and become familiar with the contents. This kind of knowledge can then be worked into practice when planning the curriculum, and when teaching.

Managing equipment and laboratories

This can be a major problem for all teachers of science, but the problem takes a different shape in the different sectors of schooling. For early childhood and primary teachers, the problem lies with obtaining the equipment needed for particular activities, in sufficient quantities. A criterion for selecting activities will often be whether the equipment can be readily obtained. This is alleviated if the school has a policy and established organisation for equipment procurement and management. In the absence of this, the teacher must fend for herself. You will need to work through your own solution to this problem. Some ideas are included in Chapter 11.

Secondary teachers usually have the necessary equipment readily available, and a laboratory assistant to do any special preparation. The problem for them becomes more one of managing the help and resources so they are available when needed. A major constraint is scheduling of classes into laboratory rooms, and timetabling with sometimes restrictive time allocations for lessons. The problem for them becomes how to juggle the various curriculum demands and subserviate the needs of learning to the availability of laboratory space and whether particular exercises can be completed in the time available. Chapter 11 contains some suggestions about this as well, which you will have to apply to your own situation.

Managing small groups at work

Related to using equipment in practical work is managing the small groups that the class is usually organised into. Small groups are common to many subjects, where they are usually used for small group discussions. Science, in common with a few other subjects such as technology and art, have the added difficulty of using equipment in small groups. This added complication can become an considerable problem for some teachers, who then resort to teaching procedures which minimise the problem. There are some very practical ideas about management which we will look at later in Chapter 9.

Learning Project 5

Choose one or two issues from the previous section which you are most concerned about, or most interested in. Find out some more about each issue. Also consider how this might relate to your own practice e.g. Do you use "cookbook" instructions for activities or laboratory work? Are you keen on discovery learning? Do you like to have the students do activities, but do not follow them up? Are you frustrated by short lessons and restrictive timetables?

Ensure you find possible solutions to these difficulties over the next few weeks.

Asking Questions

An important and prominent teacher behaviour is asking questions for the students to answer. While this may seem to be rather straight forward and simple, it can be a problem if the teacher does not take care about how he/she asks questions. There are three main problem areas:

- overuse of convergent questions compared to open ended questions,
- short wait times, or pauses after questions are asked, and
- distribution of questions around the class.

The topic of questioning is covered in many other books about teaching, so I do not want to spend much time highlighting these problem areas. The following brief summary will suffice. McGlathery (1978) provided an excellent review of this area which is still pertinent.

Convergent **and** divergent questions

In the normal course of teaching, it seems that we ask a lot of questions, up to 80% of which, by some reports, require recall of facts. I refer to this type of question as closed, or convergent. In various reports of teachers' questioning behaviour a maximum of 20% of questions asked require students to think, though mostly this is below 10%. I call this sort of question open ended, or divergent. The researchers saw these questioning behaviours as a problem because over-reliance on convergent questions tends to stifle students' thinking and cause them to rely on memory recall. On the other hand, divergent questions have many advantages in stimulating student thought. It appears that each type of question has a place, but too much of either seems to limit the students' cognitive gains compared to about an even mix of question types.

Wait times

Wait time is the time the teacher pauses after asking a question, before a response is given. The research suggests that we not only ask a lot of questions, we ask them very fast. Typical wait times tend to be very short, less than a second. Very short wait times limit the students' cognitive gains — they literally have no time to reflect or really think. Considerable gains in student learning can be achieved by increasing wait times to about **3** seconds or even longer, particularly for questions requiring thinking. Wait time 2 is also important. This is the pause after the first student response to the teacher's question. Normally, the teacher asks a question, a student responds, and the teacher comments immediately. That is, wait time 2 tends to be very short and students get little, if any, opportunity to respond to another student's answer. If the teacher extends wait time 2 by delaying his/her response, other students have a better opportunity to comment.

Question distribution

It seems we also have a tendency to select students to respond to our questions from a limited area of the class. This is a small arc in front of us, assuming we are positioned at the front of the room towards the centre. Students at the sides and rear tend not to be selected as frequently. Since engagement with the lesson task is increased with selection to respond to questions, this can create a problem for those students missing out. Once we are aware of this, it is fairly easy to correct, but it requires constant monitoring, even for experienced teachers. **A** less obvious problem is our tendency to select students who are more enthusiastic, or clamour for our attention. The quiet or withdrawn student tends not to be selected. These tend to be those who are not performing well, girls (in science), and ethnic minorities. This actually relates to equity issues, examined in the next section.

Learning Project 6

Choose one or more of the above aspects of questioning. If need be, find out some more about it. Then arrange to check on your own pattern of questioning during science lessons. Depending on your choice, you may need some help by having someone observe your teaching, or you may need to tape record a part of your lesson to listen to later.

Being Fair to Everyone

Just as there can be a subconscious tendency to overlook particular students in selecting people to respond to our questions, the same students tend to get less of the teacher's attention in other aspects of lessons. While many teachers are now aware of this, it is important to recognise this issue as problematic because it requires specific action by the teacher to remedy.

Gender bias

It is well documented that girls tend to be overlooked in the sciences, compared to boys. A consequence is that girls have been under-represented in the physical sciences in senior secondary grades (e.g. Dekkers, de Laeter, & Malone, 1989), so many do not have a full range of job opportunities available to them, particularly in the sciences. Girls even begin to avoid science by Year 6. Evidence has begun to emerge which suggests that this may be turning around after several years of close attention in high schools. However, the basic problem of gender bias remains in our society and schools, even in preschool and primary school (Clark, 1989). For example, a number, if not all of the following tendencies would apply today (Spender & Sarah, 1980):

- At least two-thirds of teachers' classroom interactions occur with boys, who perform at least two-thirds of the student talk.
- Girls wait longer for answers or assistance from teachers.
- Teachers recall more individual details about boys than girls.
- The experiences of males tend to form the subject matter of lessons.
- The achievements of boys are enhanced and those of girls devalued.
- Teachers have higher vocational expectations of males.

- Boys are given more space, resources, equipment, finance and remedial services for their needs.

Because gender roles and stereotypes are deeply embedded in our society, it takes conscious effort and time to change. I recall one of my undergraduate students had just completed some small group work with two Year 4 girls, and brought them back to their teacher. The girls excitedly began to tell her about what they had done. Another group of two boys arrived, and interrupted to tell of their work. The teacher stopped listening to the girls, attended to the boys, and turned back to the girls when they had finished. I commented to the student teacher, who was also standing nearby, "Did you see that?" She said, "What?" Now that student teacher had just completed several weeks of reading about and discussing gender bias in science. Yet she failed to recognise it when it happened under her nose. This is what I mean when I say it is deeply ingrained into our social and school practices — we simply do not notice even overt instances of bias unless we train ourselves to look for and recognise it. Only then do we have a chance to change our behaviour and that of our students.

Ethnicity

People from cultures that are somewhat different from our own can have considerable difficulties in our schools, so this issue is not peculiar to science teaching. As teachers we are usually more aware of such students if their facility with the English language is poor. But there would be many students with a reasonable grasp of English who struggle in science lessons because of different cultural behaviours and expectations. Difficulties or clashes can occur at the levels of cultural practices, belief systems, and forms of knowledge and thinking (Baimba, 1992), with disastrous effects on the students' achievement. There can also be unintended cultural bias exhibited by teachers, simply because they are not aware of the cultural differences (Contreras & Lee, 1990). This area also needs deliberate and conscious attention to overcome the consequent difficulties experienced by such students.

Learning Project 7

Choose either gender or ethnicity to investigate in a classroom you have access to, preferably during science lessons. If it is not your own class, negotiate with the teacher what you will do. The purpose is for you to help train yourself to notice occurrences of bias, not to pass judgement on someone else. If it is your own class, you may wish to videotape a lesson, or have someone observe you. Find out more about the type of bias you wish to examine, and decide how you will detect it when it occurs.

In your group discuss specific instances of gender and/or cultural bias which you have experienced or observed. Explore why these instances may have occurred, and how they might have been prevented.

Teacher Confidence

A final problem area tends to be more specific to early childhood and primary settings, but can occur in junior high schools which are short of science teachers, and science is taken by a non-science teacher. Many such teachers seem to lack confidence in teaching science and therefore avoid teaching it. The lack of confidence stems mainly from the fact that few of them choose to study much science in their schooling and teacher preparation. A considerable number also experience difficulties with the science courses they have studied. They therefore have poor images of themselves as working with science and teaching it. A lot of this is gender-based. Interestingly, I have found that teachers who experience feelings of inadequacy can achieve very well in science and teach it well, if they face up to the challenge of overcoming their fears. While their fears are real, their failures more often than not have been generated by the education system, and not by any personal limitations. Hence the problem of lack of confidence of many early childhood and primary teachers is also a problem for secondary science teachers, since this is frequently where the lack of confidence is generated.

A Case For You to Work on

A group of teachers is having a lunch time discussion after an inservice session where they heard a panel of teachers discussing these sorts of problem areas in science. Several teachers state that they do not believe that (you choose the problem area, such as gender equity) is really a problem in their classes.

In your group, pretend that you are holding that discussion. Decide who will be expressing scepticism. One of you should assume the role of Joan (the early childhood teacher), or Sally (the primary teacher), or Julian (the secondary teacher), who is convinced that it really is a problem area which needs attention. Your discussion should focus on the most relevant sector of schooling for your group. Try to draw on specific examples and instances to make your argument.

Your Chapter Review

Make a priority list of problem areas that you would like to work on in your science teaching. If there are others not mentioned in this chapter, include them.

Further Reading

Learning and classroom problems:

Osborne, R., & Freyberg, P. (1985). *Learning in science: The implications of children's science.* Auckland, New Zealand: Heinemann.

Discovery learning:

Driver, R. (1983). *The pupil as scientist?* Milton Keynes: Open University.

Teacher-student interaction:

Fleer, M. (1992). Identifying teacher-child interaction which scaffolds scientific thinking in young children. *Science Education,* 76, 373-397.

Questioning:

McGlathery, G. (1978). Analysing the questioning behaviours of science teachers. In M.B. Rowe (Ed.), pp. 13-30, *What research says to the science teacher Vol 1*. Washington, DC: National Science Teachers Association.

Equity:

Baimba, A. (1992). Science and culture: Implications of the teaching and learning of science in non-western societies. *SAMEpapers 1992,* pp. 22-30. Hamilton, New Zealand: University of Waikato.

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Osborne, R., & Gilbert, J. (1980). A method for the investigation of concept understanding in science. *European Journal of Science Education*, *2* (3), 311-321.

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3

Influences on Science Teaching: Curriculum

What **This** Chapter **Asks** You **To** Do

During this chapter you will:

- Identify influences on the science curriculum in your sector of schooling.
- Explore the notion of curriculum conceptions as a context for the science curriculum.
- Examine your science curriculum documents in terms of conceptions, organisation, and structure.
- If you work in an outcomes-based educational framework, consider the effect (if any) this might have on the science curriculum.
- Consider the place of each of technology, environmental education, history and philosophy of science, and integration for the science curriculum in your sector of schooling.
- Review the place of language in a science program, and how science may enhance a language program.

Curriculum issues impinge directly upon teaching and learning in all subjects. In recent times science education, like many other subjects, has come under close scrutiny, particularly from the political sphere. There have been demands for changes to the curriculum, and calls for accountability for the money spent on education. Some of the advocated changes, particularly at the national level, have been built into new curriculum programs with a trend toward outcomes based education..This chapter will therefore explore some of these recent trends, and look at other influences which shape the curriculum.

A Definition for "Curriculum"

The curriculum is best viewed as the totality of experiences undertaken by students in school, though some people tend to think of it only in terms of the written materials. The most influential components of the curriculum are the curriculum program, such as the syllabus or text, the teacher and the context in which she/he works, and the students and all that they bring to the learning situation. It is the complex interplay of these and the broader societal context which determines the curriculum, and what is actually learnt by the students.

Before proceeding, you should clarify your own thinking about the science curriculum for your sector of schooling, as suggested in Learning Project 8.

Learning Project 8

Consider each of the influences on curriculum mentioned in the previous paragraph, and jot down specific things which you know about, which affect the science curriculum in your sector of schooling:

- the formal science curriculum program or syllabus and consequent resources used,
- the teacher,
- the context in which the teacher works, and
- the students.

For example, what things are mandated or required in the science curriculum or syllabus?
What science experience or training do teachers in your sector of schooling tend to have?
What support and resources are available to teach science? What testing programs have been instituted by the education authority and/or the school?
What attitude to learning and to science do the students bring?

In your group discuss how each of these things you identified affects the teaching of science.

Curriculum Conceptions

In both the educational and wider community there are basic assumptions and values about the purposes of education which exert powerful influences on the curriculum. Such assumptions and values are rarely stated explicitly, consequently dissension can arise between people with different views, without them being aware of the real basis for their differences. Similarly, curriculum materials may be written from an underlying set of assumptions and values, but teachers trying to use the materials in their classrooms may espouse different sets of assumptions and values, resulting in conflict and stress for the teachers. To complicate the matter further, students may espouse even different sets of values.

The views outlined briefly below (Eisner and Vallance, 1974) are not the only ways of considering curriculum conceptions, but serve as a useful starting point. Rarely would a person identify solely with just one view; most people would espouse aspects of two or more views. These conceptions deal with views of education — views of students, for instance, who do not value schooling, are not considered.

Academic rationalism

Of overriding concern in this viewpoint is the transmission of our western culture. This is done by a study of the traditional subject disciplines which constitute the recognised pool of knowledge associated with our culture. School curricula have been traditionally organised this way. There is usually a strong emphasis on content..

Development of cognitive processes

In many ways this view has emerged as a variation of the Academic Rationalist view, in that it is usually subject discipline based, but focuses on improving thinking processes rather than on content. Such thinking processes in science have been labelled "process skills," or sometimes just "processes." These thinking processes were originally seen to be generic and transferable from subject to subject, but more recent research suggests that ability in using particular process skills is dependent on familiarity with the content being studied. Rarely is this view of curriculum proposed exclusively; it is usually closely associated with Academic Rationalism, where subjects focus on both content and process.

Humanism

Humanistic views result in curricula which are student centred, and which aim to develop each student to his/her fullest personal potential. Self actualisation is a term commonly associated with this view. There is an emphasis on both content and process, focusing on what is important for personal development: education is a liberating agent for each person. In this view of curriculum there is often emphasis on wholistic learning and integration of subjects. Disciplines like science would most likely not be taught as such, but would be included as part of a theme, like *The Sea*.

Social reconstruction

In this view of curriculum emphasis is put on using education to change society. This could be in an active revolutionary sense where the existing social order is challenged; or in a benign sense, where students are prepared to live in a future society, usually with a view to making it better. Hence the focus is more on needs emerging from societal considerations rather than individual needs. An excellent example of this is the current focus on gender in education as both a social justice issue, and a means of socially reconstructing societal views of gender and gender roles. The argument is not only that both boys and girls should be given equal opportunity in science education, but that our country is also missing out because a large pool of talented people are not going into science related employment. If schools can change the attitudes of girls toward science so they no longer avoid such employment, the future need of our society will be redressed.

Curriculum as technology

Schooling, as part of a bureaucratic system, may be viewed as a technology. In the sense that Eisner and Vallance (1974) use it, the focus is on the curriculum itself, which is seen as a technological process of learning. For curriculum as a technology, optimum teaching/learning conditions can be identified and applied systematically for a range of learning situations. The technology of learning which has been used almost exclusively in this view of curriculum has been adapted from behavioural psychology. Such a curriculum is usually viewed as a curriculum product designed to present information to the learner in a systematic controlled way.

Such curriculum conceptions provide the basic underlying value and belief systems that schools operate in. Interacting with this are the bureaucratic institutionalised aspects of education seen in traditional school structures, teacher career paths and government education policies. The influence of politics and institutionalised bureaucracy is considerable. These can impinge on curriculum in many ways.

Learning Project 9

What would you say your own dominant curriculum conception would be?

To what extent would curriculum conceptions differ between different sectors of schooling? If there are differences, how would these affect progression through the years of schooling?

In your group compare views about your curriculum conceptions. What commonalities and differences exist?

Syllabuses **and** Curriculum Programs

The syllabus ox curriculum program set by the education authority determines the main framework for the science curriculum that will be implemented at the classroom level. The influence can be direct if the curriculum requires certain topics to be included in the science program, or if there is some required testing program associated with the syllabus. The influence can also be indirect, as the syllabus or curriculum program will usually lay out some expectations about the teaching strategies, ideas about learning, equity, and the scope and sequence of the science curriculum. The syllabus or curriculum program will also have been framed in terms of recent calls for remodelling the teaching of science, and so will reflect the reports or reviews that were considered in its drafting. Very often these views have political overtones. Recent calls for accountability have led to dramatic changes instigated at the political level in some countries. For instance, England and Wales now have a national testing program linked to their National Curriculum.

In several countries some form of national curriculum or set of expectations has been developed. In Australia, this has taken the form of ***A** Statement on Science for Australian Schools* (1994) and *Science - A Curriculum Profile for Australian Schools* (1994). These have been used by each state and territory education authority to deveiop or review their science curricula, though some states have responded faster than others. Since each state and territory has treated the documents in different ways, the curriculum documents being produced have some commonalities but also considerable differences. By comparison, there is one mandated science program across England and Wales.

Learning Project 10

Obtain a copy of the national curriculum documents relevant to your situation, if they exist. Also obtain any relevant syllabus or curriculum documents. Look at the structure and organisation of each. Carefully compare and contrast documents if you have separate national and regional documents.

Are there any process strands?
Which conceptual strands are outlined?
Which issues are raised as important to consider when teaching science?
Has some form of outcome statements been included in the documents?
If so, how are these intended to be used?

You will need to be very familiar with the documents associated with your own teaching situation. Use them continually as a resource and comparison as you work through the remainder of this book.

In your group discuss the curriculum conceptions implicit in the documents you have examined.

Outcomes-based teaching

As mentioned earlier, many new curricula now include some form of outcomes statements, or objectives, showing expected levels of achievement for students at different Year levels or groups of Year levels (such as Years 1 to 3). These are contained, for example, in the *Science - A Curriculum Profile for Australian Schools* publication. For some teachers, using specific outcomes as a basis for their planning and teaching is a new experience. I have found, for instance, that in general, early childhood teachers tend to focus primarily on the integrating **experience** the students will have, primary teachers tend to focus on the activity in which the students will be engaged, and secondary teachers tend to focus on the **content** to be covered. Objectives these teachers work with therefore tend to reflect the focus each teacher has, and are not usually framed as outcomes unless the teacher makes a conscious effort to plan with outcomes as a basis.

Using outcomes in planning, and teaching toward achievement of outcomes requires careful consideration of the unit content and pedagogy in the light of the specified outcomes. Planning with outcomes is addressed in Chapter 8, and pedagogies for achieving outcomes in Chapter 7.

Where specified outcomes are also linked to some external assessment program, there is potential for the curriculum content to be aligned closely to the tests, and an emphasis on test performance rather than on learning. Note that I differentiate between these, since I do not believe that test results necessarily reflect the learning achievements of students. There is ample anecdotal evidence emerging from some places where this is occurring to support my belief.

A final consideration regarding curriculum and outcomes is the role the teacher plays in changing the focus and outcomes of the curriculum.

The teacher's role

Depending on the education system and school policy, teachers may have a choice about which curriculum materials to use. Whether or not the materials are given to teachers, or selected by them, each teacher will interpret the materials in terms of what he/she thinks the developers intended. An inservice program may be provided to help teachers understand the developers' philosophy and intentions, and to perhaps develop new slulls that may be needed in the curriculum. However, both the curriculum product and inservice work are interpreted by teachers using their own personal system of beliefs about education and science.

As teachers begin to use their curriculum materials they will always make some re-organisation or adaptation of it to suit their own local situations. This could happen in both the long-term aspects of the program that a teacher is formulating from the materials (e.g. the sequencing of topics); or in the short-term planning (e.g. changing specific activities). The materials may suggest a particular sequence of topics, but the teacher may prefer a different sequence for a whole variety of reasons. There may also be specific activities for students included in the materials, but the teacher may decide to change parts of the activities to suit the teacher personally, the students and the classroom context. When preparing a program based on the materials, the teacher will usually draw up long-term and short-term schedules, and make choices among options which may be suggested in the materials. Some of these choices may be made at the school level, depending on school policy. Developers of "teacher-proof" curricula which were produced in the 1960s and 1970s tried to minimise any choices for teachers, even at the activity level. So that equipment shortages would not cause teachers to alter activities, all equipment except perishables was often provided. Given the above comments, it is not surprising that these programs were not highly successful. So far, my discussion has mainly referred to conscious and deliberate choices and changes that a teacher may make to curriculum materials in implementing a program. Such changes may result in a program being different from that intended by the developers, and may even be contrary to the developers' intentions. These would be, from the teacher's point of view, deliberate compromises because of mismatches in educational beliefs or because of difficulties in management, organisation, or in availability of resources.

However, there are also unintentional choices and changes that teachers may make. That is, teachers may truly believe that they understand the educational basis of the materials, and may genuinely think that they have implemented the curriculum exactly as intended by the developers. But to an observer such as one of the developers, there may be minor or even major discrepancies. This does not imply that the teachers have made an error, or that they are deficient in reading skills! It does mean that there has been a failure in communication in that teachers have interpreted the materials using their "rose-coloured glasses" and not those of the developers. The teachers, and the developers, may both remain unaware of differences in interpretation because neither could even conceive that a different interpretation could be made from something apparently written so clearly! Hence the only teachers likely to use a product the way the developers intended are those who coincidently share the educational views of the developers. This emerged clearly, for example, in the evaluation of the *Science* 5/13 project in the United Kingdom (an early childhood and primary program), and was also evident in the use of *Australian Science Education Project* (a junior high school program).

An aspect of this which is of considerable concern is that many early childhood and primary teachers feel insecure about teaching science; often because of their own experiences in trying to learning science. Some teachers so lack confidence that they totally change the curriculum in order to avoid teaching science. Others may try to teach it, but use teaching strategies and approaches they feel comfortable with, but tend to be boring for the students. While this is a natural and human response as discussed above, it is unfortunate that such teachers are perpetuating their own fears with the students in their care. It can also happen that teachers who did not major in science are sometimes given junior high school science classes. They can experience the same sort of misgivings that primary and early childhood teachers feel, and resort to similar strategies. Fortunately there are also many teachers who face up to their lack of confidence, overcome it, and make excellent teachers of science. Of course, there are also some teachers who have carried their initial enthusiasm for science from their schooling into their own teaching situation, and make it a main feature of their programs.

How Technology Fits In

Technology has been defined in a number of ways, from narrow views of computers and the like to wider views such as processes selected by people to reach their predetermined ends or satisfy their perceived needs. I prefer the wider view. Technology differs from science, though in some aspects they are closely related, Science focuses on understanding natural and physical phenomena on the basis of theory and evidence, but technology focuses on the design and appraisal of systems and devices that affect the way we live. In the design and making process which is part of technology, scientific knowledge may be used to guide decisions, but many decisions can be made through experience and trial and error, without recourse to science. Politically, advances in technology are often seen as means of achieving economic advancement.

Technology has therefore become a recent addition to the school curriculum. How it has been added varies considerably between systems. Some education systems have included it as a part of the science program, as in the primary science and technology curriculum in New South Wales, Australia; and in the Alberta, Canada, primary science and technology program. Like England and Wales, the national curriculum documents in Australia have had it designated as a separate Key Learning Area. This resulted in the documents *A Statement on Technology for Australian Schools* and *Technology - A Curriculum Profile for Australian Schools.*

Links between science and technology

Technology in secondary schools, where it has been designated a curriculum area, is almost always separate from science. Historically, it has usually replaced subjects such as Manual Arts and Home Economics. However, prior to the inclusion of technology as part of the curriculum, there were moves to include science, technology and society (STS) components in secondary science. Many secondary science programs therefore include reference to technology as applications of science.

Combining science and technology at primary levels allows more economical use of the time available in the school day. There is also some overlap between aspects of science and of technology which makes for ready integration; for example, material and structures technology. On the other hand, there are some aspects of technology which do not fit well with science, and are better treated separately or integrated with other subjects; such as information technology. A danger of treating science and technology together is that technology might be taught instead of science (already documented in New South Wales). It also means that less can be covered, since the combined time allocation is usually less than if they are treated as separate areas. There is also the possibility of technology being interpreted solely as the application of science, as has occurred in Alberta.

Having separate subjects allows time for adequate coverage of both areas, provided time allocations are sufficient. It also encourages the exploration of different pedagogies for science and for technology, rather than trying to make them both fit the same pedagogy set. Having separate subjects does not preclude integration of technology with other subjects, including science, when appropriate. However, the most compelling argument for having separate subjects, is that the nature of each is different.

In this book, I have assumed that science and technology are different, and are best treated so. However, if you find that you have a combined science/technology curriculum, there are many aspects of technology teaching and curriculum which have some things in common with the teaching of science examined here.

Learning Project 11

In your group discuss the advantages and disadvantages of combining science and technology in your sector of schooling.

Do you agree or disagree with my belief that they should be separate? Why?

How Environmental Education **Fits** In

Environmental education is concerned with education about the environment, and informed, non-exploitative use of the earth's resources, including human resources.

It has not been designated a separate curriculum area in any area of schooling to my lonowledge, but is mostly treated as an over-arching and integrating idea which relates to science, technology, studies of society, health, and physical education. As such, it has the potential either to have a powerful structural influence on the curriculum, or to be forgotten in the complexities of normal school life. In Australia, it fits fairly well into the Key Learning Area, *Studies of Society and Environment*, carrying the suggestion that environmental education is part of social studies. Consequently, the place of environmental education in the curriculum depends considerably on school policy and the interest of individual teachers. Some curriculum programs place such an emphasis on their own particular requirements that there is little room for integrating ideas emerging from environmental concerns.

I have seen most environmental education programs in early childhood and primary settings, except where specific environmental subjects have been created in secondary schools, usually within the sciences. The discipline-based divisions of the secondary school tend to make any environmental subjects focus around a particular discipline, though where teachers from several disciplines work together as a team, effective integrated environmental programs can result. In early childhood and primary settings, having one teacher responsible for all subjects facilitates integration, but this depends on the whim of the teacher. Unfortunately, some teachers use environmental education as a substitute for their science program instead of integrating it across subjects.

Learning Project 12

Look at the curriculum documents with which you work, and determine what place environmental education might take in your sector of schooling.

Would you teach environmental education in the light of that? If so, how?

In your group discuss the desirability or otherwise of including environmental education in the science curriculum.

If you consider it should be included, what would be some effective ways of incorporating it into the science curriculum?

How the History and Philosophy of Science Fits In

This aspect of science examines historical instances of science discoveries and scientists at work, with a view to understanding the nature of science and how it progresses. In the curricula produced since the 1960s this has tended to be neglected, and only in the last decade has there been a move to restore this aspect to science programs. It may be tempting to think that this belongs mainly to secondary science, but I suggest it may well have a place in the middle and upper primary school as well. Some secondary teachers are tempted to see it as a "frill" which takes time from teaching content in an already crowded curriculum. However, it has been included in the national curriculum developments of recent years. For instance, it occupies about 5% of the English National Curriculum in science, and is a part of the Australian Statement's *Working Scientifically* strand.

There are some good reasons for including the history and philosophy of science (H&PoS) in the science program. These include:

- considering the people involved in science highlights the human aspect of the scientific enterprise;
- there are lessons for current science and environmental/societal issues in the history of science;
- students, particularly girls, find it motivating;
- it can serve as an excellent introduction or conclusion to a unit;
- it can help make science content more meaningful; and
- learning content alone in a school setting does not reveal the nature of science to students and can convey erroneous impressions.

There are a number of ways of incorporating history and philosophy of science into the science program. It can be fairly low-key, with occasional stories of scientific discoveries or scientists (ensure a gender balance is maintained in selecting stories). Alternatively, it can be used as a major focus for a topic, such as by using drama to reenact events and simulations to reconstruct them.

Learning Project 13

To what extent do you agree/disagree with my claim that the H&PoS can form a worthwhile part of the science program for your sector of schooling? Examine your syllabus/curriculum program and some curricula which include aspects of H&PoS as part of your consideration. Provide some reasons for your agreement or disagreement.

In your group share your views. If you consider H&PoS should be included, discuss ways of incorporating it into a science program. How might drama, narratives and simulations be used?

Integration

Integration can be of two types: science can be integrated with other subjects, or the different sciences such as biology, chemistry, physics, and earth science, can be integrated into general science. Most science programs up to the end of Year 10 are integrated or general science, with specialisation occurring only in the senior high school. Some schools also offer an integrated science in Years 11 and 12. I have found most teachers agree with delaying specialisation until late in schooling.

Integrating science with other disciplines/subjects is a more complex issue. It occurs most readily in environmental education, as discussed earlier. However, more extensive integration can be planned, not necessarily using environmental education as the focus, from early childhood to Year 10. Integration in the lower secondary school usually requires the cooperation of a group of teachers, so is much more difficult to organise. Some schools have overcome this by restructuring their program and timetable.

Integration of science can occur with just one other subject, or with several subjects. Most teachers plan for integration using a theme, issue, or problem of interest to the Year level. Early childhood teachers use integrating themes such as *The Sea* or *The Circus* often, but teachers at all levels can use them. Issues and problems tend to be used more in upper primary and secondary. These might include local environmental issues like a polluted creek or making the school grounds more attractive, or deal with broader issues like abortion or world population growth.

Teaching using themes usually calls for particular approaches to planning. These are examined in Chapter 8.

Language in science

As with any facet of schooling, language is a critical and necessary component of science. Sometimes teachers who have studied a fair amount of science, myself included, tend to think only in terms of the science content, processes, and investigations/practical work, and not the language in which **all** of this is embedded. Sometimes it is the other way round, where teachers think mainly in terms of language, and neglect other aspects of science. I would suggest that we need to consider both angles in curriculum planning, regardless of the Year level. That is, we should consider language as part of the science program, and science as part of the language program.

Language as part of the science program, and vice versa, has particular significance in three areas:

Reading. So much scientific information is presented in printed form that reading is a necessary means of accessing much of what is available. That is, it is a key means by which students can obtain information in science, apart from the teacher. This applies from early childhood settings, with picture stories and *story* telling, to tertiary, with reference books and journals. Reading in science therefore has several dimensions, each of which needs to be addressed. Students need to have an acceptable general reading level to be able to engage in reading tasks confidently. Teaching reading skills tends to be a main focus of earlier Year levels, and ideally includes reading science books as part of the reading program. As reading facility develops, using science books to find information for science investigations becomes more important. Students also need specific types of reading skills for maximum effectiveness in reading tasks. For instance, they need to be able to skim quickly through a passage to obtain the gist, and they need to be able to read a passage critically, to obtain a good understanding of the content. They also need to know the most appropriate times to use each skill. Another reading skill important in science is being able to read and implement a set of explicit instructions. These skills all need to be specifically taught, and can ideally be practiced when integrated into the chosen teaching approach for a science unit. That is, the reading has a purpose associated with “real” tasks which the students have identified.

Speaking. As part of the language program, speaking during science can be directed toward the development of speaking skills and vocabulary. As part of the science program, speaking can have several advantages. Encouraging students to speak during science lessons can help teachers gauge the sense the students are making of the work. To have students express their ideas to another in a coherent understandable way often requires them to clarify their own thinking. It helps them identify aspects of ideas which may not have been clear or may have been contradictory, and highlights aspects they do not know much about. When learning new vocabulary, using new words in speech helps locate the word in appropriate contexts and associate it with related concepts. That is, encouraging students to speak about their ideas facilitates cognitive development of those ideas. In small group and cooperative learning contexts, speech is also a vital component of working together, and negotiating towards a consensus. It can be argued that an important part of the development of science is the art of persuasion.

Writing. Science in the writing program can provide opportunities to use particular writing styles and genres which are being taught, drawing on data obtained by the students and their own experiences. This enables students to practise these genres, using experiences meaningful to them.

In the science program, it is unfortunate that the demands of dealing with a large number of students in a class has led many teachers to rely on writing, or precursors to writing (such as matching pictures, and colouring in) to keep students busy and to obtain information about the students’ learning. I find that many students dislike science, because they associate it with extensive and boring writing tasks. Writing in science therefore needs to be an integral part of the teaching approach being used, and should have a specific purpose which the students can see is useful and productive, such as recording of data or information so that it will not be forgotten, or preparing a poster for class display.

An unfortunate misuse of writing in science is asking students to ”write up” their investigations or practical work. In primary schools, this is usually done in the “Science Notebook,” and in secondary schools in the “Lab Report.” When writing such reports, students are frequently asked to conform to a specific setting out adapted from scientific writing, which is meaningless in most school contexts. While a modification of this sort of format might be useful when students are learning how to write reports, I believe that to demand it for all science investigations is inappropriate.

Learning Project 14

In what ways would you see science being integrated in your sector of schooling? Would integration be a major or minor aspect? Do you think that should change?

How does language fit with science in your sector of schooling? Are there any problems associated with this? Should any changes be made?

In your group plan how language might be used to maximum advantage in your sector of schooling.

A Case for You to Work on

In your group choose one of the scenarios below to discuss.

Early childhood

Joan, our preschool teacher, has been invited to lead a workshop during an early childhood seminar on "Building Science into Your Themes." She is rather nervous about it, but has decided to take up the challenge. She is keen to help other teachers find out how exciting it is to have science as a part of the program. She has asked a few colleagues to help her work out what to do in the two hour workshop. One of your group can take the role of Joan, and the others her colleagues.

Primary

Sally, our primary teacher, has been talking with a colleague who avoids teaching science because she lacks confidence in it. She does not believe her students are missing out as they will catch up because of television and other grade teachers, and she compensates by her strengths in other subject areas. Sally is not convinced, and has tried to help her reconsider her views, and work out how to help her. If you were Sally, what would you suggest to the other teacher? How would the other teacher respond? Role play the discussion in your group a few times using different people.

Secondary

Julian, our secondary teacher, has been arguing in the science department that the entry science program in the secondary school should be an integrated science program based around problems the students are interested in. He suggests that there should be no text, but a number of reference books. The other teachers are not convinced that they should change from their text-based general science program. Take up the discussion at the next lunch break, with one of you taking the role of Julian.

Your Chapter Review

Which of the influences explored in this chapter do you consider impinges most on the science curriculum in your sector of schooling? Why do you think so?
Which impinges least? Why do you think so?

Further Reading

Curriculum Conceptions

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4

Influences on Science Teaching: Learning Theories

What This Chapter **Asks You** To **Do**

During this chapter you will:

- Review your own views about learning.
- Examine learning theories which historically have shaped science teaching.
- Consider in detail different aspects of cognitive and social constructivist theories, which are currently exerting considerable influence on science education.
- Explore the implications of these theories for teaching science in your sector of schooling.

Some Influential Learning Theories

Learning theories have influenced the teaching of science profoundly over the last forty years. While aspects of early theories provided useful guidelines for pedagogy, they have also generated difficulties because the views about learning held at the time were incomplete at best, and in some cases were misleading. That is not to say that what we think about learning now is "right" or complete, but we do have a more comprehensive picture about the learning process now, thanks mainly to the huge research effort that has gone into this area. I will therefore examine a few of the learning theories which hold current sway in science education, and explore their application to the classroom. The examination of these theories will be necessarily brief, so you may need to find out more about them for yourself. Nor should you assume that because you have read about them elsewhere or even here, you understand them fully. You will need to apply the ideas to both your own learning and that of others to start to appreciate the potential in them. Traditionally, behavioural learning theories dominated education, then developmental theories held considerable sway, but the more recent theories are collectively called constructivism. Constructivist theories tend to come in two groups, which I will call cognitive constructivism (derived from cognitive psychology, but frequently just called constructivism) and social constructivism. Note that the noun is "constructivism,".and the adjective is "constructivist."

Learning Project 15

Before commencing this chapter, you should recall the main points that you can recall about learning theories, so you have a place to start. Jot down what you can recall which are main ideas or principles about learning, or points about teaching which you think might be derived from learning theories. It may help if you can recall particular authors or people associated with these ideas.

In your group share ideas about learning and draw up an overall chart summarising what you know collectively.

Behavioural theories

Since these have been around for some time and are no longer considered highly relevant to science education except for students with some learning disadvantage, I will give only the briefest summary. They have their origins in operant conditioning work with animals conducted by Pavlov, and later developed by Skinner (1954). Behaviour modification programs based on Skinner's ideas have enjoyed considerable success in modifying a variety of antisocial and undesirable behaviours. The following principles apply:

- The desired behaviour is identified and stated specifically. If the behaviour to be changed is verbal calling out, the desired behaviour might be "The student will raise his hand and respond only when invited." If the goal is for some skill or cognition to be acquired, the learning goal is stated in behavioural terms. For example, "At the end of this lesson, the student will state the names of the inner planets of the solar system in sequence from the sun."

- An intermediate, achievable goal is set which can be readily measured. For the calling out behaviour, this might begin simply as going for five minutes without calling out.

- A suitable teaching and/or observation period is begun, with record keeping as needed. The above intermediate goal would need to be timed and checked off as achieved. A series of such goals would need to be achieved to reach the final desired behaviour.

- An appropriate reward system for each intermediate goal achieved would be introduced to reinforce the desired behaviour. This can range from simple immediate treats like lollies, tokens which can be accumulated and traded later for privilege, or marks on a test. Since the intermediate goals are always achievable, the marks would consistently be high, providing a sense of satisfaction in the achievement.

These ideas have been highly successful in their application to some areas of schooling, such as reading and mathematics, but were applied to science education mainly through the efforts of Gagné. He laid out some general procedures for teaching skills, concepts, and principles (Gagné, 1977), and was influential in the development of the primary curriculum program *Science - A Process Approach* (SAPA) in the 1960s, in the United States. This program was the first systematic attempt to teach the (so called) thinking skills, or process skills, supposedly engaged in by scientists, such as observation, inferring, predicting, controlling variables, and so on. You might recall that this fits the cognitive processes curriculum conception described in Chapter **3**. While recent thinking suggests that process skills cannot be taught independently as assumed, are not necessarily "science processes," and cannot be separated from conceptual learning, there remain some useful principles from this early work. These are best exemplified by the *Teacher Lecture* teaching strategy outlined in Chapter 7, and specific teaching of selected processes like controlling variables.

Learning Project 16

From your own learning or teaching experience, have you witnessed or used any teaching strategies or approaches based on behavioural theories? If so, describe them briefly. Were they effective?

You may need to find out more about behavioural theories if you have not come across these ideas before. Take time now to do so.

In your group discuss the relative merits and disadvantages of teaching based on behavioural theories.

Developmental theories

In most books about learning you will find theories of intellectual development, which usually have a stage structure. The most prominent of these are the theories proposed by Piaget and Kohlberg (McInerney & McInerney, 1994). I will not discuss these since they are well known, have had serious questions raised about their validity, and no longer hold much influence in science education apart from their rich legacy. Aspects of Piagetian ideas which are still considered relevant will be examined in the cognitive constructivism section below.

Current Theories

Over the last decade, constructivist theories have influenced most the teaching of science. They fall into two broad groups, cognitive constructivism, and social constructivism.

Cognitive constructivism

Cognitive constructivism has its origins in some early progressive educationists, but the recent upsurge of interest in cognitive constructivism in science education began largely as a result of the search by educational researchers for an explanation of why students develop misconceptions in science (see Chapter 2). They drew on the work of Piaget (e.g. Piaget, 1978) and cognitive psychologists to find theories which would not only explain what was happening in students' learning in classrooms, but which would also provide pointers to suitable teaching strategies and approaches. The work by Osbome and Freyberg (1985) is a landmark example.

The basic tenets of constructivism are that people's past experiences, including feelings, are organised into related ideas called schemes (sometimes the singular and plural latin words, *schema,* and *schemata,* are used). These schemes are used to interpret and make sense of new experiences. Schemes are also visualised as being related and linked in complex ways, so that recalling one scheme from memory to interpret a new experience may invoke memories of other related schemes. **As** new experiences are encountered which do not fit the existing schemes, changes are made to fit the new information by either modifying some schemes, or creating new ones. Hence learners are perceived as actively constructing meaning for themselves for all experiences. You may find some books use the analogy of a filing cabinet with lots of files and "see also" cross references. While this may be helpful, it is a very limited analogy and can create problems for you by giving the impression that schemes are bounded and fairly well fixed. Those of you familiar with Piaget will find in the above description, notions he has labelled *cognitive structure*, *assimilation,* and *accommodation.* You will also recognise what psychologists call *perception.*

Misconceptions can be readily explained using such theories. Differences in people's past experiences will result in every student having a different set of schemes, though there would also be many similarities if they are from similar physical and social environments. New experiences can therefore be interpreted by students in different ways. Schemes may also be modified in unexpected ways (from the teacher's viewpoint), and new schemes which have few links to the student's "real world" experiences may be constructed by students for school contexts.

Within this basic umbrella which I have called cognitive constructivism, there are many theories which emphasise different aspects of the learning process, or take a slightly different view of it. For example, considerable contributions have been made by Piagetian thought, as well as by those who compare learning to the operation of computers, such as information processing theories and artificial intelligence. I will give a brief outline of only two theories. This will allow you to read further as you need to, depending on what you already know of constructivist theories. Note, however, that unless you have a good grasp of constructivist ideas of learning, much of the material in this book will not make **a** lot of sense to you.

Piaget

Much of the focus of attention by educators on Piaget's work seems to have been misplaced, since most emphasis has been put on describing his ideas of cognitive development: the so-called stages; whereas I believe that his ideas about how we acquire knowledge are more useful. The following description focuses on this aspect instead of stage development. *An* idea central to Piaget's ideas is that of equilibrium (Piaget, 1978). Piaget used the word to describe a mental state of balance, where there is nothing puzzling or worrying the learner. Try to imagine such an hypothetical state as a starting point. Imagine how the learner may now go through some experience, where he/she encounters something new, or something in a new way. This could be a new object, ox event, or an idea. He/he immediately sorts through his/her memory in an attempt to find some previous experience or experiences which will help him/her interpret the new encounter. This attempt to fit new information into old, Piaget called assimilation. The result of. assimilation is either a match, where the new and old information seem to fit; or mismatch, where there is an obvious discrepancy. If a match occurs, then the old experience/s are confirmed by the new, and no new learning has occurred. If there is an incomplete fit between the new information and the old, the new information cannot be incorporated into the old. This state, Piaget called disequilibrium. This refers to a state of imbalance or inconsistency between what the learner knows, and new information. **A** person in a state of disequilibrium is usually puzzled, concerned and curious. There is often strong motivation to resolve the problem. This motivation results in actions which attempt to reduce or remove the state of disequilibrium. If the problem appears very difficult, the learner may opt out of the learning situation, perhaps temporarily, but almost always with feelings of failure. The other alternative is for the learner is to modify the old information, or cognitive structure, so that the new information now fits. This process of change or modification of the cognitive structure, Piaget called accommodation. The result of accommodation is a better or more complete fit of the new experience with the old ideas forming the cognitive structure. In Piagetian terms, a learning adaptation has occurred, and the learner is again in the hypothetical state of equilibrium.

Piaget also warned of a process which he called *false* accommodation. In this instance the learner would acquire a verbal "answer" to explain the incomplete fit. This would satisfy the learner's state of uneasiness, but would not result in actual ideas being reorganised. Piaget did not consider this real learning as it would be simply a response to authority or to circumstances, and would not involve changed ideas.

A crucial facet of Piaget's idea is that it is the learner who learns. Learning does not necessarily occur because the teacher teaches. Piaget also believed that learning is enhanced when the learner has control and choice over what to learn. This does not imply, however, that the teacher has no role in the learning process. To the contrary, in commenting on Piaget's ideas, Duckworth (1964) said that teaching involved getting students to explore, manipulate both things and symbols, ask questions and seek answers to those questions, and compare findings with those reached by other students, and with earlier conclusions.

Generative learning

Osborne and Wittrock's (1983) generative learning theory builds further on the idea that it is the learner who learns, but provides some other pointers for the teaching process. The theory suggests that the ideas already in our heads determine the way we understand and perceive things around us. Consider yourself. You have come to this task with particular ideas in your head. An event is happening: you are looking at this book. Other events may be happening around you, but you are deliberately attending to the sensory input reaching your eyes. You have probably not even noticed the sounds around you, such as a TV, a conversation, or birds twittering. You have selectively tuned those events out, and are attending to the book in front of you. You are doing this because of some of the ideas (and associated feelings) that you came to this task with. Presumably part of those ideas and feelings would be a determination to complete this section of the book. Other parts would relate to what you believe about learning, your desire to improve your teaching and so on. In this sense, then, your ideas act as a filter for all incoming sensory input.

Now that you have selected to attend to this book, you brain is receiving the sensory input generated from light entering your eye. The light, and the resultant nerve impulses travelling from your eye, have to be interpreted by your brain before you can make sense of them. Imagine a new immigrant who cannot read English attempting to make sense of this page: his/her eyes would receive the same sensory input as your eyes, but he/she would not be able to make sense of it. The nerve impulses firstly go to the visual word recognition processing centre in your brain. As a word is recognised, you make links to various parts of your memory which allow you to interpret the word and make sense of it. You will link with, and use, those memories which seem to you the most relevant to the expectations you have about what you are reading. This is determined in part what you bring to the task, and in part by the context of the word. Perhaps you will use a memory which I would not have expected or intended, and will interpret my message in a different way from what I intended. You may use your selected memories to interpret the sensory input so that you can make sense of it. That is, you construct meaning from the sensory input using the memories you select. Note that much of what we have so far described is not necessarily a conscious process, nor does it take any noticeable time to occur.

Your meaning constructed from the sensory input is now evaluated to see how pertinent that meaning is. You weigh it up against other memories for consistency, and against other sensory inputs for coherence. If you find the constructed meaning seems to fit, then you may take some subsequent physical or mental action. If there seems to be a misfit, you will decide on the seriousness of the misfit, and either ignore it, search for another meaning which you can construct, or attempt by some action to obtain other sensory inputs which may enable you to resolve the discrepancy. A simple example of the latter point would be to consult the meaning of a word in a dictionary.

One possible action resulting from this evaluation would be to commit the experience and constructed meaning to memory. There are three ways that this information could be fitted into your memory:

- This new experience and constructed meaning may be added to your memory store, and exist alongside other relevant, even competing meanings. You may or may not be aware at this stage that the two ideas are competing, or inconsistent. If you are aware of the inconsistency, then you may tentatively accept the idea as one to be considered without really finding it useful. There may be very good reasons for doing this, such as the pragmatic one of needing to remember the information for a test.

- The new experience and constructed meaning could also be put into memory by incorporating it into a part of an old idea which is now expanded or even reorganised. The reorganisation may be fairly minor, or may be quite a major task. This may involve seeking further sensory inputs which may help the new reorganised idea fit together.

- The new experience and constructed meaning may also be put into memory by relating it to earlier (remembered) experiences and allowing these to be reinterpreted in a more meaningful way.

The final consideration in the generative learning theory suggests why a newly acquired idea may not be used by students in later discussions or tests. Osborne and Wittrock suggested that the learner subconsciously puts some status onto the newly constructed idea. The new construction may exist side by side with old ideas and will often have little status compared to those ideas. The status of an idea will determine which is used to interpret new experiences. The status of an idea may also change over time — one view may increase in status, while another decreases. If you have ever studied for an examination, and in doing so managed to understand and remember a new idea, that idea would have been given high status in the period leading up to the examination. However, once the examination was over, unless the idea were continually being used, it would decrease in status. Within a few short months much of it would be forgotten.

Learning Project 17

Jot down the similarities between these two constructivist theories, but also note the differences.

Think of a recent occasion when you learnt something new. To what extent does the experience line up with either or both of these theories?

From your knowledge or reading of other constructivist theories, such as information processing, what other perspectives could be added?

In your group share what you think are the main points about cognitive constructivism, and build a group summary. How does this apply to learning in science? How does it explain some of the problems identified in Chapter 2? How might these ideas influence the way we teach science?

Implications of cognitive constructivism for science teaching

The following are some of the implications for science teaching which emerge from cognitive constructivism:

- The teacher needs to find out the preconceptions about the topic which students bring to the classroom.
- The lessons should be built on what the students already know.
- Activities and experiences which provide unexpected outcomes or which confront misconceptions, such as discrepant events, are useful stimuli to motivate students to restructure their ideas.
- Students are more motivated to restructure their ideas if they have some ownership of the task.
- Active involvement in science experiences is an important. component of exploring ideas.
- Discussion among peers can assist students in thinking ideas through.
- The teacher needs to find out what aspects of the experiences the students are focusing on, and what sense they are making of it.

These theories have spawned a number of teaching strategies and teaching approaches, some of which are discussed in Chapter 7.

Social constructivism

There has been an increasing awareness among constructivist theorists over the last few years, of the importance of the social context in science learning. While theorists such as Piaget and Osborne and Wittrock acknowledged that social contexts may influence the process of cognitive restructuring, there has been a growing feeling that the social context plays a greater role than at first anticipated. At the same time, some theories about language development, in particular, have given full recognition of the crucial and moulding role that social contexts have. An emerging field in psychology, situated cognition, has also been gaining attention. These theories all put much greater emphasis on the social context of learning and downplay the emphasis on the individual.

Most of these theories have emerged from the ideas of Vygotsky (1978). There are several key ideas emerging from his work worth noting:

- Students' cognitive development is mediated by the social and cultural context. To Vygotsky, the student is immersed in its sociocultural context, and cognitive development cannot be separated from it — the student's cognitive development takes place in this context, and the context becomes part of his/her cognitive development. Put simply, we are a product of our culture. Hence in social constructivism there is emphasis on social development within a social context, including the school social context, instead of on developing cognitive schemes and structures.

- The process of cognitive development occurs through social interaction with adults, teachers, and peers and the use of language. Cultural tools are used to facilitate this. Tools characteristic of our western culture might be books, computers, or any other artifact of our culture.
- Different cultures may have different tools, languages and customs which influence and direct cognitive development.
- Learning can be facilitated by an adult or capable peer who provides experiences just beyond the student's current capability, and helps him/her work toward achieving a new level of performance. Such help can slowly be withdrawn until the student can manage without assistance. Vygotsky called this operating within the *zone of proximal development*. The process of providing structured assistance has been called *scaffolding*. Scaffolding can occur in social structuring and/or in language forms.
- Units of study should be meaningful, rather than subdivided into small components (perhaps a reaction against behaviourism).
- Students make sense of new school concepts using everyday ideas, but the school concepts should also inform their everyday ideas.

Implications **of** social constructivism **for** science teaching

- Choose meaningful units of work, such as topics.
- Structure the unit and lessons carefully, so the unit and lesson structures provide part of a scaffold.
- Slowly withdraw the structural (or language-based) scaffold until the students can operate without the support.
- Find out the students' current ideas, and plan each new component so that it is just beyond the students' capability.
- Plan for and encourage meaningful peer discussion.
- Build in appropriate engagement with the teacher and other adults, providing verbal scaffolding as needed.
- Recognise the influence of culture on cognitive development for students from other cultures in the class.

A number of teaching strategies and approaches have been developed based on these ideas, especially in language teaching. Some of these principles are now being applied to science teaching.

Learning Project 18

Compare and contrast cognitive constructivism and social constructivism. What similarities are there? What different emphases are there?

Are there any similarities between the constructivist theories and behavioural theory?

Many authors have portrayed these theories as an "either or" case, but some, like Paul Cobb (1994), have argued that they are different angles, or views of the same process, and can be equally useful. To what extent do you agree that they are independent, or merely different views?

In your group share you opinions about this last point. Justify your conclusions to each other.

Other learning theories

I do not want to give the impression that these learning theories are the only ones which inform science teaching. However, other theories have not assumed the significance that these have, and also tend to be more generic in their appeal. Particular theories which you might pursue if they are new to you are metacognitive theories (fox example, Baird & Northfield, 1992; White & Gunstone, 1989) and social cognitive theory (for example, Bandura & Walters, 1963), which is relevant to small group work and cooperative learning.

Putting It Together: A Model of Conceptual Development

For many years, I have been working on simple ways to portray the essential elements of the prevailing learning theories, to provide useful guidance for teaching science. This began with a largely cognitive constructivist learning model (Appleton, 1989) and has developed into efforts to somehow bring together important elements of the cognitive and social constructivist viewpoints. My latest attempt which focuses on cognitive development follows in Figure 4.1. You should recognise many elements of the preceding discussions.

Existing ideas

A learner approaching a learning task brings with him/her all previous experiences organised in the mind as sets of ideas, organised as schemes (cognitive structure). The schemes are developed through a combination of experience with the natural environment, language, and social interaction. They are shaped by the culture in which the learner lives. Specific schemes are developed for the school culture and classrooms. The schemes may include misconceptions, and some school schemes may be separate from everyday schemes.

Implications for teaching. The teacher needs to identify the learners' ideas about the science topic. This can be done by individual or group interviews, concept maps, surveys, discussion in small or large groups, or writing in structured genres or in unstructured forms like journals. This information can serve as a basis for planning the curriculum.

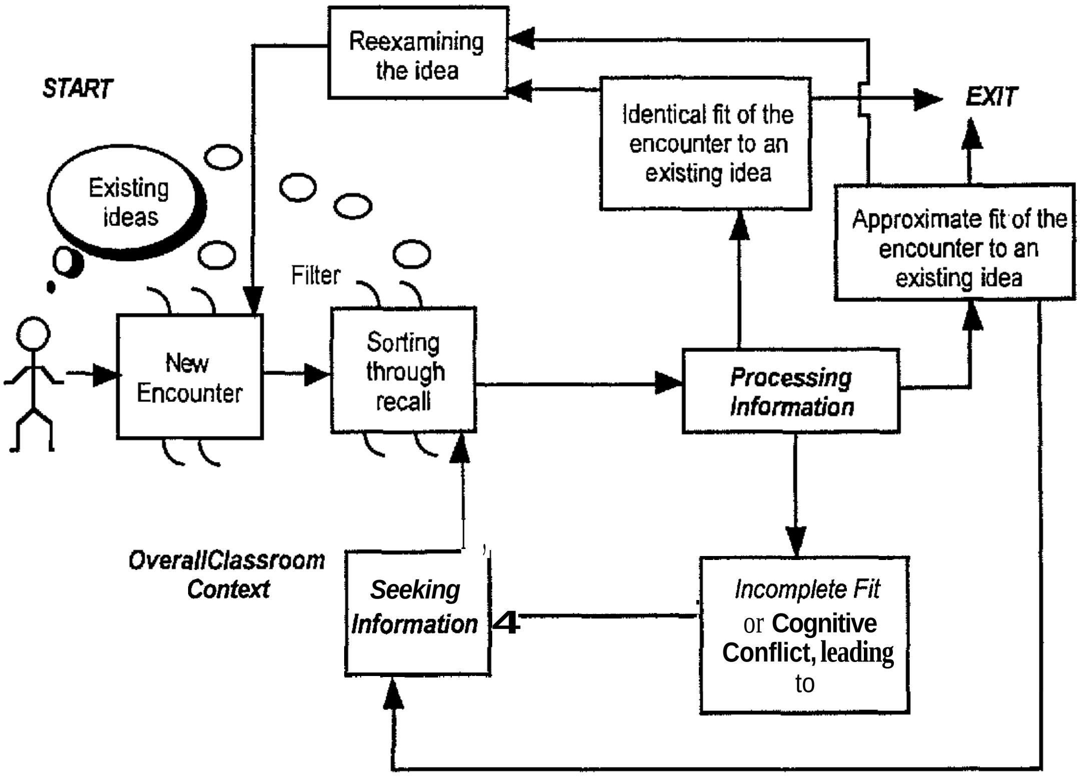

Figure 4.1 A model for conceptual development in science

New encounter

The encounter occurs in a school context, embedded within a teaching approach selected by the teacher. Depending on the teaching approach, the learner may be directly involved with the encounter individually or in small groups, or indirectly in the whole class. The learner attends to it because of social expectations within that context.

Implications for teaching. The new encounter is selected, where possible, to provide a challenge or contrast to the students' ideas, particularly if misconceptions were identified. It should be motivating, interesting, provide a link to past experiences, ideally allow first-hand exploration, and at the same time lead to an incomplete fit for most, if not all, students. It forms a part of a carefully selected sequence of experiences which are designed as a scaffold to guide the student toward the goals determined by the teacher.

Sorting through recall

Particular aspects of the encounter may be noted by the learner, and others missed. The learner makes sense of the encounter by drawing on past experiences and any related explanations which seem to the learner to be relevant. This involves a search through schemes for one which seems to fit the circumstances best. The learner takes cues from the context of the encounter, such as unit and lesson structures and teacher comments, to aid in this search.

Implications for teaching. The teacher needs to be conscious of the cues provided within the unit and lesson, and indicate any which might be confusing. Students less adept at noticing such cues may be helped if the teacher explicitly highlights them. Similarly, if there are key aspects of the encounter which the teacher considers important, these could be highlighted. The teacher uses a technique during the lesson to find out what schemes the students are using to explain the encounter, to discover possible false trails they may be following. This would usually involve students talking about the encounter and their explanations, either in small groups or whole class discussions.

Filter

When a new object or event is encountered, the learner may select to attend to particular aspects of the object or event and to ignore others. This selection may be by chance, by what is spectacular and attention-getting, or by the learner's expectations of the lesson. Learners experiencing some emotional upset may miss most of the encounter because they are unable to attend to it fully. Learners in early puberty may be distracted by members of the other sex, so they attend more to them than the encounter. The classroom context of the learning experience (Claxton, 1990) influences which ideas of the learner's cognitive structure are used to interpret the experience, both in terms of which sensory input to attend to, and which memories are activated in order to construct meaning for the experience (Osborne & Wittrock, 1983). The social setting of the classroom makes those schemes associated with that setting most likely to be called upon first, so everyday schemes may not be used.

Implications **for** teaching. The student's expectations of the lesson can be better aligned with those of the teacher's if a brief statement of the lesson goals and an overview is provided (Ausubel, 1968). Ownership of the task by the student also raises the student's expectations of the lesson. The teacher should be conscious of the social setting of the lesson, both in terms of the teaching strategies being used, and the emotional undercurrents among the students. Sensitivity to the former may provide a more productive working climate. For example, a highly authoritarian strategy used with a group of teenaged rebellious males is certain to trigger rebellion and take attention from the task. Awareness of the latter would allow compensatory action to be taken if there were problems. The teacher may also encourage comparisons to everyday events to provide better cross-links to students' everyday schemes.

Processing information

This may occur at two levels. In Surface Processing (Biggs & Moore, 1993) there is a focus on words, concrete aspects of the encounter, and rote learning. It involves a minimum of mental processing of the available information into the cognitive structure. Deep Processing involves trying to reach understanding and make sense of the encounter by relating it to remembered schemes, using thought experiments, or generating analogies. It takes considerable effort to ensure understanding is complete and to restructure old ideas to incorporate some new ones. Bereiter and Scardamalia (1993) compare two approaches to learning, a “Best-Fit” strategy and Progressive Problem Solving. In the former, the learner tries to fit the new encounter into existing ideas and rules, and chooses a “best-fit” scheme to operate with, even if the degree of fit is not particularly good (see also Approximate Fit below). This seems to involve selecting those aspects of both the encounter and the scheme which have similarities, and focusing only on them. By comparison, Progressive Problem Solving is a deliberate attempt to note differences and resolve them, constructing a new scheme if necessary. They closely link this to creativity. Bereiter and Scardamalia’s approaches to learning have many similar characteristics to the distinctions between surface and deep processing.

Which level of processing occurs depends on both the learner and the context. Learners who lack the cognitive skills to engage in deep processing must use surface processing. If the learner has the cognitive skills to engage in deep processing, then he/she may choose the level most appropriate to the circumstances and his/her expectations of the lesson. For example, if the expectations are that the lesson is important in a test involving mainly recall, then surface processing will probably be used. Processing will also be influenced by the social context, the teaching strategy, and the learner’s emotional state. If the learner has experienced repeated failure in science, then it would not be considered worth the effort to engage in deep processing. If the teacher’s questioning involves a rapid series of recall questions, the learner will be effectively prevented from engaging in deep processing. Sometimes both surface and deep processing may occur together, where aspects of the encounter are deep processed, and other aspects are surface processed.

Implications for teaching. If the teacher’s purpose is for the students to engage in deep processing, then suitable teaching approaches, strategies, routines and techniques (see Chapter 7) need to be chosen both to allow this to happen, and to facilitate it. This is just as crucial at a day care centre as it is in a senior high school class. However, the teacher also needs to be sensitive to those occasions when surface processing is the most appropriate method of engagement with the encounter. The teacher needs to be sensitive to those students who resort to surface processing as a survival technique, hoping to deep process the material at a later date. This is often a strategy employed by students whose first language is not english. If the lesson progresses too fast, some students may not be able to sustain the level of deep processing, and get left behind. The only course of action left to them is to use surface processing. Strategies and techniques for enhancing deep processing include asking divergent questions, using long wait times (1 and 2), small group discussion, judging conclusions on the basis of the evidence and consensus, and employing tasks with student ownership.

Degree **of** fit

If the past experiences and related explanations drawn from memory seem to satisfy all noticed characteristics of the new encounter, then there is an identical fit. The recalled memories increase in status so that previous learnings are reinforced. **As** far as the learner is concerned, the lesson is finished (Exit). This is not a problem if the reinforced learnings conform to the scientific explanation. However, if the learner has not noticed some key aspects of the encounter, inappropriate sets of experiences and explanations may be used to interpret it,,compared to those which may have been used had those key aspects been noticed. The learner would therefore leave the learning experience with an inappropriate explanation for the encounter, resulting in a wrong explanation being reinforced.

Another problem can arise if the learner selects from memory an explanation which superficially explains the object or event, without checking for inconsistencies. That is, a vague answer is accepted as adequate. This results in an approximate fit, where near enough is considered good enough. **As** far as many learners would be concerned, the lesson would be finished (Exit). In this case, a wrong idea could again be reinforced, or at least, the learner would have no real understanding of the explanation for the encounter. Some learners would, however, recognise that the answer was vague, and take further action to determine its validity or to seek further information. Bereiter and Scardamalia (1993) suggest that this strategy is useful in many contexts, particularly routine ones. However, it is not helpful in developing new knowledge and expertise.

If the learner recognises the inadequacy of his/her memories to explain the encounter, he/she has reached an incomplete fit, and is in a state of cognitive conflict (Piaget, 1978). **A** learner in a state of cognitive conflict experiences some degree of frustration or dissonance (Festinger, 1957), the motivational force which drives a learner to seek a solution to the learning situation. However, if the level of frustration is too high, or if the effort to resolve the issue is not considered by the learner to be worthwhile, then the learner may elect to opt out (not portrayed in Figure **4.1**).

Implications for teaching. The teacher ascertains the degree of fit that the learners are moving towards. This is best done by listening to their discourse while they are working, particularly in small groups. Concept maps or other written comments could also be used, but written short answer quizzes can be unreliable, particularly if the student's writing ability is limited. It is important that a social climate where students feel free to share their own ideas is established. Students who are afraid of public ridicule or of being wrong in public tend to be reluctant to share. If an identical fit occurs, and the student's idea seems to conform to the accepted scientific idea, then the teacher considers whether extension work is appropriate. If a misconception is detected, then the teacher considers whether to encourage the student to reexamine the idea, and if so, how to achieve this (see below). If an approximate fit occurs, the teacher decides whether to encourage the student to reexamine the idea, or to seek further information (see below). If an incomplete fit occurs, then the teacher helps the student access and make sense of appropriate information which will help resolve the problem for the student (see below).

Reexamining the idea

A learner who has effectively exited from the learning experience because of a perceived identical fit or because a vague idea is considered adequate, may be reengaged with the lesson if something occurs to cause him/her to reexamine the idea. Since the learner is constrained by the social context of the classroom and cannot get up and leave, this may happen coincidentally, or it could be a planned component of the teaching approach.

Implications for teaching. If the teacher ascertains that some students have developed misconceptions, or have become satisfied with a vague explanation, he/she can invite the students to explain their ideas. This provides opportunities for the ideas to be challenged so the students will reexamine them. Challenges may be made by the teacher (with careful wording), peers, a test of the idea using the materials, or some authority source. It may be necessary to draw the students' attention to a key aspect of the encounter which they have missed. The basis for deciding the validity of any idea should be a consensus reached by the group based on the evidence available.

Seeking information

A consequence of cognitive conflict is often information-seeking behaviour. **A** learner who has arrived at an approximate fit may also seek information to clarify the vague idea, or to test its validity. By obtaining further information, conflict is reduced as the learner again processes information, and modifies existing ideas, extends them, or constructs new ones (Osborne & Wittrock, 1983). Information may be sought from a variety of potential sources by:

- exploring the materials vicariously, such as through a teacher demonstration;
- exploring the materials directly using hands on;
- using the ideas of others who are external to the classroom, such as books, audiovisual and multimedia resources, and community experts;
- using ideas from the teacher;
- using ideas from peers, obtained one-to-one, in small groups, or in the whole class;
- waiting for the answer to be revealed, if the teacher maintains control over information flow and availability; and
- using unit, lesson, and teacher structuring cues such as the topic from previous Iessons, teacher actions, what the teacher says about the encounter, and what the teacher does not say.

Which of these information sources is used depends partly on each learner, and to a large degree on the teaching strategy used by the teacher. Some learners may not have the information accessing skills to use some sources effectively. For instance, the effective use of books depends on reading skills using a number of different reading styles, summarising skills, and so on. Similarly, not all learners may recognise teacher lesson cues and structuring — particularly those from non-western cultures. The teaching strategy, however, is the main determiner of which information sources learners may access. For example, if the teacher uses a teacher demonstration, direct access via hands on is not possible. Similarly, unless the strategy includes a period when learners may consult books and similar sources, this can only happen after the lesson. The teaching strategy also controls what is done with the information obtained — whether it is confined to one person or a small group, or shared across the whole class.

The form of the information is also pertinent. Some information is not easily understood, let alone able to be related to the task at hand, because it is too complicated, or because it is hidden in a lot of extraneous information. Some learners therefore need help in identifying and accessing relevant information. It may sometimes be necessary to "translate" complex forms to simpler ones useful to the learner. Some information sources may also be privileged in particular cultures, so there may be a preferred form for such students, and some forms may not be considered appropriate.

A further aspect of this component is the social dynamic of the classroom. Information is most useful to a learner if there is a publicly-agreed purpose for obtaining it which is not at odds with the learner's private purpose. A preschooler's private purpose may be to please the teacher, while a Year 12 student may wish to pass the next test. I, and others such as Bereiter and Scardamalia (1993), have suggested that a valid public purpose for information gathering is to arrive at an explanation which is valid in terms of the evidence (information), and which has been agreed to by the group. This means that information from all sources, including authority sources, must be considered contestable and testable. It requires specific action by the teacher to ensure that the appropriate social climate exists for such a view.

A final consideration is, again, the emotional state of the learner. If the learner is in emotional turmoil over some recent upset, he/she is unlikely to seek information, and will merely go through the motions. If the learner has experienced repeated failure in science, they are also unlikely to seek information, apart from getting it directly from a peer in predigested form, for surface processing.

Implications for teaching. In planning for the unit and each lesson, the teacher considers the availability of information sources. Since some students may access information from some sources more readily than from others, a variety of sources would preferably be made available. The suitability and complexity of the information for the age of the students would also be considered. This includes how the information may be related and applied to the task at hand, and whether help may be needed for some students in accessing and making sense of the available information. ***An*** important issue raised by Woodruff and Meyer (1995) is *when* the scientific explanation should be made available. They suggest it should be provided only when the students have already reached, by consensus, a tentative answer for themselves. The teacher therefore plans this aspect of structuring when choosing an appropriate teaching approach (see Chapter 7). If the teacher intends to provide information him/herself, providing proper verbal scaffolding for the students is planned. Of particular consideration is the size of the group with which scaffolding will occur. It is most effective for students when the group is small; attempting to scaffold with the whole class usually results in most students being left behind.

The teacher is also aware of the students who are experiencing difficulties through emotional upset or feelings of failure. They need special sympathy and assistance; perhaps even means of accessing the information at a later stage when they are better able to cope with the demands of the learning task. The teacher is also aware of any information sources or means of accessing information not acceptable to particular cultures, to avoid causing these students undue emotional conflict between cultural values and school expectations.

The information obtained through the above sources must then be processed by each student, and the whole iterative process recommenced. Many cycles may be used in a lesson, until all students finally develop a scientifically satisfactory idea, and exit with it reinforced.

Overall classroom context

The crucial role of the social and cultural aspect of the classroom in all aspects of cognitive development has been mentioned in each component discussed above. The main elements of figure 4.1 emphasise what happens with the individual, so it is crucial to keep in mind the cultural and social bounds of each individual's actions and cognitive behaviours. **A** key component of this is the cultural ethos of the sector of schooling that the teacher belongs *to* and therefore holds. For instance, many preschools retain the flawed idea from early waves of Piagetian thought, that learners only need to be engaged in play. **A** part of the primary school ethos is that the highest priority is for learners to read, write and compute, so many primary teachers believe that subjects such as science are peripheral, and spend all their time on the "three Rs." This changes dramatically in the high school, where science is now considered so important that the delivery of a large amount of content is thought to be mandatory. All these views are flawed, but hold considerable cultural influence over teachers' actions. Other cultural influences are building and room design, timetabling, and classroom management practices. Most of these school cultural views are implicit and common knowledge to both teachers and students, so are rarely questioned. Those who do are sometimes iabelled rebels or misfits.

Implications for teaching. The teacher is sensitive to the cultural background of the students, and the extent to which they may differ from his/her own background.

He/she endeavours to become familiar with the culture of those students who come from a different cultural background. The teacher is also aware of the school culture of which she/he is a part, and engages in reflective inquiry into the appropriateness of that culture, effects it has on students, and whether to make and/or initiate changes to aspects which can be changed. For example, some junior high school teachers frustrated with the constraints of teaching specific disciplines and rigid timetables have restructured their program using integrating themes or problems. The teachers work with a cohort of students across several disciplines, reducing timetable constraints.

Learning Project 19

If you found the above model helpful, make up a personal summary — your own version, not mine — of how you think students develop cognitively. If you did not find it helpful, find some other theory which is, and summarise it.

Use the cognitive development model with the implications for teaching (or your alternative if you chose one) to make up a list of teaching pointers for science for your sector of schooling.

In your group share your summaries of students' cognitive development, and try to reach a group consensus on a joint view.

Also compare lists of teaching pointers. What are common? Why are they common? Work on making a group list, and share it with other groups.

A Case for You to Work on

Select one of your group to assume the role of Joan (our early childhood teacher), Sally (our primary teacher), or Julian (our secondary teacher), who has been invited to conduct an inservice session for the school staff on using ideas from learning theories to improve teaching practice. You may refer to teaching generally, or science teaching only. If the selected person feels uncertain, select a partner to help.

Joan/Sally/Julian decides that the best way to run a workshop is to try to put into practice, or model, the ideas she/he is suggesting.

Joan/Sally/Julian should run a 30 minute session for the remainder of the group, who act as the staff, focusing on one or two aspects of learning theory. Model the ideas if at all possible. (Contd.)

After the session, discuss the workshop content and procedure, focusing on the learning theory ideas and how they were put into practice. Ensure you are constructive in your comments.

Your Chapter Review

Compare the different aspects of the learning theories and their teaching implications which you have explored, and prepare a short list of key ideas which you want to keep in mind for your own science teaching. Take the earliest opportunity to try these in practice. As you do, add to your list ways of working with the ideas in practice.

Further Reading

Learning theory overview

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Constructivism

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5

Influences on Science Teaching: How Can Science Education Reflect the Nature of Science Itself?

What This Chapter **Asks** You To **Do.**
During this chapter you will:

- State your own views about the nature of science.
- Explore some ideas about the nature of howledge, and some specific views that people hold about knowledge.
- Relate those views of knowledge to classroom practices in science.
- Consider a common or everyday view of science.
- Examine some contemporary views about the nature of science, and compare them with the everyday view.
- Arrive at a personal view about the nature of science.
- Examine specific classroom practices and make inferences about the views of science which they portray via the hidden curriculum.

Science Education and Science

You may be wondering why a consideration of the nature of science is really necessary. This is a valid question. Bruner answered it in part, when he expressed the notion that what is taught in schools should reflect the nature of the discipline (Bruner, 1963). Other parts of the answer depend on considerations such as the sector of schooling involved, helping students make career choices, preparation for future citizenship, and personal development of the student. This chapter helps you examine the nature of science, and how that relates to classroom practice.

Does science education involve teaching students in science, or teaching students about science? This is a critical issue which holds major implications for what occurs in schools, from early childhood settings to senior secondary.

If the answer is teaching students about science, then science education is really an exercise in social education, where students learn about scientific discoveries and laws, how they were made, and perhaps the people who made them. Many science programs seem to be like this, with particular emphasis on the discoveries and laws of science. Accounts of how discoveries were made, and biographies of the discoverers are often omitted because they are not considered as important as the content of the discoveries, or because there is insufficient time to deal with them in a crowded curriculum. Science education then becomes an exercise in learning content: learning about what people have discovered, and the methods they used to make discoveries.

In early childhood settings, many teachers do not see much that is relevant for young students to learn **about** science, so science is often omitted from the program. In primary schools, many teachers feel overwhelmed by the amount of science content and by the experimental methods used in science, much of which they are uncertain about themselves. So they tend to teach the parts they feel comfortable with, or avoid teaching science at all. In secondary schools, both the content and methods are considered important to learn about, and students are provided with comprehensive summaries of content in texts, and are given carefully detailed laboratory exercises to practise techniques and link to the content being read about. Teaching is frequently didactic, and laboratory experiences are highly controlled.

If science education involves teaching students **in** science: then students should learn what science **is;** they acquire an understanding of what science is — the nature of science. This would mean that students engage in science the same way that scientists would, within the limitations and capabilities of their age and experience. I am suggesting that this is more appropriate than learning about science. This chapter will help you establish a feel for the nature of science and explore what might be relevant to your sector of schooling and classrooms with which you have contact.

Where are **you** at **now?**

Your own views about what science is (not classroom science, but "real" science) influence the way you teach science in the classroom. This influence is usually subconscious and unobtrusive, but can have a major impact on the practices you engage in as a teacher of science. You will therefore need to evaluate critically your own views about science in the light of information you obtain from this chapter. A good beginning would be for you to clarify your ideas about science and about knowledge in Learning Project 20. Do not worry about being "right" or "wrong"; this is just a starting point. You may well wish to change your views as you progress through this chapter.

Learning Project 20

Jot down your answers to these questions:

- How would you define "science" (not classroom science)?
- What would you say are the essential components of science?
- What do you think "truth" in science may be?

- Would you see science as being mainly deductive or inductive? Why?
- Where would you say knowledge 'exists'?
- Can you make knowledge yourself?
- Can your students (present ones, or from a recent class)?
- Who or what is the main source of knowledge in your classroom (your present classroom, or a recent one)?

In you group decide to what extent students in your area of schooling should be taught about science? Be taught in science?

Some Ways of Looking *at* Knowledge

In order to understand science, it is helpful to explore ideas about knowledge itself, and how different people view knowledge.

Knowledge is usually considered as being organised into domains or disciplines, which are arbitrary divisions used to distinguish between different types of howledge, for example, physics, history, and so on. Each knowledge domain is thought of as consisting of a body of information, and a method for generating that information: a mode of enquiry. These different types of knowledge domains have their origins in history and western culture, are constructions of people, and are inseparable from their cultural origins. Some newer disciplines have blurred traditional boundaries, for example, biochemistry and genetic engineering. The methods of enquiry are not necessarily fixed strategies, but rather have particular characteristics and processes largely unique to the discipline.

Perry (1970) described several different views about knowledge which he discovered during his research with college students over several years. He identified a sequence of five different views about "ways of knowing" which he suggested people may progress through. It would take too long to examine his ideas in detail, but it would be profitable to compare the two extreme viewpoints which he outlined, and apply these to classroom practice.

The first view of knowledge

The world is seen as being "black and white" — either wrong or right; bad or good. Those who hold this view believe that right answers exist for everything, and that these answers are Absolute. Those in Authority are perceived as knowing these answers, and that their role is to teach them to others. Knowledge and goodness are seen as building up "rightness" bit by bit as a result of hard work and obedience (Allen, 1981).

Teachers having this view would feel very strongly that they should know all that is to be taught and that it is their job to pass the appropriate knowledge on to the students. The teacher would be the authoritative source of all knowledge in the classroom, and would structure learning experiences so that students may most effectively learn what was required. If teachers did not know the information to be taught, they would avoid teaching that topic, or at the most, would call upon some other authorities to teach it, such as books or television. Such teachers would ensure that all students unequivocally knew what the right answer was, and would assess to gauge whether students had acquired the desired knowledge. A problem may arise when teaching science, for some teachers also believe that they should not tell the students the answer, but that they should discover it for themselves. Teachers in this situation would tend to provide the students with activities which they would hope would provide the desired answer. If the students did not discover the answer, then there was justification for the teacher to tell them.

Students with this view would expect the teacher to provide the right answers unambiguously. Students desirous of being successful at school would work hard at learning the right answers, and would expect success to be linked to the amount of work. The teacher is seen as the ultimate authoritative source of knowledge in the classroom.

An alternative view of knowledge

Knowledge and values (including those of Authority) are seen as contextual and relativistic (Allen, 1981). An answer may be right in one context, but wrong in another, and answers may have degrees of "rightness;" that is, there can be shades of grey rather than black/white only. The answer considered right may even have some not-right characteristics. Frequently, the choice of one answer over another depends on commitment to a particular view or belief system. The choice of right answer is thus a reasoned, justified choice from alternatives.

Teachers having this point of view would ensure that students were exposed to at least some of the alternative answers available, and would encourage the students to compare and discuss them. Such teachers would see the student as the creator of knowledge in the classroom, where each could draw upon many sources of information, including the teacher. They would avoid making definitive right/wrong statements, and would often qualify such a statement, if forced to give one. They would try to assess whether students had considered the alternatives available, and had reached a reasoned conclusion (which may be different from the teacher's).

Students with this view would expect the teacher to present different views, and to explore the advantages and disadvantages of different views. They would be more concerned with arguing or reasoning through a particular view than with learning another's "right" answer.

Perry's intervening points of view are (Allen, 1981):

Position 2: The student notices that those in Authority sometimes differ in their opinions, and may sometimes show uncertainty. This is interpreted as exercises set by Authority so the students can arrive at "The Answer" themselves, or perhaps as confusion between poorly qualified Authorities.

Position **3:** The student acknowledges that uncertainty and differences in opinion exist, but only because "The Answer" has not yet been found. Grading of students is seen to be related to their expressing these differences, but the standards used by Authorities in making judgements remain unclear.

Position **4:** The student acknowledges the legitimate existence of uncertainty and diversity of opinion, and considers this an important aspect of knowing, where everybody can have their own opinion; though this sits uncomfortably against the perceived "right-wrong" knowledge of those in Authority. Alternatively, uncertainty and diversity are seen by the student as results of relativistic thinking and as arising from differing contexts, but these are taken as particular instances of what those in Authority want.

Mismatches in ideas about knowledge

Difficulties can occur if a student with the first view of knowledge encounters a teacher with the second view. The student quickly becomes frustrated and angry because the teacher is not forthcoming with the desired "right" answers. The teacher is seen as a poor teacher because she/he is apparently not privy to the "right" answers held by Authority. In assessment, when the teacher asks for reasons and arguments from the student rather than regurgitation, the student cannot understand what is required, for the teacher has not even provided the right answer, let alone the reasons or arguments.

Different sorts of difficulties occur if the student holds the second view of knowledge and the teacher holds the first. The student is able to work within the teacher's framework of right/wrong answers, but quickly becomes bored and disenchanted. The teacher in turn is annoyed by the student who constantly asks questions and appears to challenge the authority of answers.

You may find it helpful to pause at this stage and complete Learning Project 21.

Learning Project 21

Which of Perry's views of knowledge would you say you hold yourself?

In what ways does that come across in your teaching?
For the sector of schooling in which you are interested, does it make any difference?

Some Ways of Looking at Science

Such views of knowledge overlay views of what science is. I will now describe two views of what science is, which I call "A Common View of Science" and "A Contemporary View of Science." The former seems similar to aspects of Perry's first view of knowledge, and the latter is more compatible with Perry's final (fifth) view of knowledge.

People's views of what science is have changed over the years, so it is not surprising that we find several views. Nor should it be surprising that people's attempts to rationalise and philosophise about a human activity such as science have brought about some rather different ideas.

A common view of science[2]

There is a view of what science is which is quite common in the community. This is the picture of science that is often portrayed on television and is revealed in everyday conversations. This view would include some typical everyday notions such as:

- Science is a collection of laws and principles of nature that scientists have discovered by using complex equipment and a systematic, objective, scientific approach.
- The essential components of science are the laws of nature, the scientific methods used to discover them, and the scientific information published about those laws.
- Truth in science is anything that has been proved scientifically — scientific information.
- Science is mainly inductive because the scientist makes lots of observations and discovers the laws of nature from relationships induced from the observations.

This view of science seems to have several main characteristics:

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[2]The views in this and the next few sections draw considerably on the work of Kuhn (1962) and Popper (1965) and the debate which their works have generated.

- There are laws of nature "out there" waiting to be discovered.
- This discovering is done by scientists because they have some unique, infallible way of discovering these laws.
- Scientists usually use complex equipment.
- Once these laws of nature have been discovered, they have been proved true, and become authoritative knowledge.
- Science is mainly inductive.

Learning Project 22

Think of some recent television programs on science or with some science interest that you have seen. Alternatively, plan to view some this week. Which view of science do they tend to portray?

Do the same with a science book written for the sector of schooling in which you are interested. You should not need to read the whole book if it is lengthy - just skim read, and select a few parts to look at closely. What view of science is portrayed?

In your group talk about your answers to these questions. How prevalent does this view of science seem to be?

What this view of science means for teaching

In terms of modem thinking, this view of science is at least eighty years out of date, but many classroom practices continue to portray this view of science, rather than a more contemporary one. Teaching based on this out-dated view means that science education consists largely of transmitting the laws and facts of science to the students:

- either directly, by the teacher or a textbook telling, with laboratory work providing examples of the laws and facts (so all experiments "work).This is common in the secondary school;
- or indirectly, by "guided discovery," where an activity is expected to "tell" the students (so the experiments must "work" for the telling to be effective). If the activity does not tell the students, then the teacher must tell them, by playing word games so that they "arrive" at the desired answer. Sometimes the teacher chooses not to tell the answer, in the belief that if the students could not obtain it from the activity, they were not "ready," and will learn it

at some later time. Both forms of "guided discovery" are common in primary and early childhood settings.

In contrast, a brief outline of a contemporary view follows. You should note some similarities with the learning theories suggested in Chapter **4.**

A Contemporary View of Science

Science is a human activity whereby people attempt to describe, and devise explanatory models for, their surroundings. The descriptions and explanatory models are the theories, laws and principles of science: the products of science. The methods scientists use to gather information and test models are the "methods of science" such as controlling variables and experimenting. The essential components of science are the people who conduct it, the community of scientists to which they belong, aspects of their surroundings they choose to examine, the theoretical constructs they hold about phenomena, the mental constructions they devise to explain or describe their surroundings, and the techniques they select to validate their explanations and descriptions.

Truth in science can therefore be one of three things:

1. That which is observed repeatedly under identical conditions. For example, if an object is held one metre above the ground and released, it falls. Repeat this as many times as you like, under the same conditions, and the same thing happens. "Truth" in this instance is that objects held above the ground will fall if released. It may also be necessary to state the conditions which apply for this to be true. Note that this "truth" did not refer to gravity. Gravity is an explanatory model which explains why the object falls, and describes the relationship between the force which causes it to fall, the mass of the objects interacting, and the distance between them.

2. Definitions and conventions that a group **of** people agree on. For example, people have agreed that pure water boils at 100° Celsius (at normal atmospheric pressure). Therefore it is true that pure water at normal atmospheric pressure boils at 100° C, because people have defined it so, and that definition has been widely accepted in the community. Similarly, it is true that pure water at normal atmospheric pressure also boils at 212"**F,** because people have defined the Fahrenheit scale so.

3. **A** theory that a group of people agree is the best explanatory model available for a particular context. For example, people have agreed upon a common understanding why a laser, such as found in a CD player, produces a beam of coherent light. They use a model or theory which considers light to be propagated as waves generated from within excited atoms. **A** completely satisfactory explanation of this phenomenon would draw upon many theories, each considered to be true. However, the context in which they are considered true is usually carefully defined, and there may be

> contexts where they are considered not true, or incomplete. For instance, if light is considered as a means of propulsion for a spacecraft, as in a solar sail, it is best thought of as a stream of tiny particles. Furthermore, a theory considered true now may be considered untrue or incomplete at some time in the future. Newton's laws of motion were considered true for many years, until Einstein's theory of relativity suggested they were inadequate for some contexts. Yet for contexts where Newton's laws are valid, they are still used extensively.

Theories cannot be proved true. Specific events can be predicted from a theory and checked to see if they come about. If the events are observed as predicted, then the theory has greater explanatory power. It still has not been proved true, as some other predicted event not yet checked could turn out different from the prediction (Cleminson, 1990). If the events are not observed as predicted, then the theory has been demonstrated to be false for those events. The theory itself may be inadequate, assumptions it is based on could be invalid, or the test used to check the event could be inappropriate. Since any or all of these could be the reason for the predicted event not being observed, the theory cannot be considered to be proved false either, since it is not possible to ascertain whether the problem lay with the theory, underlying assumptions, or the test. Only with further experimenting to establish the validity of the test and the underlying assumptions may the hypothesis be finally rejected.

Scientists have devised ways of investigating phenomena to reduce personal bias, make it possible for the investigation to be replicated, and to ensure that what is purported to be investigated **is** what is actually being investigated. The general principles relied upon include the need to control variables systematically, to describe conditions and assumptions carefully, and to replicate outcomes before they are accepted as valid, and reported.

Science is both inductive and deductive, with deduction playing a major role. This is because observations are largely theory driven. **A** scientist usually looks for particular observations because theory suggests they will occur **— a** deductive process. Sometimes an "accident" will happen, where a scientist notices something unexpected has occurred, perhaps an observation not predicted by theory. **A** classic example of this from history would be Rontgehn's discovery of an exposed photographic plate (the precursor of photographic film) in a drawer, which he knew should be unexposed. With the plate in the drawer had been some radium, so he reasoned that something to do with the radium had caused the plate to become exposed, just as if light had fallen on it. Pursuit of an answer to this accident led to investigations of radiation and radioactivity, and pointed the way to what we now understand about these phenomena.

This view of science has several main characteristics:

- Scientific knowledge is a mental construction of human minds (Robottom, 1992). Cognitive psychology provides insights into how this process works (see Chapter 4), and why theories are sometimes not rejected, even in the face of overwhelming contradictory evidence.

- Scientists have an understanding of only a limited part of all scientific knowledge. To pool and preserve what they know, they communicate information about their part of knowledge in a variety of media, usually books and journals. Other scientists can access this information, reach their own understanding of it, and replicate the work if desired. The original communication needs to be recognised as valid and reliable, so journals tend to use stylised formats to facilitate communication of theories, tests, and observations.

- Tests scientists use for a prediction or exploring an idea are the best they can devise for a particular context. If the test is unsatisfactory, a better one is sought. If some observations cannot be made, new instruments which will enable the observations to be made are created, within the bounds of available technology. Much scientific endeavour today is occurring in fields where specialised equipment is necessary to make observations or to control a test.

- Theories which have considerable explanatory power and which have withstood extensive testing may eventually become considered to be “laws of nature.” This, together with their wide acceptability in the scientific community give such theories an authority: the authority stems from high reliability and acceptance from recognised experts in the field.

What this view of science means for teaching

Based on this view of science, science education is helping students:

- build their own explanations of our world (as closely aligned with the accepted views of scientists as is possible for those students),

- learn conventional terms used in science as needed, and

- become skilled in procedures for building and reviewing explanations.

Learning Project 23

To what extent is this contemporary view of science consistent with your views about science?

In your group decide to what extent you think the contemporary view is reasonable and acceptable.

The **Components of Science**

Another way of putting these ideas together is to analyse in turn the various components of the scientific enterprise. Science can be seen as consisting of several parts. The most visible of these are the products, the accumulated knowledge presented in boolcs and other media, but there are other equally important components to be considered. These components are all interrelated, but are separated in the discussion below for convenience. Figure 5.1 presents an overview of this.

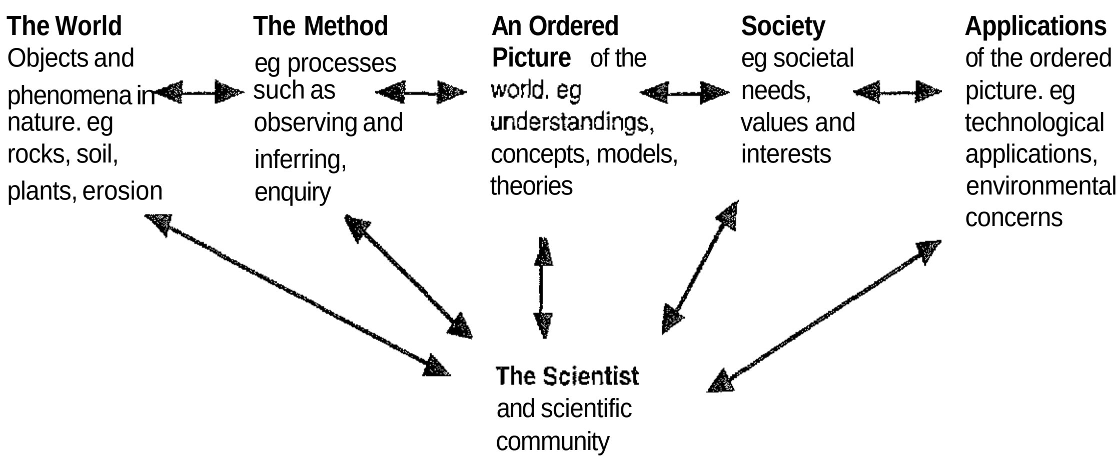

Figure 5.1 Relationships between the components of science

Nature

Science operates on the world around us, that is, on nature. The various elements of nature — the things and phenomena — are the raw materials, so to speak, of science. Different sciences focus on different aspects of the world around us. For example, the focus of study in geology may be on roclcs and soils and phenomena like vulcanism; the focus in biology may be on plants and animals and phenomena like respiration. A basic assumption about nature made by scientists is that it is consistent in time: events occurring under identical conditions are replicable.

The Method

This is the "mode of enquiry" mentioned earlier. It has been described in various ways by different people, from the now out-dated "scientific method" to the rather nebulous "scientific enquiry".

The so-called scientific method is a rationalised view of the scientist's mode of enquiry. It is often described in a sequence like:

- a problem becomes evident
- an hypothesis is proposed
- the hypothesis is tested
- data are collected and analysed
- the hypothesis is accepted or rejected.

A popular perception is that, if this sequence is followed, then a "right" answer should be obtained. This relates to the common view of science I mentioned earlier. By contrast, I would say that a result has been obtained, which must then be interpreted.

This sequence of steps in the "scientific method" portrays the apparent objectivity of science, its logic. Of course, science does not happen this way. The above steps are a rationalised post-hoc summary. They omit the false starts, the intuitive hunches, and the existing knowledge base of the scientist — especially the theories being applied to the investigation. The view is understandable however, since it originates from the main activities of scientists — those of research, and the reporting of research.

The notion of scientific enquiry covers a range of ideas about the activities of scientists, but generally includes the set of thinking processes and laboratory or field techniques used by scientists. Commonly recognised thinking processes would be observing, inferring, controlling variables, predicting, and hypothesising. However, it is also evident that many of these thinking processes are not unique to science. Other issues of importance in considering scientific enquiry are:

- the physical context of an investigation, such as location, and availability of funds;
- the social context, such as the workplace, the research group and wider research community, and the funding body;
- the theoretical constructs the scientist brings to bear on the investigation; and
- elements of creativity and rationality used by the scientist.

While it is sometimes useful to think of the mental functioning of scientists as they go about the scientific enterprise, it is impossible to separate it from the other components of science.

The Product

The products of science are the conventions, laws, theories, and reproducible observation data accumulated over the years of scientific endeavour, for example, the theory of evolution, Boyle's Law, and the boiling point of water. It is this aspect of science that is usually represented as science in books, texts, and the media; often as an authoritative "truth." However, they are only true because the scientific community decides that they are, or because they are reproducible under identical conditions.

The Scientist

Science is done by people, so is subject to the foibles and weakness that people bring to tasks, as well as the strengths. One consequence is that observations are interpreted .according to the ideas scientists have already. That is, along constructivist lines as outlined in Chapter 4, the theoretical constructs held by scientists determine what they will look for in making observations, what they consider as valid evidence, and may even result in their "observing" something happening because they expected it to, even though it did not actually occur. An everyday example is the well known Muller-Lyer optical illusion shown in Figure 5.2.

People from western cultures interpret the lines to be of different length — they are the same — because we draw on past experience of two-dimensional representations to interpret what we see, instead of what is actually there. People from other cultures are not necessarily as easily deceived (Bruner, 1971). Scientists are not immune from their observations being coloured by the glasses of their expectations. There is also a very human reluctance of scientists to abandon what seems a good idea for a marginally better one.

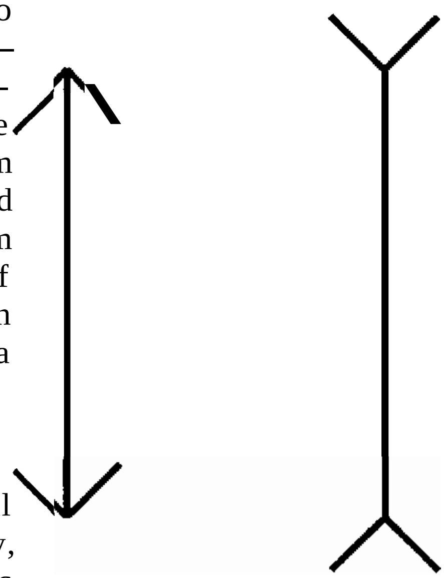

Figure 5.2 The Muller-Lyer optical illusion

The Scientific Community

The scientific community is also a powerful controller of the scientific enterprise (Albury, 1981). Like any community, the scientific community has the power to accept or reject others who seek to be members. *Also*, like any community, the scientific community will accept more readily those it sees as similar, or like-minded, and reject those seen as different. A scientist with a new idea, who is not part of an accepted faction in the community will have little success in having his/her idea published, let alone accepted by other scientists. If he/she is sufficiently persuasive, a few others may agree. If these are sufficiently successful in rallying others to their cause, a new publishing outlet may well result, or the established journals may relent, in recognition of the new movement. The effects of the scientific community touch not only careers, research topics and funding, but also the ideas and theories accepted as true.

Society

The scientific community operates within the broader context of society. It must respond to the demands of that society, and compete against other communities with vested interests in obtaining funds. Since funds are dispensed by government or business, political policies and economic factors influence funding. Government priorities tend to be in areas such as defence, health and agriculture. Business priorities, on the other hand, can be free-ranging, provided there is the potential for profit. Both government and business frequently look to technological developments arising from science. During times of depression, competition for funds becomes fierce, and funding becomes more goal oriented. The elite in the scientific community tend to be those who attract funds in these circumstances. Ethical issues, such as human genetic engineering, are rarely considered by business if a profit is likely and if others are known to be working in the field. Governments rarely make decisions on ethical grounds, but rather on the basis of political expediency. Sometimes, however, it may be politically expedient for a government to make a decision based on ethical considerations. Scientists will not always consider the ethical implications of their work, for they usually have invested a significant proportion of their careers in the work, there is an intellectual curiosity and drive to succeed, and most importantly, a pay packet and self esteem. Ethical decisions must therefore come from concerned citizens who become politically active. For instance, most research organisations now have an ethics committee which approves research involving animals or humans.

Application of science

Some of the issues mentioned earlier overlap with this component of science, as it is difficult to separate the intertwined threads of society, the scientific community, science, technology, and environmental concerns. One use made of scientific discoveries is their application to technology (which does not imply that all technology is an application of science). An example of this is the application of lasers to hifi music in the CD player, and later to CDROMs for computers. The laser has also been applied to weapons technology and vehicle speed detection. All of these applications reflect the values society places on the uses of science. The main motives which seem to underlie western society's applications of science are to do with power over others, or economic advantage and profit.

Another area of application of science is in environmental issues. Science is used here as a watchdog over development projects as part of "environmental impact" studies, but is also called upon to overcome the problems caused by industrial and technological development such as environmental pollution.

Principles for Science Education Based on these Components

If the components of science just outlined provide a workable picture of the scientific enterprise, then we can extrapolate this to school science. Each of the six components can then be considered in terms of science education, revealing the extent that school science can reflect the activity of science.

1. **Students interact with aspects of the world which interest them, and which are accessible to them.** Constraints of the classroom community and school society may restrict choices.

2. **Students engage in some form of scientific enquiry appropriate to their mental capability and experience.** Adults should not limit the students' functioning to their preconceived ideas of the students' capability. Students should therefore conduct investigations for a purpose they have determined,

for example, to gather more data about a phenomenon, or to test an idea. They should actively think about, and evaluate the results of their investigations, using a range of cognitive processes.

3. Students consciously engage in the construction of mental models of the world. Sometimes they would draw on the models proposed by others such as scientists, but may also generate their own models for testing. Scientific conventions would be introduced on a need-to-know basis.

4. The values and constraints of the school and wider society may be explored at an appropriate level. Since many students will not pursue careers in science, but will be part of society which monitors ethical aspects of scientific developments, technological applications, and environmental issues, ethical considerations would need to be explored at a suitable depth for the age of the students, together with the political means of influencing government and business actions. These aspects might link closely with social science studies.

5. The applications of scientific endeavours can be identified. They would usually be explored to develop understanding, particularly with respect to environmental and social consequences.

6. The student as a part of the classroom community could function in parallel ways to the scientist in the scientific community. Students would follow personal interests within the given constraints of the school, curriculum and classroom. It would be openly acknowledged that students will bring ideas to investigations which will influence their perceptions of what to do, how to do it, and the results obtained. Within the classroom community, the social and personal interactions will influence investigations undertaken, group composition and functioning, ideas considered and accepted, and personal satisfaction and self esteem of individual students. (Within the upper primary and junior secondary school, these issues are complicated by the students' growing sexual awareness, which cannot be ignored.) The consideration of theories and what truth is can be dealt with at the classroom community level, if the class is involved in deciding the validity of ideas according to the available evidence.

If these notions are new to you, you will find Learning Project 24 helpful in clarifying your thinking.

Learning Project 24

- How would you now define science (not classroom science)?

- What do you think truth in science might be?
- How would you suggest scientific knowledge change?
- Reflect on a recent science lesson in which you were involved (or become involved in one for this purpose). What aspects of the "common" view of science were evident? What aspects of the "contemporary" view of science were evident?
- Consider each of the components of science, and note down what you feel is appropriate for the classroom in your sector of schooling (e.g., early childhood, junior secondary) in each. Bear in mind that classroom practice should resemble as much as possible the nature of science, but that students cannot actually function as scientists.

In your group decide to what extent students in your sector of schooling should act as scientists, within the limits of their age and experience.

The Hidden Curriculum and Views of Science

The hidden curriculum is a commonly used term to describe what is taught unintentionally via the school and classroom rules, teacher talk, and so on. What the teacher believes about the nature of science is reflected in the way the teacher talks, conducts activities or laboratory classes, and goes about teaching. This is conveyed to the students through the hidden curriculum when repeated instances are presented to them over a period of time. For example, contrast the two statements "We know that all matter is made up of atoms" and "Scientists think that all matter is made up of small particles, which they call atoms." The first type of statement, if repeated regularly, conveys the idea that this is an obvious, true, authoritative statement determined by others. If it is not obvious to the students, then they do not belong to the clever group who know such things. The second statement suggests that things like atoms are defined conventionally, and are a construct invented by people.

Consider what message the teacher is giving the students if experiments are always conducted as a teacher demonstration. This reinforces the everyday view that science is conducted only by authoritative experts and is not available to most people. Similarly, practical work which is always strictly controlled by a specific set of instructions from the teacher or a manual suggest that experiments have one correct answer which is obtainable if the correct procedures are followed. Contrast this to a teacher who regularly involves students in open ended, problem-based practical work. This suggests that science is available to the students, and that there can be alternative answers which need to be evaluated in terms of the available evidence.

Views of Science in the Syllabus/Curriculum

Your syllabus or curriculum will have some statements about science, and may include a section on thinking processes or process skills. It is important for you to contextualise. what you have learned from this chapter with your own education system and local context, which is the focus of Learning Project 25.

Learning Project 25

Look at a copy of your science syllabus or curriculum.

From the introductory statements decide what view of science is suggested.

If any teaching strategies are suggested, what view of science is portrayed?

If a text book is used in your local school situation, what view of science does it portray?

In your group share your conclusions about the syllabus/curriculum and text book, where relevant.

If the view of science portrayed fits the every day view, what changes would you suggest?

What *All* This **Means** for the Different Sectors of Schooling

As you read this chapter, did you see the relevance of the different aspects of science to your area of interest? Your views of a particular sector of schooling may have coloured your perceptions of parts of this work, so check your views with some of the ideas summarised below.

In early childhood settings, the following principles in particular would apply:

- Students are in the early phases of establishing their experience base with natural phenomena, investigatory techniques, and science concepts. Scientists in this situation tend to engage in exploratory work where they simply try to find out the characteristics of particular phenomena they are interested in. Early childhood students can do the same.

- Scientists also try to find out what is already known by others about the phenomenon by talking to colleagues and by reading. Early childhood students would have to rely more on adults, picture books, and selected media.

- Scientists practise important investigatory techniques until they can perform them properly. It is important that early childhood students be shown how to use simple investigatory techniques, and be given the opportunity to practice them in meaningful contexts.

- **As** scientists gain more knowledge, they begin to specialise in narrow areas of science. Early childhood students should start with a broad knowledge base where components would be identifiable as science.
- Scientists often conduct research in teams and work on problems of mutual interest. Early childhood students can similarly work together cooperatively on science projects, particularly to share ideas.
- Scientists record their findings systematically. Adults can help early childhood students record their findings in suitable forms.

You should be able to add other ideas to this list.

In **primary** contexts, these same principles would apply with modifications, as well as others you might add:

- Exploratory techniques would still be used, but there would be an increasing emphasis on testing ideas.
- Primary students would be able to draw on a greater variety of information sources to construct their understanding of phenomena.
- More complex investigatory techniques would be learnt, with an increasing use of instrumentation.
- Primary students would begin to focus specifically on science as a discipline, and increasingly examine a range of science topics which fit within traditional science disciplines.
- When working on team projects, cooperation, sharing ideas, and specific team roles would become an emphasis, and be practised by all members of the team.
- Recording of data from investigations would become more sophisticated, drawing increasingly on mathematical techniques to transform data to understandable forms.

Extending these principles to **secondary** contexts would include:

- Much of the laboratory work would involve tests of ideas so that evidence from the tests could be evaluated.

- Secondary students could exploit the full range of information sources available, though more complex sources such as journals would only be used in the senior school.

- Laboratory sessions would include specific contextualised instruction on particular investigatory techniques and the use of selected instruments.

- Secondary students would increasingly begin to work in the subdisciplines of science such as chemistry, biology, physics and geology.

- Team work would become more purposeful and focused on sharing and justifying ideas, on group tasks and projects, but also on finding team roles to specialise in without being stereotyped into a particular role.

- Recording of data would become increasingly systematic, and make greater use of mathematical techniques for transforming data.

These lists are by no means complete. Add to them yourself.

Learning Project 26

In your group, make up a more complete list of principles for your sector of schooling based on those listed on the previous pages.

A Case for You to Work on

Joan, our early childhood teacher, Sally, our primary teacher, and Julian, our secondary teacher, have each been invited to be part of a panel during a session at the science teachers association conference. Each has been asked to prepare a five-minute statement about how their teaching of science is influenced by their perceptions of the nature of science. They have been asked to refer to specific teaching practices as much as possible.

Assume the role of Joan, Sally, or Julian as appropriate, and prepare your contribution to the panel.

In your group, take turns to present your session. Compare views put forward by others in your group, and discuss any differences in views.

Your Chapter Review

Write two paragraphs. In the first, describe what your perceptions of science were before you began this chapter. Use your responses in Learning Project 20 to help you. In the second, describe what you think now. What similarities and differences are there? Do any changes in your perceptions imply that changes should occur in your teaching? If so, what?

Further Reading

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Influences on Science Teaching: Equity

What This Chapter Asks You To Do

During this chapter you will:

- Consider ways cultural and gender bias are exhibited in our society and in schools.
- Examine some ways of conceptualising our culture and the existence of a number of subcultures within it, and consider how these ideas can inform our teaching of science.
- Explore ways of reducing cultural and gender bias in our science classes.
- Consider the range of special needs that students in our classes may have, and devise ways of meeting those special needs.

There has been a growing move over the last decade to ensure that all students, regardless of ethnicity, gender, economic circumstance and capability have equal access to education. If a group of students with some identifiable common characteristic or origin is not performing as well as other groups, then the assumption that there is something "wrong" or "inadequate" with those students no longer applies. Rather, the question is being asked, "What are we doing or not doing in our provision of education for these students that does not allow them to achieve as well as other groups of students?" This presents a major challenge for teachers, not only in coming to grips with the issues involved, but also in how to make education available to all students — one of the problem areas we considered in Chapter 2. Learning Project 27 will help you clarify what you already know about these problems and possible solutions.

Learning Project 27

Make up two lists of stereotypes which are typical in our society, one for cultural stereotypes, and one for gender, e.g. "Italians are good lovers," or "Blond women are dumb." To what extent do you believe any of these are true?

Be honest now: do you exhibit any bias in your behaviour toward a person from another ethnic group or culture? Toward the opposite sex?

In the next week, record any instances of cultural and gender stereotyping or bias that you hear reported or witness yourself. Look particularly at movies and television.

What classroom instances of cultural or gender bias have you seen or experienced?

What would you say might be done to reduce cultural and gender bias in classrooms?

In your group share your answers to the above questions (You may choose not to share personal revelations of cultural or gender bias). Is there anything problematic about stereotypes? Where do they come from?

Arrive at a group list for classroom instances of bias, and possible ways of reducing it.

Understanding Cultural Differences and Problems

To strive for effective means of reducing bias in our classrooms, it is helpful to understand something of the cultural basis of our society, and the different subcultures which make it up.

Societies

We can gain some appreciation of the difficulties for ethnic groups by considering the notion of "society." For my purposes, I will define a society as a group of people with a shared, common knowledge of beliefs and interests, language, and rules for conduct. The culture of a society, then, could be considered as the beliefs and interests (including art, dance, and so on), language, and rules for conduct identified in the society. The "common" knowledge in a society is what everyone in the society knows. Because it is common to all, it is also implicit and is frequently at a non-conscious level. It is this common knowledge which enables people in the society to interact in predetermined ways, and allows them to operate in the society with a sense of belonging and security. People who belong to the society behave and talk in the accepted ways of the society without hesitation. Those who do not, clearly do not belong to the society.

Societies can be identified with national groups of people, or with subgroups of nations. We usually refer to these as cultural or ethnic groups. With international travel, some of the geographic boundaries separating ethnic groups are less distinct. We can also consider "supersocieties" which embrace several nations, but which still have much in common. For example, people from the United Kingdom, North Americas, Australia and New Zealand could be considered as belonging to a Caucasian based Western cultural group (though this is changing rapidly with recent immigration trends). The majority all talk a similar language, and could easily adjust to small differences in beliefs and behaviour. The notion of a supersociety is a useful concept, for it allows us to also consider the idea of a "world view."

World views

A world view is a way of looking at the world and how it works. It is culturally based. A sharp contrast, for example, can be made between the world view of a person of Caucasian origin in Canada from that of a person of Arab origin living in Iran. One characteristic of an Canadian Western cultural world view might be that all physical events have a rational cause and effect explanation, whereas the Iranian Muslim world view might include an acknowledgement of Allah's hand in the physical world.

Subsocieties

Just as we can consider several similar cultural groups belonging to a supersociety, we can consider a society consisting of many smaller societies, each with its own variations of beliefs, interests, language, and rules for conduct. In most countries, for example, Australia and Canada, there are some obvious instances of this based on immigrant cultural groups, but there are also more subtle instances. For instance, in many cities and districts, there would exist a "football" subsociety. People from each would interpret "football" as meaning Rugby League, Rugby Union, Gridiron, Australian Rules, or Soccer depending on their subculture. Although they all use the same word, the meaning is slightly different for each. There would also be a specific language surrounding each of the codes of football. Another example would be the "bikie" subsociety. Again, members of this subsociety have their own language and meanings for words, behaviour codes and beliefs which would have many similarities to, say, middle class public servants as a group, but which would also have many key differences. This is represented in Figure 6.1.

Membership of societies

As indicated earlier, membership of a society is judged by a person's knowledge of that society's language and so on. **A** person who does not know the "correct" use of language, does not believe the "right" things, or who does not behave in "acceptable" ways is clearly identifiable as an outsider. People from ethnic cultural groups with their own language are usually born into the group, and acquire the common knowledge incidentally and over a period of time. Outsiders who would join the group often have great difficulty acquiring all the necessary common knowledge — particularly language and accents — so they never really attain full recognition as a member of the society. Joining subcultures is usually easier. People who set about joining a subsociety such as a Bridge Club would have to spend some time learning the appropriate rules and behaviours before they are accepted as a member of the society, but could achieve this in a relatively short time. It is possible for a person to belong to two or more subsocieties. For example, a person may belong to an aerobics fitness subsociety, as well as a chess subsociety. Many people would belong to several subsocieties. *An* important aspect of membership of societies and subsocieties is pride in membership and the consequent rivalry that can arise between groups in the same geographic area. While the rivalry can be good natured, it can also become intolerant and even violent.

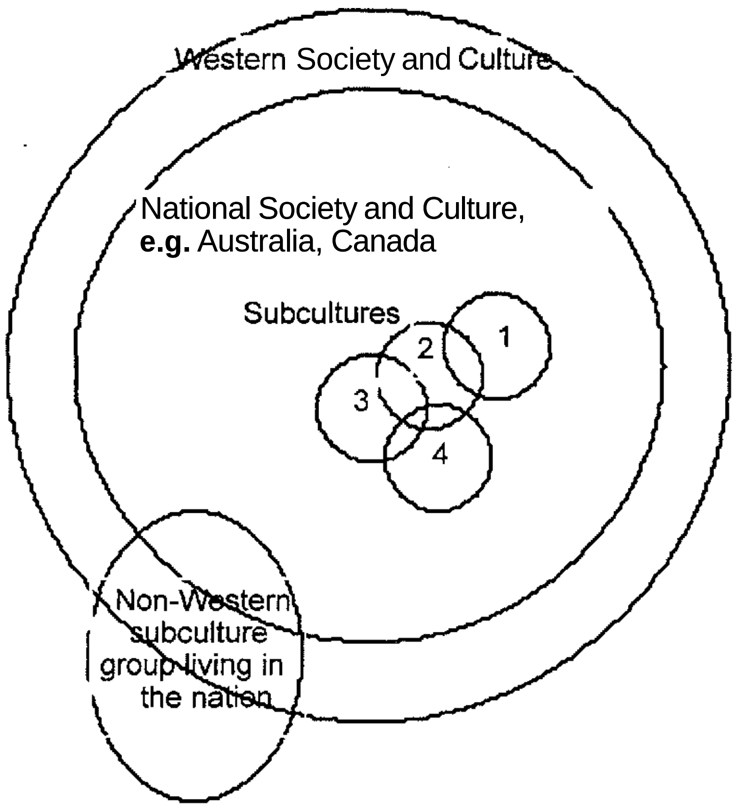

Figure 6.1 Cultures and subcultures

The Cultural Basis of Science

Science as we know it in Australia has arisen from the traditions of the Western cultural group of societies. In other words, it is a construct of our society, and reflects our Western world view. In fact, this cultural basis is one of the strengths (and perhaps weaknesses?) of science, because a basic premise of our culture is that rational cause and effect explanations exist for physical events. Science therefore appeals to the constancy of physical events to substantiate its constructed principles and relies on rational interpretation of evidence to judge the validity of ideas.

It would also be appropriate to consider the group of scientists in the Western world as a subsociety crossing national boundaries, with its own special set of behaviours, language, and so on. Since science has had its foundations over the centuries in a male dominated society, it has been suggested (Kahle, 1988) that membership characteristics of the scientist subsociety are essentially male, and have masculine overtones. Women who wish to become members must assume the masculine aspects of the behaviours, ways of thinking and so on.

It is apparent, then, that people from non-Western cultures as well as women, have to make greater adjustments than Western men need do, to acquire membership of the scientist subsociety. Herein lies the basis for inequity in access to science for many people in our society. It is not appropriate to say that these people need to work harder to achieve what others can achieve much more readily. Some may not consider the extra effort worthwhile, or may consider the outcomes undesirable in other ways. For example, some women have asked why they should assume some masculine characteristics to access careers in science. This question is valid if it is used to work towards reconstructing science as part of reconstructing gender roles in our society.

School subsocieties

In the same way that bikies may be a subsociety of our society, so too are schools. There is the general "school" subculture, and each school would have its own version of that subculture, with small but identifiable differences from other schools. Within each school subculture, there would be a classroom subculture for each teacher and class combination. The rules for behaviour and language for each classroom would be negotiated by teacher and students. Again, there would be many similarities between classroom subcultures, but there would also be small differences.

Some people may assume that the *science education* subsociety is the same as the *scientists'* subsociety. However, I suggest that this is a false assumption. I see them as two different subsocieties with different rules and language. Some people may belong to both and there may be considerable exchange between the subsocieties, but they are different. The science education group belongs to the school subculture, but the science group does not. For instance, most secondary science teachers would feel they belong to the science education subculture, but only a few would also belong to the science subculture. Many early childhood and primary teachers, on the other hand, would tend to feel they belong to neither, but to an early childhood, or a primary subculture.

Schooling as enculturation

This leads us to a reconsideration of what school science is for the different sectors of schooling, which we looked at in Chapter 3. An aspect of all schooling is that it enculturates students into a particular culture. A valid question is, "Which type of science culture is the student being introduced to?" I touched on this in Chapter 5, when I considered the difference between teaching *about* science and teaching *in* science. Most people would agree that it is unrealistic to think that we might enculturate students into *science* until late in their undergraduate university work perhaps even only when they begin postgraduate studies. We are left to conclude that schooling enculturates students into *school science,* which might reflect some characteristics of science, and those characteristics might change with the different sectors of schooling. School science, however, has been constructed as part of the school subsociety, based on the traditions and history of schooling. This is why secondary science in particular is seen as Western, male, text dominated, with laboratory work supporting the text; and early childhood and primary science are not given the same priority as the traditional 3Rs, yet frequently borrow the Western, male, laboratory aspects from the only model available — secondary science. Where these clash with the early childhood primary subcultural beliefs, the latter win out; for example texts tend not to be used in primary grades.

Cultural "clashes"

As mentioned earlier, each classroom has its own set of rules and language which becomes common knowledge in the classroom. For a teacher or student to belong to the classroom, they must know the language, rules and behaviours associated with it. If someone does not know the rules, they clearly do not belong to the classroom, as any relief teacher has experienced. Further, the learning of these rules is culturally embedded. For example, in Western culture, a student who is spoken to by a teacher is expected to look the teacher in the face. Students from a Western culture would know this implicitly, and behave accordingly. However, a student who does not know this cultural behaviour may not comply. An Australian aboriginal student, for instance, would avoid the teacher's gaze, and look down. This is an appropriate response in Aboriginal culture. If the teacher is unaware of this, he/she may interpret the student's behaviour from his/her own cultural viewpoint and become annoyed with the student's "insolence" for apparently not listening. Similar cultural behaviours which could be misinterpreted would be identifiable for other aboriginal or first nation peoples.

This is the crux of equity issues in science education for students from low economic backgrounds, non-Western cultural groups, and women.

In science classes, the routines and teaching approaches used (see Chapter 7) all have a particular cultural emphasis — namely Western, rational, schooling, science, masculine. Students who have not had the opportunity to acquire the common knowledge for this cultural emphasis are effectively disenfranchised from achieving in science classrooms. Those at greatest disadvantage are students with greatest cultural differences. In Canada, these would tend to be First Nation students, Southeast Asians, and students from some Mediterranean areas. A complicating factor is the *expectation* the teacher has on the student's performance. This expectation is usually subconsciously judged by the teacher from the level of a student's conformity to cultural rules and behaviours, and perhaps the history of the student handed down from other teachers. Research clearly demonstrates that the teacher's expectations of a student's performance is a large determiner of that student's success in school. It influences the teacher's selection of teaching approaches, management, interaction with students, and grading of work.

Gender bias **as** a **cultural** clash. Note that gender bias is a particular aspect of our cultural makeup, and seems to be present in many cultures in varying degrees. Gender roles have evolved historically and have their basis in both biological functions and societal images of men and women. Being assigned to societal subcultures and expected roles on the basis of gender provides a predictable social world, but also perpetuates inequalities in access to resources and power. Historically, men have tended to have privileged access to these over women. Hence there has been in recent years concerted moves to remove these inequalities, particularly in education. Science is one area where the inequalities have been particularly noticeable. While there is recent evidence to suggest that some success may be being achieved, especially in access to science classes in secondary schooling and in performance in science, basic gender expectations continue to be dominant in our culture.

Learning Project 28

What subcultures in our society do you belong to? Make a list. Are there any marked differences between these subcultures in language, terminology, and/or rules of behaviour?

Choose one of the subcultures you belong to, and work out what it is that allows you to quickly identify another as a member of your group.

Have you ever felt culturally isolated or sidelined in some way? How did you feel? What did you do about it?

Identify some events in society and/or classroom practices which reinforce particular societal images of men and women. Do these images have any effect on access to resources or power?

What counter-stereotypical gender roles or events have you experienced or witnessed recently?

In your group decide on some key aspects of cultural clashes and gender bias which are evident in your sector of schooling.

Do you think that any counter-stereotypical gender roles or events have had any effect on society or in schools?

Addressing Inequities in Science Teaching

The most difficult aspect of addressing cultural inequities is being aware of our own implicit cultural behaviours, expectations, and biases. Once we are aware of these, we can begin to change the way we ourselves, think and behave. The second most difficult aspect is implementing specific classroom practices which reduce cultural disadvantage, and maximise opportunity for all students.

There are no ready-made solutions. The starting point is teacher awareness. It is not possible to alter the cultural framework of a classroom from the dominant cultural group of its members. However, it is possible to learn how the other cultures represented in the class behave. It is possible for the teacher, armed with such knowledge, to avoid cross cultural errors, help such students learn the cultural and classroom routine rules, and adjust teaching approaches to better suit the students effected.

Some possible steps **to** reduce cultural bias in science **classes**
If most people in the class are from the same cultural group, their behaviours and rules will be dominant in the classroom. If the teacher belongs to that dominant cultural group, there will be few problems in dealing with the majority of students. However, any students from different cultural groups will have difficulties. To make the transition easier for them, the teacher should find out the key social communication behaviours of the minority groups; change his/her expectations about classroom behaviours so minority group behaviours are included; try to understand the minority group behaviours from their cultural viewpoint; and help students from each cultural group recognise and value the behaviours of the other groups (Appleton, 1995).

If the teacher is from a minority cultural group compared to the rest of the class, there will be greater difficulties unless classroom rules and behaviours are based around those of the dominant group. For example, Australian Aboriginal children are much more concerned about the social group in a class, whereas Caucasian students tend to be more individualistic and competitive (Malin 1990). During practical work Aboriginal students are likely to spend a lot of time looking at what other groups are doing, and helping out if they think they are needed. From a Caucasian teacher's view, this can be seen as chaotic and the teacher may be tempted to ascribe to the students an inability to attend to prescribed tasks. However, a culturally-aware teacher will expect this sort of behaviour and will take it into account when devising teaching plans.

Cultural beliefs and science. Even within our Western culture, and often with non-Western cultures, some students' cultural beliefs will be in direct contrast to principles we might teach in science. This difficult issue has led to, in some instances, hostile arguments and court battles such as in the evolution and creationism debates. The real dilemma in such instances is how to resolve the differences in a culturally sensitive manner. To help you see the complexity of the issue, do Learning Project 29, preferably in your group.

Learning Project 29

Read this scenario (adapted from Anderson et al, 1972), then discuss the questions below in your group.

Imagine you have accepted a teaching position at a village school on a remote island. The people living there continue with much of their traditional lifestyle. The village is situated in a valley between high mountains. The staple food of the people is potato, which they grow themselves, supplemented by goat hunted high in the surrounding hills and mountains. The people only go to the mountains when they need meat, for they believe that the mountains are inhabited by evil spirits. They know this, because high in the mountains, accidents often happen, like stones dislodging underfoot – obviously moved by evil spirits. Furthermore, up there the potatoes do not cook properly in the earthenware pot. No matter how long they boil them, they do not cook

However, they have found that they can stop the evil spirits from getting into the pot if they put a heavy lid on it.

After settling into your teaching position, you discover the next science topic is to do with the boiling point of water, and how the boiling temperature may change with changes in air pressure. How are you going to handle this in terms of the students' beliefs about evil spirits and the potatoes not cooking?

In your group, discuss the different options available, and the consequences of each for the students' cultural beliefs.

What do you think might be the best culturally sensitive solution? Why?

I am often asked what the right answer to Learning Project 29 is. Of course, there is no right answer. Whatever action the teacher takes will generate some conflicts. To launch in with the scientific explanation as "This is right and your beliefs are superstition," runs the risk of arousing the parents' anger and eroding the cultural base. It also smacks of the arrogance of cultural superiority which characterised our colonial past. Treating their cultural beliefs as misconceptions to be "erased" has similar problems. The softer option of just telling the students the scientific version and letting them make up their own minds is just as problematic, as is explicitly teaching both scientific and local cultural versions for the students to "choose" between. Avoiding the topic altogether, or just teaching the local cultural version of spiritism is not fulfilling your responsibility in teaching the mandated curriculum, and is not serving those students who may later leave the island. So my answer (you can decide if it is the "right" answer) is the rather unsatisfactory one of letting the community decide what should be taught, and how.

I recall how, some years ago, a teacher working in a remote Australian Aboriginal community wrote a science program for the school in conjunction with the community elders. It was based on the vast environmental experience of the community living in its traditional lands, and the cultural practices and cycles of life they followed. However, it also examined each component of traditional knowledge in terms of the Western science involved, which was drawn from the required syllabus. That is, it approached Western science through the local culture, giving importance to both.

Some possible steps to reduce gender bias in the science classroom. Much has been written about this, with excellent suggestions coming from people like Hildebrand (1989). She outlined some specific gender-inclusive principles for the science classroom (as opposed to system and school procedures). While her points were directed at secondary science, many are also relevant to other sectors of schooling. In terms of the covert, or hidden, curriculum she pointed out that the physical environment, human interactions, and use of language need attention. She suggested that students should feel some ownership of science areas, and they should be pleasant places to be. Dedicated science classrooms can be quite drab compared to, say, an art room. **A** bit of colour, some plants and posters can make the room environment much more inviting. Making flexible arrangements of furniture to facilitate discussion is also important.

Human interactions includes both teacher-student and student-student interactions. Hildebrand discussed the former, suggesting that teachers monitor their own behaviours in questioning and providing help, and change their behaviour as need is revealed. You may wish to revisit Chapter 2 to recall the biases associated with teacher questioning. An important aspect of addressing stereotypical gendered behaviours is to ask the students to monitor and perhaps modify their own student-student interactions, which frequently reflect gendered stereotypical behaviours and posturing. For example, a typical gendered behaviour many females learn is to be helpless with technical things, while males are expected to handle these with ease. These roles can be exaggerated during puberty. Another example would be some typical male aggressive interactions which would be labelled harassment in non-school settings (Clarke, 1989), but can occur at all levels of schooling.

Segregated science classes in secondary schools have been found to benefit females and have been used effectively to improve their access to science and their performance. However, while segregated science classes may force each gender to assume non-stereotypical roles, it does not address gendered roles and behaviours in student-student interactions. Solutions in this area should begin very early in schooling. An effective strategy is to highlight the effects of particular behaviours on others. For example, if the boys exclude the girls from handling the materials during practical work, the girls can share how they feel as a consequence, and both boys and girls can work toward a solution.

The use of non-sexist language is probably one of the more obvious areas which has received considerable attention in recent years, and most people are now careful to be inclusive in their language'. Implicit non-verbal language has received less attention, and problems can persist, such as the teacher who always asks a boy to clean the board.

Hildebrand also discussed aspects of the content of the formal curriculum. She suggested the social context of science should be addressed using a thematic or problem solving curriculum organisation. Where possible, she advocated the negotiation of curriculum with students to encourage ownership and relevance. At secondary levels, career education could point women to non-gender-stereotyped occupations. She also highlighted the importance of providing opportunities for girls to tinker with materials, and to become actively involved in exploring them. Boys usually have many more opportunities at this than girls, so deliberately planned tinkering is important for the girls. In line with Hildebrand's suggestion, most teaching resources available are now using gender-inclusive (and culture-inclusive) language, illustrations, and examples. The final aspect of curriculum that she addressed was assessment. In particular, she recommended that criterion based assessment be used, with full details of requirements and deadlines being made available to students early. This has since assumed greater significance with the increasing emphasis on performance goals in syllabuses and curriculums.

Hildebrand highlighted some changes which were needed in teaching strategies as well. While there are many which could be discussed, she singled out creative writing, role play and drama, values clarification, and cooperative learning as particularly powerful strategies for helping both boys and girls learn science.

Learning Project 30

Read more widely about gender inclusive practices for teaching science. Make a list of specific practices relevant to your sector of schooling.

In your group share your lists to create a group list.

Discuss to what extent gender stereotyping and gender bias can occur in a class of girls with a female teacher, or a class of boys with a male teacher. What is the nature of the problem? How could it be addressed?

Students with Special Meeds

While every student can be considered as one who has special needs, from a teacher's point of view there are some whose particular needs can require special attention and sometimes specialised knowledge. The following ideas are suggestions only, and should be used in conjunction with expert advice when necessary. I have not included suggestions for dealing with students who have major impairments or disadvantage.

Gifted and talented students

These students are capable of high achievement. Some are gifted in all or most areas, and others are gifted in a particular subject, like science. Bear in mind that gifted students frequently hide their exceptionality because they do not want to appear different. In highly teacher-directed classrooms they may become bored and find ways to amuse themselves, sometimes resulting in disruptive or anti-social behaviour. For example, they may engage in overt humorous behaviour, or in covert practical jokes. Gifted and talented students tend to work best when given personal responsibility and ownership of their learning. Specific strategies for catering for such students include projects, devising and conducting their own investigations, and peer tutoring.

Physical handicaps

This includes students who are hearing impaired, visually impaired, health impaired (e.g. diabetics, asthmatics) or physically impaired. The severity of impairment can cover quite a range.

Hearing impaired

- Seat the student for optimum viewing of you, other students, and teaching aids because of their dependence on vision. This presents a particular problem for small group work, since the students may not be able to communicate well in their group, or hear instructions given while the groups are working.
- Find out how the student best communicates, for instance, whether by signing or by lip reading. You will also need to learn how to use any special equipment, such as a microphone. Many students have partial hearing, and use a hearing aid to enhance the facility they have. Many students will also have a sign language interpreter assigned, so you need to learn how to work with this person. It is invaluable to have an interpreter present for small group work.
- Find the student a "listening helper" from among the hearing students. If the selected student can sign, it is of greater benefit to the hearing impaired student. The helper can then alert the student to attend to you when needed, or help with instructions or explanations.

Few science activities require modification to cater for these students, except those in which hearing is necessary for observing results. Sometimes they can feel vibrations, but on other occasions may have to rely on their listening helper.

Visually impaired

- Special equipment, such as specially designed scales, can be purchased if the money is available, but in my experience few schools have the resources to purchase this.
- Seat the student for optimum hearing as the sense of hearing is relied upon. Think carefully about using book-based research activities, and putting written instructions for practical work on the board, worksheets or a laboratory manual.
- If the room is reorganised for group work or some other purpose, reorient the student as to how it is arranged. Students with visual impairment usually have to remember the location of furniture to negotiate their way in the room.
- Allow as much hands on as possible; do not be over-protective of the student.
- In whole class work, say aloud what is written on boards and charts.
- Address the student by name when you speak to him/her.
- Remember that the student cannot see your non-verbal communications, so use verbal variations and touch to convey meaning and encouragement.
- Assign the student a seeing helper.

Since people depend considerably on sight, there are many science activities drawing on this sense which would need modification or special arrangements made. Sometimes touch may be used as a substitute sense in activities, but on other occasions a helper may be the best option.

Health and physically impaired

- Special materials are available for these students if there is money available.
- Eliminate architectural barriers and furniture arrangements which may cause problems for students with limited mobility. Be aware of any health problem "triggers," such as what brings on a student's asthma attack. Be particularly aware of normally harmless things which could be hazardous for these students, such as a diabetic tasting honey.
- Educate yourself about special devices such as a wheel chair or calipers the student may need for mobility or to perform simple tasks. Also learn about any medication and possible side-effects, and how to recognise and manage unexpected health-problem responses. For example, what would you do if an epileptic had a major fit during an activity using candles; or an asthmatic had an attack while on a camping excursion?

Apart from considering safety issues which could emerge for these students from seemingly harmless situations, special arrangements may need to be made to allow for limited movement and coordination.

Emotionally, socially and/or culturally disadvantaged

- For culturally disadvantaged students, try to understand some aspects of the cultural world view from which the student is coming. If the majority of students in the class are of the same cultural group, consider approaching the science from their cultural viewpoint rather than yours (see earlier in this chapter).

- Emotionally and socially disadvantaged students usually respond better to being given ownership of task and personal responsibility (within carefully defined parameters – remember that it takes time to "unlearn" antisocial behaviour).

No special arrangements are needed to cater for activities for these students, except where disruptive behaviour may occur.

Speech/language impaired

- Ensure your use of language fits the pattern needed for the special remediation of the student's problems. If the student is receiving assistance from a therapist, consult with him/her. Take care to provide a good model.

- Help the student focus on his/her own language problem so errors are drawn to his/her attention (use sensitivity here).

These students may experience reading or writing problems so care needs to be taken not to publicly expose their limitations, as might happen if you provide written instructions for activities, or ask students to write laboratory reports.

Learning disabled and mildly mentally impaired

- It is best to use individually designed learning programs based on behavioural models of learning for these students. You may need to seek special assistance regarding this.
- Use multi-sensory approaches to maximise use of all senses.
- Listen carefully so you can understand what the student is saying and understanding.
- Help the student build self-esteem — so use the student's strengths, and diminish his/her deficiencies.
- Because attention spans are often short, minimise interruptions.
- Watch for frustration levels rising, and stop or redirect the student's work as needed.

Learning goals in terms of understanding for these students may need to be revised according to their existing knowledge and capability. Patience is needed in giving explanations. Merely repeating an explanation does not necessarily help, as it needs to be presented in different ways. The use of other students' explanations can be helpful.

Learning Project 31

Find out what special support systems are available to teachers in your area of schooling for students with special needs.

The next science lesson or unit your prepare, consider how you might cater for a student with a particular need.

A Case for You to Work on

Choose one of the following scenarios to work on in your group. Also choose whether your context with be early childhood (Joan), primary (Sally), or secondary (Julian). The group's task is to arrive at some specific suggestions for Joan, Sally or Julian (as the case may be) to help him/her in the next teaching situation. Try to focus on the science teaching, though obviously these situations impinge on the whole curriculum.

Scenario 1:
Joan/Sally/Julian has just been appointed to a school where most of the students are from a different ethnic group (You choose which ethnic group this is). In preparing to teach science, what should she/he do?

Scenario 2:
Joan/Sally/Julian has just been appointed to a school where about half of the students are from three different ethnic groups. (You choose which ethnic groups these are.) In preparing to teach science, what should she/he do?

Scenario 3:
Joan/Sally/Julian has just become aware that students in her/his new class have been exhibiting some undesirable gender bias (or cultural bias if you prefer). How should she/he deal with this?

Scenario 4:
Joan/Sally/Julian has just received a new student in her/his class who has a fairly demanding special need (You decide what this is). How should she/he deal with this in everyday science teaching?

Your Chapter Review

For teaching situations involving multicultural and mixed-gender classes, make a list of important teaching practices to keep in mind, to reduce any bias in your science classroom. Make a similar list for dealing with a student with a particular special need which you nominate.

Further Reading

Science for non-western cultures

Atwater, M.M. (1994). Research on cultural diversity in the classroom. In D.L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 558-576). New York: Macmillan.

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Christie, M.J. (1991). Aboriginal science for the ecologically sustainable future. *Australian Science Teachers Journal, 37* (1), 26-32.

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Hildebrand, G. (1989). Creating a gender-inclusive science education. *Australian Science Teachers Journal, 35* (3), 7-16.

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Appleton, K. (1995). The first few weeks with a class: Another look. *The Clearing House, 68* (5), 293-296.

Hildebrand, G. (1989). Creating a gender-inclusive science education. *Australian Science Teachers Journal, 35* (3), 7-16.

Kahle, J.B. (1988). Gender and science education 11. In P. Fensham (Ed.), *Development and dilemmas in science education* (pp. 249-265). London: Falmer Press.

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Building Blocks of Teaching

What This Chapter **Asks You** To Do

During this chapter you will:

- Reflect on your own perceptions of teaching in science.
- Consider how routines can be used to simplify science teaching.
- Identify a range of teaching techniques important to science.
- Explore the range of teaching strategies which can be used during science lessons.
- Examine several teaching approaches useful for structuring the teaching of science units.
- Arrive at a personal set of preferred routines, techniques, strategies and approaches for your own teaching situation.

Teaching **in** Science

The teaching strategies and approaches used in science do not really differ much from those used in other subjects. You will already be familiar with many of these, though your ideas may need to be clarified a little. So you can see how to fit the following pages into what you already know, do Learning Project 32.

Learning Project 32

- Make a list of ways of teaching that you think might be applicable to science for your sector of schooling (early childhood and so on).
- For each, jot down any particular circumstances or constraints that might be relevant.
- What routines are you familiar with in teaching?
- How would you go about establishing a new routine?

Unfortunately, the terms teaching techniques, strategies, and approaches are often used interchangeably in education. You may have struggled with that when doing Learning Project 32. In this book, I use these terms in specific ways as a practical means of differentiating between different teaching actions. However, all teaching actions occur within the overall social context of the classroom.

The Overall Classroom Social Climate

All teaching activities tale place within the established social climate of the school and classroom. The classroom climate in a school setting usually conforms to well established patterns based on the teacher's authority and expected behaviour patterns of teachers and students. However, there are variations within this general pattern, the establishment of which depend very much on the teacher and the students. Some social climates are more conducive to learning than others. In science, it is generally accepted that classroom climates should reflect constructivist and social constructivist views of learning as well as equity principles. These all tend to result in the same type of climate, which is warm, supportive, and encouraging. The students should feel as if they are able to contribute to the curriculum meaningfully, and are valued as persons where their ideas are accepted as valuable contributions to the lesson. Establishing such a climate is a task which may take some time, and for primary and early childhood situations, needs to apply to all subjects. It is within this overall climate that lessons are conducted.

Science Lessons

When we think of science teaching, the first thing we usually think of is a "science lesson." Lessons are identifiable as specific time segments during which the students engage in particular tasks which are most often set by the teacher. Normally the tasks are all organised around the same topic, but sometimes multiple tasks on a variety of topics or subjects are assigned. Multiple tasks are very common in early childhood settings and in some special primary settings such as multi-age groupings.

Unfortunately, thinking of a lesson as the basic building block for science teaching can create difficulties, for it creates the impression that a lesson stands alone. While this might sometimes be so, lessons are usually part of a bigger picture, which I call a unit. **A** unit is normally developed to teach a specific topic from the curriculum, and may continue for some weeks. **A** unit therefore consists of a number of lessons arranged in a carefully selected sequence which acts as a scaffold for the students' learning. I call this a teaching approach.

Naturally, lessons need to be somewhat self-contained, with an identifiable beginning and some form of closure. Quite often, in a lesson, the teacher will use what I call a teaching strategy to provide an internal structure to the lesson. Sometimes a lesson may involve only part of a teaching strategy, on other occasions more than one teaching strategy may be used within the one lesson. Each teaching strategy consists of several segments arranged in order, the sequence again being designed to act as a scaffold to aid the students' learning. Each segment of a teaching strategy is made **up** of one or more routines, which provide the basic social structuring of the classroom. The teacher also uses a number of teaching techniques to engage the students with the content being considered at the time.

I explore each of these building blocks in the rest of this chapter, starting with routines. Remember that all of these are part of the overall social climate of the classroom, and should be chosen to be consistent with constructivist and equity principles, and a view of science appropriate to the students' age, as examined in earlier chapters.

Routines

Routines are ways of doing things in the classroom that both students and teacher have established (Gump, 1969). Each routine should have its own set of explicit and implicit rules that are known to both teacher and students (Edwards & Mercer, 1993). Easily recognised routines are the common organisational ones like entry to a room, and timetable sequences. In a high school, this could simply be having Mathematics at 9.00 am on a Tuesday, or in a preschool, it could be having outside play time prior to morning tea. There can also be routines for more complex teacher-student interactions, such as for story telling, for a whole class discussion with students seated at their desks, for a whole class discussion with students seated more informally on a carpet, for using a "tinkering table" in early childhood settings, and for doing experiments or laboratory work in small groups. The list of possible routines that a teacher draws on could be quite lengthy. Some, such as timetabling and entry to rooms, may be dependent on school policies. I have found that early childhood and primary teachers tend to use a greater variety of routines than upper primary and secondary teachers, possibly reflecting the greater variety of tasks the students engage in. An advantage for teachers of later grades is that the rudiments of many routines have already been established by teachers in earlier grades, malung their task much easier.

Every lesson or session can be considered as consisting of a series of routines, with transitions from one routine to another (Coles, 1992). Routines do not depend on particular subjects and are independent of the content of the lesson or session, though obviously some types of tasks will be more closely associated with particular routines. For instance, using equipment or materials in small groups would usually be associated with science or craft work.

Take a moment to reflect on the list of routines you generated from Learning Project 32, and note similarities or differences in the way you used the term to the way I have defined it.

Establishing routines

An important characteristic of each routine is that it is a social event which has its own set of "rules" which define how everybody involved should behave and talk. The rules in one routine may allow or even encourage student talk, for example, but in another routine student talk may be prohibited. None of these rules would be contradictory to the general social tone of the classroom, so routines may be considered as subsets of the overall classroom social climate. Routines work well because when the teacher gives a command which initiates the routine, both the students and teacher know what the routine involves and how to behave. The rules have become common knowledge in the classroom (Edwards & Mercer, 1993). New students or teachers who are unfamiliar with the established routines of a class will have difficulty coping, for they have to rely on following the lead of the others in the class. To feel that they belong to the classroom, both teachers and students need to know the signals that initiate a routine and the behaviours and language associated with it, so that they are able to function at an automatic, subconscious level (Appleton, 199.5).

It is best if routines are established in the first week of contact with a new class, as this will promote orderly class work and higher on-task behaviour (Brophy, 1987). To establish a routine, the teacher firstly needs to clearly think through the explicit and implicit rules associated with the routine, as well as how to initiate it. Some rules may already be known from established routines, and can readily be incorporated into the new routine. The rules need to be explained to the students in a way appropriate to their age. Sometimes it is useful to involve the students in making up the rules. Then several practice sessions should follow, where the teacher emphasises the rules and the whole routine is worked through. Depending on the age of the students, and the complexity of the routine, it should be possible for the heavy emphasis on the rules to be withdrawn after a few days. However, bear in mind that the students will test the spoken rules against their implementation in practice so that a process of negotiation will go on between teacher and students. It is therefore critical that the teacher be consistent with the application of the rules, and avoid ambiguity in implementation. Control problems will quickly emerge if the teacher is inconsistent. A common mistake made by teachers who try to begin practical work in their classes with students who have never done this before, is to launch straight into an activity without firstly teaching the routine of using equipment in a small group. The result is often chaos, with the teacher unwilling to try small group experimentation again because it "didn't work."

Learning Project 5[illegible]

What routines would be useful for teaching science in your sector of schooling? Which have you used in your teaching?

In your group discuss how you would go about establishing any new routines.

Teaching Techniques

Within some routines, there will be particular teaching actions taken by teachers to organise, manage, or facilitate the students' learning, which I call teaching techniques (or skills, if you prefer). As for routines, many teaching techniques are common to all subjects. Teaching techniques include such teacher behaviours as asking students questions, eliciting students' ideas, explaining an idea, and giving instructions.

Pause for a moment to reflect on the list you made in Learning Project **32,** and identify any which might be teaching techniques.

Because these are general teaching behaviours, I will not elaborate at any length on them, but will attempt to highlight a few important aspects for those techniques used frequently in science teaching.

Asking questions

Asking students questions can serve a number of purposes, from ensuring students are on-task as a management technique, to encouraging students to think about the information available to them. Some of the problems with asking questions were outlined in Chapter Two. Issues to be aware of include:

- The type of question being asked. Questions can be closed (convergent) or open-ended (divergent). Convergent questions, such as "What temperature does water boil at?" usually require a brief answer and frequently involve simple recall of factual information. Divergent questions, such as "What do you think might happen if an astronaut released a pen while orbiting the earth in a space shuttle?" demand a greater depth of thinking, and may have more than one possible answer. When considering the type of question being asked, Bloom's Taxonomy (Bloom, 1956) is a useful aid. The different levels of questions he suggested, in order of complexity, were knowledge, comprehension, application, analysis, synthesis, and evaluation. It is important to have a mix of different levels of questions.

- The distribution of questions. The tendency for teachers to ask questions of students sitting in a narrow arc in ,front of them was mentioned in Chapter 2, as was the tendency for boys to dominate when bidding for the floor to answer questions. It is helpful to be consciously aware of patterns of question distribution we are using and take corrective steps. A useful technique is to have a colleague observe a lesson while we teach and plot the distribution of questions we use.

- Wait time after a question is asked. The short wait times used by teachers was also noted in Chapter 2. Short wait times may be suitable for convergent recall questions, but are inappropriate for divergent questions. Minimum wait times of three seconds are recommended, but sometimes a wait time of 10 to 15 seconds may be appropriate. Rowe (1978) has listed numerous benefits to the students' learning resulting from increased wait times. It is also useful to encourage student-student discussion after asking divergent questions. To achieve this, wait time 2, that is, the pause after the first student's response to the question, should also be extended. The normal interaction pattern in a teacher-led whole class discussion is teacher-question — student-response — teacher-acknowledgement. A longer wait time 2 encourages a pattern of teacher-question — student1-response—student2-

response—student3-response—teacher-acknowledgement. This pattern enhances student learning considerably.

Learning Project 34

The next time you teach a science lesson, try to organise for a colleague to observe some of your teaching where you engage the whole class in a teacher-led discussion or explanation. Choose one of the above aspects of questioning for the colleague to observe. Discuss how the observations should be made, and talk about the findings with him/her.

Explaining an idea

This may sound like a silly thing to say, but before you explain something to a class or student, you need to be sure that what you are saying is accurate. If you are not sure about the accuracy, say so. If you know very little, find someone who knows more, or find some other information source. I mention this because it seems that some teachers feel that their image and authority are challenged if they reveal to the students that there is something they do not know. In fact the less they know, the more likely they are to try to bluff their way through an explanation rather than admit their ignorance.

The timing of your explanation is important. If you try to explain an idea to the students because it is in the curriculum, or your lesson plan, or will be in the test, without first creating a “need to know,” the students are not likely to be interested in listening, let alone trying to understand. Younger students will quickly give non-verbal signals about not attending. Older students are usually more polite: they pretend to listen while assuming all the non-verbal behaviours characteristic of an avid listener. In the high school, some students will become quite open about their feelings regarding perceived irrelevant information being delivered to them verbally. Engaging in lengthy explanations without creating a need to know can result in behaviour problems at any level of schooling.

It is wise to think carefully about how to make the idea you are explaining understandable to the students, and what level of complexity is appropriate to the circumstance. For instance, early childhood students exploring objects which float or sink would be quite happy to know that floating depends on both an objects’ size and mass. Upper primary students would be able to cope with explanations relating to relative densities, such as, “The stuff in the potato is packed in more tightly than the stuff in the apple.” However, lower secondary students would be able to examine upthrust forces and displaced water as explained by Archimedes. It is very helpful if you have already diagnosed what the students know, so you can start your explanation from there. This may involve malung a story out of it, using an analogy, using frequent examples from the students’ experience, or using a model. Scaffolding is a useful learning approach to keep in mind when giving explanations.

Characteristics of a good explanation are that it is clear, focused on the topic, and brief (Smith & Land, 1981). Clarity requires a minimum of word fillers like "OK" and "um," and avoidance of long rambling statements. For an explanation to be focused, it should deal with the point and not be sidetracked. Ideas need to be continuously referred back to the main point. Examples and analogies help. Attention spans of students, particularly younger ones, are brief when listening. The younger the student, the briefer should be the explanation.

A trap is to assume that because you have explained some science idea to the students, they will not only understand it but remember it accurately. Sometimes an idea may make sense when it is explained, but be a mystery again the next day. That is, scaffolding may have worked effectively while giving the explanation, but support was withdrawn too early for the student to sustain the level of comprehension.

Giving instructions

Since an important aspect of science education involves using equipment, giving clear instructions about its use, safety, and perhaps the activity or laboratory procedure to be followed is critical. As students' reading proficiency improves, it is tempting to resort to written sets of instructions, and even to published laboratory manuals. It should never be assumed that such instructions are meaningful to students, and that they can follow them and understand their purpose.

When giving instructions verbally the principles mentioned in explaining ideas are also relevant. You should be clear in your own mind about the instructions you will give. The instructions you provide should be brief, clear, and to the point. The sequence should be given without backtraclung. If the instructions are lengthy or complex, you should also consider giving them in subsets, and pausing to review them before proceeding. Most students find it helpful if you use aids such as demonstrating some or all of the instructions, and providing a written list or series of pictures.

Techniques to elicit students' ideas

An important principle derived from constructivist theories discussed in Chapter Four is the elicitation of students' ideas. There are several well established techniques which can be used to do this.

Conversations. Conversations are similar to the interview research technique described in Chapter 4. A conversation can be held with one student, a small group, or less successfully, with a whole class. The main purpose of the conversation is to find out the students' ideas about the topic, which is usually introduced with some focus situation or picture.

Sharing stories. Students share stories about experiences, interpretations of information, or activities conducted. The sharing usually takes place in small groups, though under some circumstances could be in a whole class situation.

Concept maps. Concept maps, also called semantic webs, are ways of representing ideas and relationships between them in diagrammatical form.

Surveys. Written surveys are convenient but less reliable means of obtaining students' ideas. They can be open ended, or multiple choice. Open ended surveys where students may write up to a paragraph in response to a question, suffer the difficulty of interpretation of the question by the student, and interpretation of the answer by the teacher. Multiple choice questions are only helpful if the choices are genuine student responses derived from research data, and still suffer the problem of the students' interpretation of the question and the available choices. However, surveys are the most effective means of gauging the ideas of a larger number of students.

Techniques to challenge students' ideas

Another important principle derived from some aspects of constructivism is to challenge students' ideas which reveal some misconception or misperception. There are many techniques to do this, but all need to be used sensitively so students do not feel they have failed. Students are particularly sensitive to the teacher asking for another answer to their question when an incorrect one is given. This is a common classroom pattern which the students may assume always applies. Consequently, if the teacher accepts all answers without evaluation, the students need to be made aware of this changed pattern of responses.

Testing all ideas. All ideas are tested against experience under controlled conditions to determine which is the best. This needs to happen to both misconceptions and scientifically correct ideas, or the students will quickly recognise the implicit message of "incorrectness."

Presenting an alternative. The teacher presents or directs the student to an alternative idea to consider along side his/her idea. Both ideas can then be weighed up in terms of the available evidence.

Inviting the student to explain further. When an incomplete or "good enough" idea is suggested by a student, an invitation to explain more detail will often reveal to the student gaps or inconsistencies in the idea according to the available evidence.

Pointing out aspects of an event not noticed. Sometimes a student's idea is based on a misperception of an aspect of an experience or activity/experiment. This can occur if something is not noticed, or if the student thinks something occurred when it did not. Merely pointing out the misperception sensitively, and helping the student to note the event again is usually sufficient.

Teaching Strategies

A teaching strategy is a series of routines linked together in a lesson or part of a lesson. There are numerous teaching strategies in science, and many are also used when teaching other subjects. Unfortunately terminology for teaching strategies is inconsistent, and can mean different things to different people. For example, what I have called a teacher lecture strategy may also be known as direct instruction, teacher explanation, the transmission approach, or traditional teaching. Here I will discuss a limited sample of common and useful strategies in science. Please note that no one strategy should be used for all lessons. Strategies such as those described here should articulate with a teaching approach being used to teach a unit.

The teacher lecture strategy

The teacher lecture strategy usually fits within part of a lesson, and may sometimes constitute the whole lesson, If crafted carefully, it should provide a scaffold for students' learning, though this is best achieved when working with a small group rather than a whole class. The strategy would normally have the following or a similar set of segments:

1. Focus. This would usually involve a brief teacher-to-whole-class routine, such as a teacher demonstration, or a teacher-led discussion. Its purpose is to focus the students' attention onto the topic, arouse their motivation, and to aid them in recalling relevant personal experience so the information to be provided can be suitably contextualised.

2. Presentation. This would usually consist of a series of teacher-explanation whole-class and teacher-led whole-class-discussion routines. The points to be made would usually be organised as a logical series, each of which would be explained using examples and analogies consistent with the students' experience. Demonstrations, pictures or diagrams would be used if at all possible. This would be followed by a discussion phase to help students think about the information and allow the teacher to determine what sense the students were making of it. The presentation should provide a verbal scaffold to aid the students' learning.

3. Application. Several forms of application are possible. The students may work individually on an written application task using the individual-seat-work routine, or they could be asked to individually make a copy of what had been presented using an individual-carpet-work routine. Alternatively they could work on a group task using a group work routine. The task would always involve a direct application of the material covered in the presentation. This segment also helps students engage with the content presented, and relate it to their own ideas. It provides a further opportunity for the teacher to determine the level of understanding being achieved and provide further assistance as necessary.

Variations of the teacher lecture strategy exist for teaching small groups and individuals as well as the whole class version described above. This teaching strategy draws heavily on the explaining an idea teaching technique, but also involves the asking questions technique. This strategy can be useful for presenting students information which is not readily available elsewhere, or for helping them make sense of information obtained elsewhere, but which is difficult for them to understand. This strategy can be highly effective when used as part of a suitable teaching approach. When it is used is crucial, as it has most benefit for students after they have reached their own conclusions from an investigation.

The investigation strategy

Another common teaching strategy in science can be called the investigation strategy. This too may be known under other terms such as discovery, and enquiry. However, I would use these terms reluctantly given the problems outlined in earlier chapters about guided discovery. You should identify the differences between this strategy and those described as guided discovery. The investigation strategy may often fill a whole lesson, but could be used as part of a lesson in conjunction with another strategy such as the teacher lecture strategy. If the data collection phase is a lengthy process, it may extend over several short lessons. **A** common set of segments would be:

1. **Focus.** ***As*** in the teacher lecture strategy, this could involve a brief teacher-to-whole-class routine, such as a teacher demonstration, or a teacher-led discussion. More commonly however, it would be a brief exploratory hands-on activity using a small-group-using-equipment routine. **A** routine for distributing equipment would also be needed in this case. **As** before, its purpose is to focus the students' attention onto the topic, arouse their motivation, and to aid them in recalling relevant personal experience so the information to be provided can be suitably contextualised. Students should be encouraged to share their ideas and previous experiences as they work.

2. **The setting.** The purpose of this segment is to clarify the goal and procedure for the next segment. It would usually draw on a teacher-to-whole-class routine using the giving instructions teaching technique, but may involve a whole-class-on-carpet or similar routine where the teacher and students jointly plan the procedure. The goal may be derived from a curriculum or laboratory guide, the students' own questions, or a problem posed by the teacher. The derivation of the goal would also be influenced by consideration of the students' preconceptions obtained earlier. The subsequent segments are planned in detail, so that the students are aware of the purpose of collecting and analysing data. If possible they should be involved in the planning so they have some personal sense of understanding and ownership of the task.

3. **Data collection.** This involves some form of hands-on work, usually in a small-group-using-equipment routine. When the students work toward the set goal, they gather information or data based on observations, perhaps malung measurements. Depending on the age of the students and the complexity of the task, it may be necessary for the students to record the

information as it is gathered. How this is to be recorded is usually decided beforehand in segment 2. While individual notebooks are commonly used for data recording from middle primary grades, group or even class data records can be very useful. The teacher needs to keep in mind the potential problems about students missing observations mentioned in Chapter 4.

4. Data processing. Data processing involves making sense of the data gathered. The data processing will always be directed toward helping students arrive at the predetermined goal. It may mean that the data has to be transformed in some way to make it more understandable. For instance, drawing a graph may reveal a trend not obvious from the raw data. Students will usually need help in thinking of these transformations and how to do them. The students are also encouraged to think about the data and its meaning by making inferences and hypotheses. Naturally, this sense-making occurs in the broader context of the science topic being investigated, the goal identified in segment 2, and the science ideas being drawn upon to explain the data (or perhaps the data are being used to construct an aspect of the science ideas). Routines used in this segment may be quite varied, perhaps including teach-to-whole-class, small-group-discussion, or individual-seat-work routines.

This strategy can be used whenever students need to be involved in some practical work which is directed toward obtaining information about some phenomenon. Note that it would rarely be inductive in nature, which is a characteristic of “guided discovery.”

The concept substitution strategy

This strategy has been developed more recently to deal specifically with known misconceptions students may hold, usually those which are due to confusion between two concepts or terms, such as heat transfer and temperature, or electric current and electrical energy (Grayson, 1996).

1. Identify the misconception. This can be done using a variety of techniques, ranging from interviews to concept maps.

2. Devise an activity or incident that will show that the misconception cannot hold, i.e. a discrepant event. The activity or incident must present obvious evidence that the misconceptions held by the students are inadequate to explain the outcome. For example, to confront the idea that electric current is used up in the bulb in a circuit, ask the students to predict the brightness of three bulbs in series in a circuit.

3. Describe, predict, implement. The teacher describes the activity to the students, who are asked to predict the outcome. They then implement the activity and observe the actual outcome, which should be different from the prediction based on their misconceptions.

4. Introduce the scientific term. The teacher now introduces the scientific term or concept in relation to the activity, with no further elaboration of it (that can come later). For instance, in the above example, all three bulbs are of equal brightness because electrical energy rather than electrical current is used in the bulbs. Since many such misconceptions are based on incomplete knowledge of scientific terms and students' intuitive ideas, this allows students to transfer those intuitions to the new science term (electrical energy) rather than associating them with an inappropriate term (electric current).

It is helpful for the teacher to be aware of content areas where students are likely to have misconceptions, so students' potential learning problems can be anticipated. The teacher can then select appropriate teaching approaches which include strategies like this one, so that misconceptions based on intuitive conclusions can be dealt with early.

Conceptual change strategy

This is a more general strategy for developing students' cognitive understanding of a particular topic, which is useful for all sectors of schooling. The main segments are derived from Smith and Neale's (1989) discussion of conceptual change teaching.

1. Introduction. The teacher begins the session by commenting on the content or activities which will be covered during the session. Links to other lessons or sessions may also be pointed out.

2. Review. The teacher tries to get the students to relate the current work to previous lessons by inviting them to describe problems, findings, and conclusions from previous work.

3. Session development. The teacher now presents a new problem or some new information. As he/she does so, she/he elicits students' ideas about the topic, which are used as a basis for discussion. The students' ideas are probed so that their ideas are clarified.

4. Investigations/activities. The students now engage in practical work arising from the problem or new information. They test ideas which emerged from the discussion in segment 3. They might work individually, or in small groups.

5. Representation. The students record the results of their practical work using appropriate means, such as drawing, graphing, tracing, or writing.

6. Discussion of activities. The students now present their results to the class. They are expected to include explanations for their results, and comment on the adequacy of those explanations. Wider discussions in the

class exploring satisfactory explanations may emerge from these presentations.

7. Summary or tie up. The teacher or the students conclude the session by summarising the findings, and pointing out links to findings from other sessions and lessons.

Other strategies

Other well documented teaching strategies used in science are POE (predict what will happen, observe what happens, explain what happened), PMI (pluses for, or good things about the idea, minuses for the idea, and interesting things about it), PMS (identify a problem, decide a means of solving it, and arrive at a solution), and KWL (what do you already know, what do you want to learn, what have you learned?).

A final group of strategies worth mentioning are those involving the presentation of a discrepant event. A discrepant event is something which has an unexpected outcome. For example, if you saw a person pick up a pot of coffee which a few seconds earlier had been boiling vigorously, and quickly drink the lot, you would be surprised that the person was not injured or in pain. You might be similarly surprised to see a wooden sailing boat with sail fully extended from a small fan at the stern of the boat, sitting motionless in a tub of water — especially after seeing it quickly moving the length of the tub a few moments before. These types of discrepant events are the sort suggested by Suchman (1966) and others as a way of introducing a unit of work in science. The discrepant event is often presented as a teacher demonstration, sometimes on film, but it can also involve hands on work with the students directly involved. Friedl (1995) and Liem (1987) have outlined a number of discrepant events as well.

Learning Project 15

There are many other possible teaching strategies in science. Identify some (say, two) for your sector of schooling, and write a summary of the main segments of each, in a similar way to the examples provided above.

In your group share the teaching strategies you identified. How should each be used?

What do you see as advantages and disadvantages of each of the teaching strategies outlined here? When would it be best to use each?

Constructivism and the teaching strategies

It may be tempting to think that, for example, the investigation strategy is a "good" teaching strategy and that the teacher lecture strategy is "bad" because educational rhetoric gives the impression that teacher telling is inappropriate, or because the investigation strategy seems to fit well with constructivist philosophy. This would be a mistake, for both, and other, teaching strategies are important in constructivist based teaching. It depends on how and when they are used. Timing is crucial, and is usually determined by the overall approach to teaching the unit of study. For instance, if a unit commenced with a teacher lecture strategy, it may cause implementation problems and learning difficulties for students. However, if the teacher lecture strategy is used after an investigation strategy, the information provided may be much more meaningful to the students. The teaching approach selected (see the next section) is consequently quite important to the success of a unit.

Another important aspect of teaching strategies and routines is the nature and type of interaction which occurs between teacher and students. There are several aspects from earlier chapters which impinge upon teacher-student interaction, such as constructivism, gender inclusiveness, and ethnicity.

Teaching Approaches

I view a teaching approach as a way of structuring and linking several lessons which are focused on the same topic. A teaching approach would therefore consist of a series of teaching strategies, possibly with linking routines. An equivalent term 'might be a teaching model. It would normally contain several phases, each of which would be a teaching strategy or a linking routine. A teaching approach would usually cover one unit of work for a topic, and would most often include several segments of practical work. Since teaching science using topic-based units extending over several weeks is a sound planning and pedagogical approach (see Chapter 8), having a teaching approach which integrates the instructional procedures across the unit results in more effective teaching and learning.

There are many teaching approaches used in science, some with several variations. Those outlined here relate in varying degrees to constructivist learning theories. They also can be related to the contemporary view of science discussed in Chapter 5. I have chosen several of the more useful teaching approaches to outline in some detail as a resource for your own planning, though you will undoubtedly be able to think of others. Nor should you assume that because some approaches have not been included they are not useful. For instance, the use of simulations and drama can be a very powerful approach to teaching aspects of science such as astronomy.

Interactive approach

The interactive approach was proposed as a constructivist-based approach by Biddulph and Osborne (1984). It has also been called the question raising approach. It is one of a group of approaches which are based on negotiation of the curriculum with the students. In this approach the negotiation occurs by inviting the students to ask questions, some of which are chosen for investigation. The students are also involved in planning how to obtain information which might help them devise answers to the selected questions. There are several variations to the approach. It is applicable from early childhood settings to high school, though some upper high school teachers may feel that the students do not cover the content quickly enough. However, this is usually compensated for by in-depth learning of the work covered.

1. **Preparation.** The unit is usually based on a topic, which should be chosen from the school curriculum or work plan. It is important that you clarify your own understanding of the topic before beginning so you are aware of any misconceptions and gaps in understanding which you might have. You should also discover your students' understanding of the topic, and then assemble resources for the exploration and investigations which might emerge from it.

2. **Exploration.** Words can mean different things in different contexts, so it is important to clarify the topic with the students. This can usually be done using some pictures or objects as a focus and inviting the students to explain their own thoughts about them. This helps you establish what they already know, so you can use their understanding as a starting point. This component should not be lengthy, especially for younger students.

   The students should then be given a hands on exploratory activity or experiment to conduct, though sometimes a demonstration may be appropriate. This allows them to become familiar with the phenomenon to be investigated, and will serve as a basis for raising questions. It is therefore important that the exploratory activity be chosen carefully.

3. **Students' questions.** Information about questions that other students have asked on the topic can be helpful, as this will provide indications of the types of questions your students might ask. Questions on a number of topics have been published. Whether this information is available or not, give your students the opportunity to ask questions emerging from the exploratory activity. To obtain the questions your students might raise, it is best to invite questions explicitly, ensuring that they understand that you want genuine questions. Keep a record of the questions asked, and help the students select questions which will be investigated. You may wish to exclude some questions because they are not able to be investigated fruitfully by the students, or because they do not fit within the parameters of your curriculum. **As** much as is possible, the students should have ownership of the questions raised and selected.

   It is often wise to pause for a day or two after this component so you can engage in some further planning based on the actual questions selected. This will involve reviewing the information sources available which are pertinent to the selected questions, working out likely activities and experiments, and assembling resources.

4. Specific investigations. Investigations are then planned which will provide information that will help the students arrive at answers to the selected questions. Note that the students' learning is more effective if they feel that they have done the planning for the investigations. However, you would normally bring to such planning sessions your own ideas about appropriate practical work which would be fruitful. Depending on the age and experience of the students, help in planning will be necessary. Even older students will need to be reminded about conducting fair tests (controlling variables), judging ideas on the basis of evidence, seeking alternative information sources, and thinking of appropriate experiments.

   It may be necessary to teach the students specific conventional terms to facilitate communication, teach a science concept which is needed in order to understand the answer to a question, or to teach a specific skill needed for an investigation. Investigations usually go on for several lessons, particularly if more than one question has been selected. You will constantly need to review progress in terms of the current question to maintain lesson continuity. Teachers who have used this approach have often found that information sources available to the students do not always provide information relevant to their selected questions, and that data from their experiments are sometimes ambiguous. If the you are not an expert on the topic, it is best to invite someone who is into the classroom to help the students finalise their answers to their questions. But do not do this until the unit is drawing to a close.

5. Problem solving. This phase is my own addition to those originally proposed by Biddulph and Osborne (1984). The students should now be given the opportunity to solve practical, real-life (to them) problems arising from the questions. In trying to solve the problems they will draw on their newly acquired knowledge. This phase is quite important in helping them gain facility with the knowledge they have gained.

6. Reflection. To close the unit, some form of reporting the students' answers to questions,and their solutions to problems should be used. Take care though in having too many verbal reports, as they can become long and tedious, with the resultant loss of interest and enthusiasm. Students' reports also provide an opportunity to assess their learning and progress toward the learning goals. It may be possible to integrate this phase with other subjects like language, such as when teaching about written reports.

Comparing approach

The comparing approach (Harlen, 1985) is designed around testing consumer items to determine the "best buy." However, it can be adapted to some other situations where comparisons might be made, such as, "Which is the best soil for growing lettuce?" It is suitable for all year levels.

1. **Preparation.** Choosing the topic from the curriculum and framing it as a comparison question is the first thing to do. It is also helpful to estimate types of tests which may be conducted to make the comparisons, so resources can be prepared. Also find out what the students know about the topic and the comparison question or objects.

2. Posing the comparison question. The unit is initiated with the introduction of the focus question, "Which is the best ...?" For example, "Which is the best paper towel?" The context for the comparison also needs to be established to set boundaries for the investigations which follow.

3. Defining "best" operationally in this context. This next phase involves students discussing the notion of "best" in relation to the posed question, usually in small groups. It is often helpful for groups to hear what others have decided, so a report system to the teacher and class is useful.

4. Planning tests. The students now plan tests which will give information about their idea of "best." Depending on the age of the students, you will need to provide some assistance, particularly in devising fair tests. Plans should be reported to you before the students implement them, and you may want to consider having them report to the class. It may be helpful to assign tasks to different groups so a large number of tests can be conducted in a shorter time. For many topics it is also necessary to devise tests informed by current scientific thinking. This will mean students must search for background information about the topic. For example, if exploring the best soil for growing lettuce, they would need to search for information about soil types.

5. Conducting tests. The planned tests are conducted and data gathered. The idea of repeating tests to establish the validity of data needs to be emphasised. **As** well, the notion of redesigning a test to improve it needs to be introduced.

6. Evaluating data. The students evaluate their data, and reach a conclusion about what is "best." New tests may need to be devised if data are found to be contradictory, or if a test was found to be unsatisfactory. If groups are working independently on different aspects of "best," it is often helpful if findings are shared in the class. The conclusions reached are compared to students' preconceptions identified earlier, and to the scientific ideas related to the investigation.

SCIS approach

The *Science Curriculum Improvement Study* (SCIS), developed in the 1960s, proposed a teaching approach which has endured the test of time. However, some modifications have recently been proposed. The version adopted in *Primary Investigations* will be examined here. **A** very similar version was proposed by Hill, Boylan, Francis, and Bailey (1987). They are both suitable for all year levels. The *Primary Investigations* version has been described in a recent primary science publication sponsored by the Australian Academy of Science. It was adapted from some BSCS (*Biological Science Curriculum Study*) sets of materials developed for both primary and secondary levels.

1. Engagement — engage the learner. This first activity or set of activities indicates the learning task and topic to the students. It helps students make connections between past and present learning experiences, and organises students' thinking toward the learning outcomes of current activities. These activities mentally engage the students with an event or question. Engagement activities capture the students' interest and help them to make connections with what they know and can do.

2. Exploration — explore the concept. This is intended to provide students with a common base of experience within which you can identify current concepts? processes, and skills and upon which you can build. Provide experiences in which the students explore the concept further. Give them little explanation and few terms at this point, because you want them to define the problem or phenomenon in their own words. The purpose at this stage is for the students to acquire a common set of experiences from which they can help one another make sense of the concept. The students must spend significant time during this stage of the approach talking about their experiences? both to articulate their own understanding and to understand another's viewpoint.

3. Explanation or solution — explain the concept and define the terms. Here you focus the students' attention on a particular aspect of their engagement and exploration experiences. You provide opportunities for them to demonstrate their conceptual understanding? process skills, or behaviours. At this stage you also have the opportunity to introduce a concept, process, or skill. Only after the students have explored the concept, do you provide the scientific explanation or technological solution and terms for which they are studying. They then use the terms to describe what they have experienced? and they will begin to examine mentally how this explanation fits with what they already know.

4. Elaboration — elaborate the concept. This section challenges and extends the students? conceptual understanding and skills. Through new experiences, the students develop a deeper and broader understanding, more information, and adequate skills. The remaining activities in the unit serve to help the students elaborate on their understanding of the concept. They are given opportunities to apply the concept in unique situations? or they are given related ideas to explore and explain using the information and experiences they have accumulated so far. Interaction between the students

is essential during the elaboration stage. By discussing their ideas with others, the students can construct a deeper understanding of the concepts.

5. Evaluation — evaluate the students' understanding of the concept. This final activity encourages the students to assess their understanding and abilities. It provides opportunities for you to evaluate students' progress toward achieving the educational objectives. The final activity in the unit has a dual purpose. It is designed for the students to continue to elaborate on their understanding and to evaluate what they know now and what they have yet to figure out. You can also use this phase to assess where the students are in their construction of the concept. Although the key word of the phase is "evaluate," the word does not indicate finality in the learning process. Indeed, the students will continue to construct the understanding throughout their lives.

A generative teaching approach

In this, the last teaching approach I shall describe, we see a greater emphasis on the social context. It has been developed by Karen Meyer and Earl Woodruff (Meyer & Woodruff, 1994; Woodruff & Meyer, 1995). I have reorganised their description slightly for consistency with my other descriptions of approaches. As with the other approaches, the phases are not rigidly organised in sequence, but are fairly flexible and may have some phases repeated. Do not confuse it with the approach with a similar name proposed by Osborne & Freyberg (1985). As presented, the approach suits middle primary to secondary, but with some small adaptations, could be used across all Year Levels. It has many similarities to the *Contrastive Teaching* approach used by Schecker and Niedderer (1996) in secondary classes.

1. Preparation. A key aspect of the preparation is identifying a sequential set of activities or laboratory exercises, all related to the topic, which are designed to require increasing explanatory power and coherence. Without a coherent explanation, the results of the activities appear to be unrelated or discrepant. The activities are selected using knowledge of common student misconceptions about the topic and an understanding of the scientific principles involved. They represent key aspects of the scientific principles related to the topic, and are sequenced to deepen understanding of the topic.

2. Students make predictions. The initial activity situation or laboratory experience is described to the students, who are then asked to make and record a prediction about what will happen. Predictions may be discussed, but no judgements are made about them. This phase engages the students in the task, and challenges the coherence of any explanations they are arriving at.

3. Conducting the activity or laboratory experience. By actually doing the activity, the students determine the accuracy of their predictions. It allows

them to deepen their understanding through manipulation and observation, including "what if" experimentation, hypothesis testing, and possible investigations of their prior beliefs.

4. Small group discussion. The students discuss their results in small groups, brainstorm ideas, and work toward a coherent explanation. The group members work together to advance their understanding. If Phase ***3*** is conducted in small groups, this phase may coincide with it.

5. Whole group discussion. The small groups feed the results of their discussions to the whole group, either through formal reporting processes, or informal discussions. The whole group also functions to further understanding by evaluating ideas, brainstorming, and developing coherent explanations.

6. Repetition of phases 2 to 5 for each activity in the planned sequence. From each activity and consequent discussions, the students should be progressing their understanding of the topic and broadening their awareness of the circumstances and conditions associated with it. After a few cycles, the teacher may move to Phase 7 to introduce some aspect of the scientific explanation, and then reengage the students in some further activities. The extended time for repeated cycles is necessary as students need time to develop and discuss their explanations and the implications of them.

7. Provide the scientific explanation. If this is provided too early, students tend not to work toward their own understanding, but merely defer to some external authority such as the teacher or a textbook. It is best introduced after students have developed their own explanations and communicated them to the whole class.

Learning Project 36

Which of the teaching approaches outlined would you feel most comfortable with in your own teaching? Why?

Think of the way you would go about teaching science at the moment. Could it be classified as a teaching approach? If not, what changes might be made?

In your group discuss the advantages and disadvantages of planning science teaching around topics and using an organising teaching approach for the topics. What would be the best way of organising this for your sector of schooling? What other teaching approaches are you aware of which might be useful in your sector of schooling?

Some common features

If you study the teaching approaches I have included here, you will see some similarities. The approaches all:

- take into account students' preconceptions, either prior to teaching, or during teaching;
- use some technique to engage the students early and provide some sense of ownership;
- use hands on as key components of sense-making;
- involve student discussion of both findings and conclusions;
- emphasise student growth in understanding of the topic toward the current scientific ideas; and
- require reasonable time frames for students to engage with the content.

These features all have their roots in aspects of cognitive and/or social constructivism. Most would also include social constructivist features of scaffolding via structured experiences and/or verbal interaction. Note that some of these features also relate to gender- and culture-inclusive strategies (such as student ownership and discussion). These, and perhaps other features you may want to add, should be kept in mind as you work towards extending your expertise in teaching science.

Other approaches

Remember that there are other approaches to teaching science which I have not outlined. These include the story-based approach described in *They Don't Tell the Truth About the Wind* (Fleer, Hardy, Bacon, & Malcolm, 1995), simulations, where the topic is taught within a drama simulation, and metacognitive approaches such as those used by Mitchell and others (Baird & Northfield, 1992). The hypothesis-generating approach, of which there is a number of versions, is also well known. For instance, one version, the cognitive conflict approach, was suggested by Nussbaum and Novick (1982). However, people who have tried this have not always found it to be successful since it seems to be most useful for dealing with deep-seated misconceptions.

Making up your own teaching approach

It is important for you to recognise that the teaching approaches outlined above are not complete, or "the answer" to teaching science. Nor are they made up by especially clever people. Anybody can devise very effective teaching approaches, or adapt existing ones to their own situation. You need to decide for yourself which teaching approaches to use for each topic as you come to it. Some approaches will not suit some topics, and some teachers may have difficulty using particular approaches in their own situation.

As an aid to devising your own teaching approaches, look again at the conceptual development model described in Chapter 4. The implications for teaching outlined for each part of the model provide a useful means of deciding what each phase of your own teaching approach might include.

Learning Project 37

Look again at the list of common features to the teaching approaches included. What other features would you want to add to describe teaching approaches which you think are desirable? Explain why you would add each feature. Are there any you would want to delete? Why?

Use the teaching implications for the conceptual development model described in Chapter 4 and your list of desirable features to devise your own teaching approach for a particular topic for your sector of schooling, or to adapt one of the teaching approaches outlined earlier.

In your group compare your lists of features for desirable teaching approaches. Also share and critique each others' teaching approaches which you have designed.

A Case for You to Work on

Choose one of the following cases to work on in your group. For your chosen case, plan the development of the topic for the teacher. If you wish, you could substitute the topic for one you are working on yourself.

- Joan, our early childhood teacher, is planning a theme on *Water*. She deliberately plans for a science component to include in the theme so she does not overlook it. For her science topic in the theme, she thought of focusing on *Floating and Sinking*. She chose the *Interactive Approach* to implement the science topic.

- Sally, our primary teacher, was preparing to teach her next science topic, *Forces*, to her Year 4 class. She decided the best teaching approach for this would be the *SCIS/Primary Investigations* approach.

- Julian, our secondary teacher, noticed that the next scheduled topic in his Year 10 Biology text was Cells. After initially considering the *Interactive Approach*, he decided on the *Generative Teaching Approach*.

Was the choice of teaching approach a good one? Why or why not?

Your Chapter **Review**

Take time now to summarise what you now know, that you did not know before starting this chapter. Think through each of the sections to identify particular aspects that have been new to you. You also need to make sure that this is more than just a "head knowledge" for you, so ensure you take the time to work out and embed these ideas in practice. At the earliest opportunity, for example, teach a new routine, try a new strategy, or work **with** a new approach.

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8

Planning for Teaching

What This Chapter Asks You to Do
In this chapter you will:

- Clarify your existing knowledge about planning for science teaching.
- Consider each of long term, medium term, and short term plans, and collect examples of these.
- Examine the normal planning frames teachers use in preparing for science teaching.
- Work with a framework for developing a unit (medium term) plan in a topic of your choice for your sector of schooling.
- Develop a short term plan from your unit plan.
- Extend your repertoire of teaching ideas for science.

Your use of this chapter will depend on your experience in teaching science. Novice teachers will have greater need than experienced teachers to become familiar with the ideas here. Though even if you have been teaching for many years, you may well find something here illuminating. However, since planning is a general issue in teaching, I will deal with it specifically in terms of teaching science. Before you go any further, complete Learning Project 38 to clarify what you already know about planning in science.

Learning Project 38

What types of plans have you seen or used in teaching science? Make a list.

What is the purpose of each? What are important features of each?

Experienced teachers do not seem to have as much planning written down, or as much detail, as novice teachers. Why do you think that might be?

In your group share your answers to the last questions. What level of detail do you think is appropriate for a beginning teacher? A teacher of two years experience? A teacher of ten years experience?

Does it matter whether the teacher stays with the same Year level?

Also compare ideas about important features for different types of planning.

Why Pian?

It is important to recognise that planning for teaching is somewhat idiosyncratic. **As** well, much of a teacher's planning is done in his/her head. That which is written represents only a. portion of the planning. The main purpose of planning is so that you know where you are heading in your instructional program, and others such as a relief teacher or an administrator can find out also. Your planning must consequently aid your memory of what you have mentally prepared, and communicate to others the essential components of your intentions. Experienced teachers therefore tend to have less written, and novice teachers tend to have to write more. Novice teachers may also need to convince others that they have thought of the range of necessary issues, so need to write more detail than they may normally. Experienced teachers' plans for the same work may look very different in the level of detail and/or the form of organisation and presentation. Consequently, there is no one right way of organising and presenting written planning. On the other hand, particular institutions may request a specific form of planning for consistency and ease of communication.

There are three levels of planning which are necessary, and which are done by every teacher. Some teachers, however, may combine some levels. I have called these long term plans, medium term plans (also called unit plans or topic plans) and short term plans, which include lesson plans and daily plans.

Long Term Plans

A long term plan is like a road map showing the unfolding of the science program for a class, and often a school, over a full semester or year. Its purpose is similar to that of having a map to find your way through some unfamiliar countryside. It is usually organised under the conceptual themes mandated by the syllabus or curriculum guide, such as Life or Living Things, and Physical Sciences or Energy and Matter. Under each theme there are usually lists of science topics such as Magnets, Constellations, Food Webs, and Erosion. The long term plan maps how the various topics are to be scheduled during the year, with expected durations for each topic noted. In some sectors of schooling, particularly early childhood, the list of topics is translated into integrating themes which are mapped across the semester or year. In sectors of schooling which are text-based, such as secondary, the map may be translated into text chapters. The long term map for each Year Level should. articulate with the plans for other Year Levels, so that particular topics are not repeated at the same Level each year, or unpopular yet important topics are not glossed over. Long term plans can, and possibly should, be constructed to allow for some elements of choice by the teacher and students.

The long term plan is frequently prepared at the school level or by a department like a secondary science department. Therefore not all teachers may be involved in preparing the long term plan, and may simply receive it from an administrator or curriculum coordinator. However, it is usually possible for the teacher to provide feedback for inclusion in the following year's planning. If the school or department does not organise any long term plan, then the task falls on the individual teacher.

In larger schools this can be problematic as use of equipment cannot be coordinated and organised in advance and there may be competition for resources. In early childhood and primary classes, such lack of planning sends the implicit message that science is a low priority and does not have to be taught.

Constructing a long term plan means taking into consideration aspects such as resource availability, time of year (crucial for some topics like seed germination, and static electricity), other school activities and subject topics, logical sequence and sequential development of prerequisite knowledge within and across grades, time needed for a topic against available time, syllabus and curriculum requirements, safety issues, and staff, school, or equipment limitations. For example, this is the time to decide that a particular topic should not be included because resources will not be available. Because they require coordination across the school, long term plans are best prepared by small committees of teachers rather than being efforts by one person.

The long term plan should be used as a basis for medium and short term planning, an important aspect of which is planning frames.

Learning Project 39

Find a long term plan relevant to your sector of schooling.
Identify its organisational features.
Find out how the plan is prepared and reviewed.

In your group compare organisational features of long term plans which you have examined. Also compare preparation and revision procedures for long term plans.

Planning **Frames**

When developing medium and short term plans for teaching, we use what have been called planning frames. These are key aspects of the implementation which have to be considered beforehand so our teaching may be successful, Our ideas of what constitutes success in teaching influence not only the choices of frames that we male, but the priority or sequence in which we contemplate them when planning. The sector of schooling we work in will also influence which frames we work with, and when.

Research has revealed the frames that teachers usually use when planning for science teaching. These are (Appleton & Asoko, 1996; Smith & Sendelbach, 1982):

- the syllabus or curriculum and long term plan
- a text and/or other resources
- the activities and experiences the students will engage in

- teacher preference for particular activities and experiences
- time
- management and order in the classroom
- equipment distribution, and
- learning goals for the unit/lesson

Surprisingly, teachers usually consider these roughly in the sequence listed. Note that learning goals are a long way down the list of priorities. There is some evidence to suggest that this low priority on learning goals contributes to limited success in learning achievement for students (Appleton & Asoko, 1996). However, I am not entirely convinced that teachers think of learning goals last. I believe that, early in their planning, teachers develop a preliminary conceptual goal for the unit of work. However, it seems that this is often not translated into specific goals for the unit or for lessons. The research also showed that teachers' planning frames do not include eliciting or considering the existing preconceptions of students, which should be an important facet of planning.

I suggest that, in your own planning, you consciously attempt to put learning goals and students' preconceptions at a high priority. The planning frames and their priority sequence I recommend are outlined below.

Concept or process gods?

When planning a unit, most teachers have some concept goals in mind, but they may occasionally have some process goals, some manipulative skill goals, or even attitude goals as longer term objectives. Early in the planning process it is important to clarify which type of goals are going to be the ***main*** emphasis of the unit. For instance, will the main outcome of the unit be acquisition of particular concepts, or will it be to improve development of specific process skills? This is a key decision, as it will influence the choice of teaching approach for the unit, and the way any practical work is integrated into the unit.

Medium Term Plans

Medium term plans, usually called unit plans, are based on the topics outlined in the long term plan, and specify the detail for teaching each topic. They frequently include the learning experiences which will be included, associated content, and the sequence which these would follow. Objectives or goals for the unit are usually included, as are considerations of resources and assessment procedures. Units planned around themes also show activities from all subjects being used for the theme. Units planned around a text chapter will often include page references and section headings. Articulation of laboratory work with classwork in secondary programs usually occurs at this level. A unit plan will most often outline the work for several weeks, but could be for as little as one week if there is considerable time devoted to the unit. It is usually done in advance, before the unit is commenced — though if the unit involves student negotiation of the curriculum, the introduction to the unit would be planned in advance, and the remainder of the unit after the student negotiation phase. A teacher drafting a unit plan would use the frames listed above in putting it together.

Unit plans can look very different. I have seen them organised in columns, as a sequence of headings, or as a web. The actual organisation is immaterial. What is important is that the unit plan prompts the teacher to consider appropriate planning frames, makes sense to the teacher, acts as a memory aid for details, and communicates to others who might need to refer to the plan, such as a relief teacher.

I believe that a unit plan is the most crucial planning phase for a science program. It is at this level that important issues for the effective learning for students is planned. This includes things like finding out any student preconceptions, identifying specific student learning outcomes as unit goals, selecting a suitable teaching approach which will sequence the activities and information available to maximise student learning, and helping students reach meaningful and scientifically accurate conclusions about their work.

In Figure 8.1, I outline a planning framework for putting together a unit plan, which includes the planning frames discussed earlier.

Selecting a topic for the unit. The first task is to select a topic. The topics from which selections could be made are determined by the syllabus or curriculum and the long term plan. If theme planning is used, the topic will be selected to fit with the theme. If a text is used, the topic will conform to the relevant chapter/s.

Finding out preconceptions. It is crucial that some notion of preconceptions be obtained at this stage. Other general preparation, such as collecting and perusing resources, may go on simultaneously, of course. You need to have either a good feeling for the types of preconceptions *likely* to be held by the students, or the preconceptions *actually* held by your students. The former can be obtained from experience with the topic in previous years, from colleagues who have actively sought students' preconceptions in the past, from resources which include them as background information, or from the literature. The latter can be obtained by interviews, conversations, a survey, concept mapping, or journal writing. If you have no idea about the students' preconceptions you run the risk of planning a unit which is either too difficult or is already well known to the students.

Devising a preliminary conceptual goal for the unit. Once you know your starting point, obtained from the curriculum and knowledge of the students' preconceptions, you can decide on a preliminary conceptual goal for the unit. This could be a fairly specific statement derived mainly from the curriculum guide, or may be a rather vague statement about the type of concept learning you think is appropriate for the age, experience and preconceptions of the students. This would always be framed by the curriculum guide or syllabus. For younger students a preliminary goal might be something like, "The students will learn some basic properties of magnets," or for older ones, "The students will learn about magnetic field strength." This goal will later influence your selection of activities and learning experiences. As mentioned before, your choice of a preliminary goal will always be influenced by the curriculum — particularly where performance outcomes are a mandated part of your program.

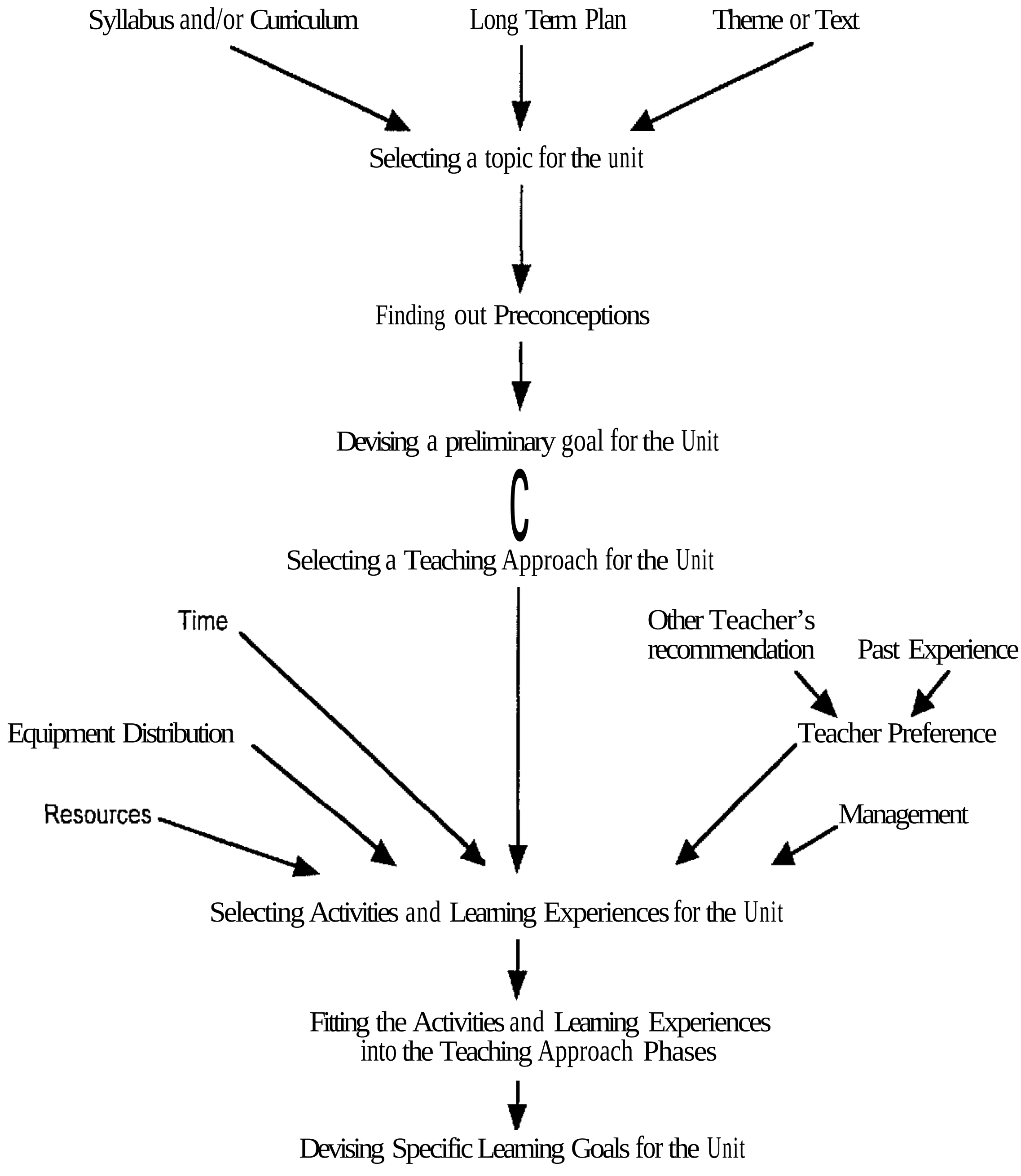

Figure 8.1 A framework for unit planning

Selecting a teaching approach **for** the unit. One of the factors which will determine the students' learning achievements in the unit is the teaching approach selected for the unit. Many teachers do not seem to plan this way, but experience and research are suggesting that this aspect needs to receive greater attention. In Chapter 7, some examples of teaching approaches were outlined. Approaches like the ones listed can be used, or you can devise your own approach based on your knowledge of learning theories. Not all approaches suit all topics or all Year Levels, so care needs to be taken. Part of the consideration of the teaching approach for the unit, is deciding which information sources will be available to the students, and when they will be made available. Whether some information source will be used as an authority, and whether that authority will be challenged, also need to be considered.

Selecting a teaching approach for the unit provides a carefully planned sequence of experiences for the students which acts as a scaffold for their learning. It gives coherence to the activities and learning experiences in which they will engage. In my experience, it is essential to choose the teaching approach early in planning, so activities can be chosen to fit with the approach. If chosen later, it becomes'difficult to fit a group of perhaps disparate activities and experiences into a sequence which may ultimately lack real coherence. If you were unable to elicit your students' preconceptions earlier in your planning, you should ensure that the selected teaching approach allows for this step. For example, the interactive approach allows you to identify preconceptions from the questions raised by the students, and the tentative answers they give to their selected questions.

Selecting activities and learning experiences **for the** unit. The main exercise in planning a unit is the selection of activities and learning experiences which the students will engage in. **A** number of factors need to be considered simultaneously by the teacher in making these selections. These were mentioned earlier as planning frames. The most important frames are the preliminary learning goal for the unit, and the preconceptions students bring to the learning situation. Learning experiences being considered for inclusion need to be weighed up in terms of these to see if they will build on what the students already know, and will help them progress toward the desired learning goal. Time is also a key factor, both in terms of lesson length and unit length. Each learning experience selected must therefore fit within the lesson times available, and the number of learning experiences chosen must fit within the total time available for the unit. Yet the totality of the learning experiences must be sufficient for students to achieve the desired learning.

Another key factor in selecting learning experiences is what might "work." For an activity or learning experience to work, teachers like it to have a predictable outcome, and for it to engage the students, hold their interest, and keep them busy. Experiences that fit this category are usually those which the teacher has used previously, seen elsewhere, or obtained from word of mouth recommendations — ideas shared by other teachers who pass on their experience. Busy teachers are often reluctant to try a new activity or experience just from reading about it in a resource book or curriculum. Activities and learning experiences for which resources are not available are rejected out of hand, regardless of how good they appear.

Another frame for selecting learning experiences tends to focus on management and equipment distribution. If the teacher visualises potential management problems when considering a learning experience or activity, she/he will often decide not to use it. While this process of simultaneously juggling a number of planning frames seems to be an efficient and effective way of selecting learning experiences for inclusion in a unit, the selection may have limited value for students' learning if any of the frames is not considered. As well, good teachers will take some risks, where they try new ideas and explore new ways of doing things.

As a final comment, please note that, if the selected teaching approach involves negotiation of the curriculum with the students, only the introductory activity or experience can be chosen before commencing the unit. Once that is done with the students, and the direction of the unit clarified through negotiation, then the remainder of the activities and experiences can be selected. That is, the planning is conducted in two stages.

Fitting the learning experiences into **the** teaching approach phases. This is the process of fitting the selected activities and learning experiences into the appropriate parts of the teaching approach. Selecting the most appropriate activity or experience to introduce the unit is particularly important to its success. Similarly, if information sources such as video, television, books, text, or a visiting expert are to be used, they are best scheduled into a teaching approach phase later in the unit. They are usually unsatisfactory experiences for commencing a unit. At this stage, consideration also needs to be given to the time available in lessons, and the gaps between lessons. If the flexibility exists, it is sometimes best to compress some teaching approach phases into larger blocks of time rather than having isolated lessons several days apart. It is wise to flag this and any other special preparation needs at this time, to make the preparation of the short term plan easier.

Devising specific learning **goals** for the unit. By this time, you should have a much clearer idea of where the unit is headed. You have used your preliminary goal to guide selection of the teaching approach and activities/experiences. You have mapped out both the activities/experiences and the sequence in which they will be used. Now you can identify specific learning goals for the unit which are realistic in terms of the students' existing knowledge and the requirements of the curriculum. You may also use some other resources to identify specific goals, but you may need to devise some yourself. If you have a syllabus or curriculum which specifies performance goals, you will need to review these to ensure that the unit is addressing them adequately, and perhaps alter your selection of learning experiences. It is usually helpful to think of goals which include some concepts, thinking (process) skills, attitudes, and possibly manipulative skills; but the main focus is usually on conceptual learning.

I think of goals as potential learning outcomes — targets at which I aim, or signposts pointing to where I wish to go. I can later assess how far from the target or my destination I actually am. This means that I need to have a good idea of where I am heading in the first place. You therefore need to select goals which are limited in number so they are manageable, and ones which are specific. This can be a real problem for some teachers. Many experienced teachers are reluctant to write their specific goals down, but if they do not, I find they tend to stay with the preliminary goal only. Many novice teachers try to write every possible goal, instead of being selective. **A** number of teachers seem to have trouble being specific, so I will focus on this a bit.

A common problem for many teachers seems to be in devising specific *concept* goals. Identifying process skills, attitudes, and manipulative skills does not seem to be such a problem. Devising specific concept goals can be a problem for some secondary teachers because they tend to get bound up in the textbook, and cannot see past it. Some early childhood and primary teachers tend to be uncertain about the content, so are reluctant to expose their supposed ignorance. **As** a way forward, I suggest trying to state the three of four main concepts which you would expect the students to gain from the activities and experiences planned, taking into account where they are starting from and the preliminary goal from the curriculum. You then need to ask yourself if these are worthwhile concept goals — why this concept and not another? If you are happy that they are worthwhile, you can now state each goal in precise terms. I am *not necessarily* advocating performance goals or behavioural objectives, though they can sometimes be useful. I have found that even some so-called performance objectives in syllabuses and the like are not precise.

I would say that a goal like, "The students will understand how current moves in a circuit," is not precise. My idea of a precise goal is, "The students will understand that current in a circuit moves from one end of the battery, through the wire and bulb, and back to the battery with no loss of current." Another comparison would be, "The students will know what fossils are," as opposed to "The students will know that fossils are formed from the hard parts of animals or plants, impressions of the soft parts, or from the whole animal being preserved." **A** final comparison: "The students will know the types of bonding in methane," compared to "The students will know that the carbon in methane forms single bonds with each hydrogen atom." I should point out that this goal is related to but different from knowing about the shape of the molecule or the nature of the bonds.

Assessment. A related issue to the choosing of goals, is assessment. It is often wise to plan assessment techniques and recording methods in conjunction with the selection of goals. You need to decide how you will obtain information that will enable you to determine the extent to which the goals have been achieved. You need to decide whether you need that information for all unit goals for all students, or a selection of goals for a selection of students. You will also need to decide how to record the judgements you have made. Assessment is examined later in Chapter 10.

Learning Project 40

Find some samples of medium term science plans that you have used or seen other teachers use. Identify the planning frames evident in the plans. Also note the level of detail and organisational structure.

Use the planning framework in Figure 8.1 as an aid to prepare a science unit plan for your sector of schooling. Preferably, make it a plan you can actually use in a teaching situation.

In your group share copies of the samples of medium term plans you have collected. Discuss the advantages and disadvantages of each organisational format.

Also share the unit plans you have prepared, and take collective responsibility to check that all necessary areas have been considered.

Planning from Performance Outcomes

In Chapter *3*, a comment was made about the recent move toward the introduction of legislated performance outcomes across many school systems. Some education systems have therefore laid down expected outcomes in science at each year level. These may be in association with a scope and sequence structure of content, or may by themselves determine the scope of the science program. The best time to consider the outcomes in planning is at the long term and medium term planning phases.

In some curricula, the outcomes are listed without reference to specific science topics. In others, possible topics with associated outcomes are provided. If the curriculum outcomes are not associated with specific topics, this will have to be done at the school level for long term plans, and by teachers for unit plans. This allows several related outcomes, perhaps from different sections, to be grouped for a particular science topic. It also provides potential for integration with outcomes from other subject areas. If the curriculum lists topics with outcomes, there may be scope for integrating topics and outcomes both within the science program and across subjects. Opportunities for integration can help reduce the pressure on covering the curriculum. Planning for integration is best conducted by a group of teachers so expertise can be shared.

Outcomes associated with each topic constrain unit planning, as they clearly define the direction the unit will take, and the types of activities and laboratory exercises which might be possible. A planning technique which can be helpful, is to use the required outcomes to arrive at the preliminary goal for the unit, and use that as an initial planning guide as suggested earlier. When selecting activities and information sources, the outcomes need to be considered more carefully. It must be possible for the students to achieve the outcomes from the unit as structured. Using outcomes in this way means that activities and outcomes are planned together, rather than in the sequence outlined earlier.

Associated with performance outcomes, there is often some form of assessment required to determine whether the outcomes are achieved by students. This is looked at in Chapter 10.

Learning Project 41

If you are operating in an education system which has outcome statements in science, look at the curriculum to determine whether there is a link between topics and outcomes. Make up a long term plan based on the curriculum, preferably with your group. Plan a unit topic using the outcome statements for that topic.

Short Term Plans

Short term plans are usually in the form of weekly plans, daily plans or lesson notes. They are derived from the unit plan, from which are extracted logical sections of work that will fit within the available lesson times shown in the short term plan.

A weeldy plan resembles a weekly timetable, and shows days, lesson or block times, and the section/s of the unit plan to be covered for each science lesson or block during the week. It may also include specific reference to an activity, text page, or content.

A daily plan looks like an extended daily timetable, showing lesson or block times for the day. The level of detail varies considerably, from brief statements such as in the weekly plan, to brief lesson notes. Most experienced teachers would operate from a weeldy or daily plan; some are even able to work directly from a more detailed unit plan which combines elements of the unit plan and weeldy plan. Novice teachers will frequently need to include more detail, such as in lesson notes, even to the extent of planned questions and instructions.

A key planning frame in preparing a short term plan is the time factor. The unit plan must be segmented into manageable pieces which will fit into the lesson times available. Early childhood and primary teachers have the flexibility of using block times to allow them to shape the short term plan to the needs of the unit and the students, but secondary teachers usually have serious constraints in timetabling classes and laboratory work. Inexperienced teachers may underestimate the time it takes to distribute equipment and clean up, so realistic times fox these need to be factored into the time planning.

While accepted educational practice suggests that goals need to be stated for each lesson, I think this is often unrealistic in science — especially if a detailed unit plan has been prepared. This opinion is supported by the fact that most teachers do not prepare lesson goals. Do not misunderstand me. I am not saying that lessons are aimless. However, if the unit plan contains *specific goals for the unit*, then specific goals for each lesson may be unnecessary, because they are partial steps toward particular unit goals. That is, several lessons are often needed for students to grasp a new concept. On the other hand, there may well be occasions when one concept is clearly associated with a particular lesson, in which case specific lesson goals would be highly appropriate.

At this level of planning it is important for beginning teachers in particular, to consider the types of transactions which will occur with the students in each lesson. This includes asking questions, wait times, question distribution, giving instructions and explanations, scaffolding, and making the lessons gender and culturally inclusive. Other issues to consider are catering for students of all capabilities, whole class versus small group organisations, the roles students assume within small groups, and management principles to be followed — including distributing and collecting equipment. All of these need to be planned beforehand to maximise students' learning opportunities.

Learning Project 42

Collect some samples of short term science plans that you have used, or seen other teachers use. Note the organisation and level of detail. Also note the presence or absence of lesson goals.

Use your unit plan that you prepared in Learning Project 40 to draft a short term plan. You may want to experiment with several different formats.

Transforming Content Knowledge and Teaching Knowledge into Instructional Strategies

An important aspect of planning and teaching science units and lessons is combining what you know about the topic and what you know about teaching into strategies which are effective in helping your students reach your intended goals. By this I mean, "How can I teach about Archimedes's Principle to Year 10s?" and "How can I teach the needs of animals to Preschoolers?" To some extent you can rely on the expertise of others, by using teaching approaches such as those outlined in Chapter 7, activity and learning experience suggestions in resources, and by drawing on other teachers or experts. Ultimately, however, it comes down to your personal teaching knowledge in these areas. A part of this is shown in Figure 8.1, under "Teacher Preference." The teacher's preferences are informed by past experience and/or the experience of other teachers. This is how a teacher knows what works. One of the characteristics of a good teacher, then, is his/her continual efforts to expand this repertoire of instructional knowledge.

Learning Project 43

You may find it helpful to begin a collection of teaching ideas for particular topics or concepts for your area of schooling. It is best to write these down and index them for easy access. You will forget them if you are not using them frequently.

In your group share teaching ideas you are aware of, so others in your group can expand their repertoire of ideas. You may find it helpful to provide written summaries as well as verbal accounts.

A Case for You to Work on

Choose one of the following cases to work on in your group.

Joan, our early childhood teacher, has been discussing with a colleague the problems for science teaching associated with planning using themes. She argues that while themes are useful ways of presenting knowledge in a holistic form for young children, science is often omitted or is given superficial treatment. She believes that specific goals are never identified for science because of general thematic planning and because of common beliefs that the students only need to have experiences to learn. Her colleague takes the view that deliberately including science in the theme is restrictive and constrains creativity. She believes that students will learn from a variety of experiences and devising specific goals forces formal learning onto them too early. Take the role of each teacher, and outline the arguments they would put forward. What theoretical ideas underpin each view?

Sally, our primary teacher, has been reviewing with her other Year 4 colleagues, their science planning. They usually plan a unit for a topic using a column format, but base it on the science resource materials without much modification. Sally is thinking about whether to plan using themes, and whether they should use a teaching approach to guide their teaching of the unit. What should she say to her colleagues? What do you think they should do? Why? What advantages and disadvantages for each step would there be? Take the role of the Year 4 teachers, and discuss these issues.

Julian, our secondary teacher, has always planned his junior science by the text pages to be covered each lesson. It has been suggested that the science department change the way they plan. The idea is to organise their own units around science topics, and slot the relevant text pages into the related parts of the topic. This would mean the text sequence would no longer be followed, and there would be extra planning time. Continue the discussion at the next lunch break. What advantages and disadvantages would there be for making the suggested change?

Your Chapter Review

If you have had some experience teaching, identify the type of planning which you now use for science, and evaluate its appropriateness to your needs. Would a different format be useful? Can you improve the way you express your specific goals for a unit?

If you have had limited teaching experience, organise to prepare a science unit at your next teaching opportunity, and implement it if possible. Draw on the existing long term plans and classroom resources. Use an integrating theme if appropriate, but ensure you plan for an identifiable science component with specific science goals.

Further Reading

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Smith, E. L. & Sendelbach, N. B. (1982). The programme, the plans and the activities of the classroom: The demands of activity-based science. In J. Olson (Ed.), *Innovation in the science curriculum* (pp. 72-106). New York: Croom Helm.

9

Managing the Implementation

What This Chapter **Asks You** To **Do**
During this chapter you will:

- Consider selected aspects of "good" classroom management in science, and to what extent you might change your practice to incorporate them into your teaching.
- Explore how your management of small group work in science may be enhanced.
- Considerheview the use of cooperative learning as part of your small group work in science.
- Consider/review your laboratory/investigation and field trip management procedures.
- Become familiar with safety requirements for science teaching, and identify specific aspects related to your education system and school.

This chapter looks at the "doing" aspect of teaching science, probably something you already know a fair bit about. In a book such as this I can only take a brief look at a couple of issues, and will focus mainly on management. However, I do not intend to replicate the material found in books about classroom management. The main question which I will focus my discussion around is, "What makes management in science lessons different from management in other subjects?" I think there are two main differences:

1. Few other subjects have students engaging in hands on work with materials.
2. Few other subjects involve taking students out of doors for field trips.

Other factors which can make science different from other subjects are the desirability of using small groups, and encouraging students to think and solve problems.

Learning Project 44

What do you think are important management issues or situations to consider when teaching science in your sector of schooling?

Rank them in order of difficulty for you.

In your group share lists and rank orders. What similarities and differences are there?

Which management issues or situations do you think might exert most influence on students' learning in science?

Being a "Good" Manager

Good management is usually recognised as an important component of a productive classroom, as achievement seems to depend on on-task behaviour (Brophy 1988; Reynolds 1992). An important aspect of management, then, is keeping the students on-task. Looking at the on-task behaviour of students and comparing it to what the teacher is doing can help us better understand aspects of management (Butler, Beasley, Buckley, & Endean, 1980). Butler and colleagues found, as might be expected, that teacher behaviours changed from setting to setting, for example from whole class to small group work (see Chapter 7). Noticeably, students' on-task behaviour varied between teachers, who could be classed as good managers or poor managers. Teachers categorised as good managers tended to be good managers in small group settings as well as whole class settings (Beasley & Butler, 1986). Good managers also seem to establish the classroom routines very early in the first week of class (Appleton, 1995).

Another aspect of management is the degree of teacher structure and student freedom that the teacher incorporates in lessons; that is, the level of teacher dominance. An intuitive response by many teachers to students exhibiting behaviour problems, especially in small group settings, is to increase teacher structure and lay down the law. However, Shymansky (1978) reported several studies which suggested that lower teacher dominance results in reduced disruptive behaviour in students identified as behaviour problems, and in lower anxiety levels in highly anxious students. To many teachers these findings would be counter-intuitive. I should point out that lower teacher dominance does not mean less supervision of groups working, or laissez faire teaching. It means that the students have a greater say in determining what they will do, how they will do it, and with whom. It is usually associated with activities which tend to be more open-ended and less prescriptive. The classroom climate associated with this is best to be warm and supportive rather than highly authoritarian. (Please do not interpret this as meaning the teacher relinquishes control or allows any sort of behaviour!)

Some principles for good managing to think about (there are many others which you can add):

- Know what routines related to science teaching you wish to establish in your new class, and establish them early.
- Decide how you can establish a warm, supportive, but firm classroom atmosphere.

- When possible provide intrinsically interesting tasks which are open ended. For example, play is used extensively in early childhood settings.
- Be clear and purposeful in giving instructions.
- Monitor group work constantly.
- Ensure group tasks and roles are clearly identified by the students.
- Ensure that you are always visible in the classroom. That is, the students must be able to see you. Primary and early childhood teachers in particular need to balance this against the desire to crouch or kneel so they are at face level with students they are talking with.

Note that Smith and Sendelbach (1982) reported how a teacher's concern about management issues could over-ride his/her goals for achieving concept and process development. That is, the teacher might focus so much on managing the equipment and groups, that key aspects of the lesson for helping the students achieve conceptual learning are forgotten or overlooked. Good learning is facilitated by good management, but good management alone does not result in good learning.

Learning Project 45

From what you know about classroom management, and the above ideas, what would you do to try to ensure good management in your science classroom? Make some specific suggestions.

This book has not examined dealing with students with a serious behaviour problem in science. Seek the advice of others, including books, as to how to deal with such a student.

In your group share your impressions of your preferred management style. Metaphors such as "I like to run a tight ship." can be helpful in sharing ideas.

Provide feedback about what you see are good or problematic aspects of each others' style.

Small Group Work

Since much of science teaching involves small group work in all levels of schooling, it is worth taking a specific look at this aspect. Small group work can involve discussion, research (in books), project preparation, and hands on with equipment. The first management consideration is the extent of your own experience in teaching with students organised in small groups. The second consideration is whether the students have used small group work recently. If you have never tried teaching with small groups before, you need to ease into it gently. If the students have never tried it before, you will have to introduce it using a carefully controlled plan. You need to work towards establish a routine (see Chapter 7) for each small group situation, such as small group discussions, project work, and doing practical work.

Some issues to think about in planning small group work include:

- What task will each group be engaged in? Having different groups work on different tasks can be useful if tasks are all part of a broader issue. If the tasks are all different and you want every student to do each task, you have to also think about switching tasks, time, and a pedagogy to tie all the tasks together somehow. Primary and early childhood teachers may also choose to have different groups engaged in different subjects like science, mathematics and language. Having groups do different tasks has the advantage that, if equipment is involved, only one set of each is needed. **A** disadvantage is that it is harder to supervise and monitor several groups all engaged in different things. Having all groups do the same task is managerially simpler, but requires multiple sets of equipment.

- How will you tell each group what their task is? This is easiest if all groups are doing the same thing. If they are doing different tasks, it can be difficult to set the task unambiguously for each group in a reasonable time, and monitor each group to ensure that they have got it right. Obviously, if students can read, written instructions can help. However, research has revealed that tasks set without the students having ownership and a clear understanding of the task can result in poor learning (Tasker & Freyberg, 1985).

- How many students should be in each group? I have found that the optimum group size is three, especially when the task involves equipment. Early childhood teachers may prefer to use pairs. However, other constraints such as the amount of space available to a group, or the number of groups which can be accommodated, may determine the size.

- How many groups should be formed? If equipment is involved, sometimes the number of groups will be selected to suit the number of equipment items available. Care needs to be taken, however, that the group size does not get too large. In an average sized class, having groups of three would result in eight to ten groups. If they are working on the same task, this is easier to manage than if they are on different tasks. You may want to consider having another adult helper in the room if you have a large number of groups doing different tasks. Young students may need a helper for each group. Sometimes you might want to have one or two small groups with whom you work closely, with the remainder of the class working individually.

- How will you organise students into their groups? You could choose from friendship groups, ability groups, interest groups, or randomly assigned groups. Which you select will depend on the circumstances, such as the age of the students and the nature of the task. Sometimes it is easier to have fixed groups which are changed every month or term. You also need to consider whether to use cooperative learning principles (see below). Another consideration is the designation of specific roles within the group. These might be Group Manager, who obtains and returns equipment; Group Speaker, who is the only person in the group who initiates interaction with the teacher or another group for help; and Group Director, who helps group members focus on the task and work toward achieving it. Care needs to be taken that students are not "type cast" into the same role all the time.

- Where will the groups work? This depends on the number of groups, the size of the groups, and the space available in the room. Each group needs adequate physical space, and movement around the room should not be blocked. You also need to make procedures for distribution and collection of any equipment explicit. Room areas can have location names, or maps of the room can assist for more complicated arrangements.

Cooperative learning

Some people think that cooperative learning is the same as small group work, but the term has a specific sense which applies to a particular form of group work. It appears to be a very effective way of structuring group work to increase on-task behaviour. In cooperative learning, there is a focus on both cognitive learning and social learning, so that students can see the value of working together. Constructive interaction between group members is a key element. However, it does not happen naturally when students are put into groups — they need to be taught how to function cooperatively in their group. The following principles should be kept in mind when planning for cooperative learning (Plumb, 1996):

- All members of the group work toward a common goal. For the group to achieve the goal, all members must succeed in their contribution.
- Each member of the group is responsible for his/her own contribution to the group's goal.
- Group members sit together and face each other in their interactions.
- Each member consciously focuses on selected social skills which will facilitate *the* functioning of the group, such as turn taking, listening, helping each other, checking understanding, and probing.
- Groups review their collaboration as a group and decide how they might improve.

There are some implications which arise from these principles:

- Groups need to be arranged carefully. Often teacher-organised groups are most effective, especially in the early training of groups. Groups should be kept together for at least several lessons.

- New groups need to have some specific tasks to facilitate social interaction and group cohesion. Choose such "warm-up" activities appropriate to the age group.

- Specific goals, both cognitive and social, for each group need to be provided. It is also necessary to make explicit the criteria by which a group and each member will be able to determine when their task is completed. For instance, "Complete the worksheet and do the outlined investigation within 30 minutes. Each group member must make at least one observation from your investigation, and suggest one idea to explain your results."

- Any group roles such as Group Director and so on should be assigned. If conflict arises, it is best to help the group resolve the conflict rather than disband the group.

- Both the cognitive and social tasks need to be made clear. The social skill may need to be made concrete by examples. The cognitive task should not only be understood by group members, but they should be helped to relate it to other tasks and experiences.

- Croups need to be carefully monitored while working, to gauge progress toward both the cognitive and social goals.

- Groups should be given feedback on their cognitive learning, and the opportunity to reflect on their development of social skills.

Cooperative learning in science has been demonstrated a highly effective way of enhancing students' learning if implemented carefully, and if the above principles are adhered to.

Learning Project 46

How would you introduce small group work in science to a class in your sector of schooling which has never experienced it before?

If you are unfamiliar with cooperative learning, find out some more about it. Suggest some specific advantages of cooperative learning over normal group work.

In your group reflect on your own group's functioning, both in cognitive and social terms. In what ways could you improve the functioning of your group?

Student Practical Work

Practical work has traditionally been a central component of science programs in all sectors of schooling. There are several aspects to consider.

Purposes of practical work

Practical work has tended to have had different emphases in different sectors of schooling. In early childhood settings, the emphasis has usually been on experiences and play. In primary schools, it has typically been on process skills — often interpreted as "hands on." In secondary schools, it has frequently been to illustrate aspects of content, and to provide training in laboratory skills. However, these traditions have largely been derived from Piagetian thinking, process skill curriculum ideology, and university models, respectively. Reflection on the work of earlier chapters will show that these emphases are no longer necessarily valid.

It appears that we need to redefine the role of practical work in science at all levels. I have already alluded to this in Chapter 7, where investigations were incorporated into specific teaching approaches. Unfortunately, there is no simple and clear cut "right" way of viewing practical work. It might best be conceived as serving several purposes, the main focus at a particular time depending on the topic and context. That is, sometimes the emphasis for a lesson might be on exploring a new phenomenon, or some new materials. Sometimes it might be on learning how to "science" better by focusing on a particular process skill, or a selected manipulative skill. Often, the focus will be on learning new concepts. Since practical work becomes most meaningful for the students if it is an integral part of the overall program, how it can be best used in each instance needs to be thought out in terms of the selected teaching approach. For instance, Garnett, Garnett, and Hackling (1995) have suggested that chemistry can be taught by students doing investigations which include laboratory work. However, they suggest that the laboratory work should provide a means of helping students access the concepts and make sense of them. This is also a Characteristic of several of the teaching approaches looked at in Chapter 7.

Process skills and the "scientific method"

Students, particularly those in high school, are often expected to follow some formula for approaching practical work such as a "scientific method." Process skills are also a common focus. I believe these ideas come from a dated view of the nature of science and laboratory work (see Chapter 5), and suggest they should not figure prominently, even if the students' text book does outline a so-called scientific method.

Recording practical work

Recording observations so they are not forgotten is an important part of doing science, and using appropriate recording techniques for the age group should be taught from early childhood. However, recording practical work is often called "writing up the prac" in upper primary and high school. This often takes the form of an artificially structured layout with headings like "Aim, Apparatus, Experiment, Conclusions." Rather than this restrictive and boring requirement, I believe the whole issue can be better addressed if the students are engaged (with the teacher's guidance) in deciding how to record and make sense of their observations before the practical work is begun. This then becomes part of the process of providing for student ownership. Consequently, any need for making tables of data or graphs are established beforehand, and how to construct and interpret these has been considered. I also query the practice of making every practical a small assignment designed to assess whether each student has made sense of the practical work. This can become burdensome for both students and teachers.

Managing practical **work**

The first consideration is the establishment of appropriate routines for investigations and laboratory work. This includes the distribution and collection of equipment. Safety rules need to be explicit, stated frequently, and rigidly enforced. The following points should be considered in relation to practical work

- The investigation must be safe. This includes the use of safe materials, using safe procedures, and obligatory use of safety equipment such as goggles. Sometimes unsafe materials such as mercury filled glass thermometers can be replaced by safe ones, such as alcohol filled plastic ones.
- Try the investigation yourself beforehand. Do not assume you know how to do it.
- Get the equipment together in ample time. If you have an assistant, provide an explicit list of requirements early.
- If the practical involves group work, plan the group work aspects listed earlier carefully.
- Decide the extent to which the practical will have student ownership and be open ended. *Also* decide how to engage the students in taking ownership in a meaningful way.
- Check equipment items after collection. Some things like magnets are very attractive to students.

Learning Project 47

Science investigations/practicals/laboratory work are usually considered integral parts of a science program. To what extent do you agree or disagree about the importance of practical work? Provide some reasons.

What would you say the main purpose of practical work in science is? For example, many high school programs use practical work to provide worked examples of "theory" covered in the text or classwork. Many early childhood and primary teachers would say practical work provides a means for students to make sense of their experiences.

Make a list of key issues for you in organising science investigations/practical/laboratory work.

In your group discuss the purposes of practical work in the science program, that is, what does practical work do that other teaching cannot do?

Talk about the forms of recording that are appropriate for your sector of schooling?

Field Trips

Field trips are really practical experiences taken outside of the normal classroom or laboratory, and can range from a few hours to a few weeks. Therefore most of the points mentioned earlier also apply to field trips, although there are some further considerations:

- Any policies about field trips determined by the school or education system. You need to be familiar with these and ensure you follow them.
- Parental permission. This needs to be obtained early. Each school would have an established procedure for obtaining permission. If there is no permission, students cannot go. Something must be provided for students left at school.
- Travel. Journey time, cost, reliability of bus firms, and making bookings all have to be considered.
- Medical. Students on special medications or who are susceptible to particular environmental factors need to be closely monitored.
- Pre-visit. Always visit the site beforehand, unless another teacher has already done this. If it is a commercial or environmental education site, make sure the operators know you are coming.

- Adult helpers. You should have one adult per ten students unless otherwise advised in school or education system policy.
- Equipment. If any special equipment is needed, you need to ensure it will get there with you.
- The educational value of the experiences. The field experience needs to be integrated as much as possible with work commenced before the trip, and afterwards.

Planning of even a brief field trip may need to be done weeks ahead, and months ahead for longer trips.

Safety

Safety is obviously an important issue, especially when you consider the welfare of the students in your care. You also have a legal obligation toward the students, and if you do not take adequate safety precautions or are negligent, you could be legally liable. Most education systems and schools have safety rules, safety manuals, and emergency procedures clearly specified. You need to know these, and rehearse procedures such as fire evacuations with students. If there is emergency equipment like a fire blanket available, you need to know how to use it. Secondary schools will also have to ensure that their laboratories meet the required standards.

You also need to be aware of potential hazards and hazardous situations. Most of these are common sense, and if you are unsure, it is best to err on the side of caution. Just because an investigation or practical is in a book does not mean it is safe. If you do note an investigation with a potentially hazardous substance, be aware that many hazardous substances can be substituted for harmless ones — for instance strong acids like hydrochloric acid and sulphuric acid can often be replaced with vinegar (depending on the purpose of using a particular acid of course). Each laboratory exercise involving hazardous substances or potentially hazardous processes would also need to have a health and safety risk assessment made of hazards and potential exposure by teachers, laboratory staff, and students, as determined by local legislation. There are now strict legal requirements for doing this in many countries, which the school should have policy on.

The following points should also be considered:

- Emphasise safety rules, potential dangers, and prevention of accidents with students as often as necessary.
- Anticipate problems and dangers and take action to ensure they will not occur.

- Never relax vigilance in supervision and monitoring of students at work. Take special care about being absent from the room, or having your back to the class for extended periods.

- Ensure the students use any necessary protective equipment such as goggles.

- Enforce all safety rules consistently and persistently.

If you take all reasonable precautions, then it is very unlikely that an unsafe situation will occur in your classroom. If it does, remember that your first priority is the well being of the students.

Learning Project 45

Find several science investigations/practicals suggested in books for your sector of schooling. Identify any potential hazards associated with them. For instance, making a model fire extinguisher using a glass jar, a nozzle fitted to the jar lid, sodium bicarbonate, and vinegar — if the extinguisher "nozzle" became blocked, pressure build up could shatter the glass.

Can changes or substitutions be made to eliminate the hazards you identify?

Find out what safety rules and procedures exist for the sector of schooling where you are situated, if you do not already know them. Explore both the school and the education system requirements.

In your group decide how to deal with a student who is a persistent behavioural problem to the extent that he/she may generate a hazardous situation, for example, prodding others with scissors, lighting gas outlets.

What is the policy followed by your education system and area of schooling for such problem students?

A Case for You to Work on

Select someone to be Joan, Sally, or Julian, who has been asked to identify potential hazards and advise on safety procedures for science (or a number of subjects, if that suits better) in her/his school, for the appropriate area of schooling. She/he has decided to call together a committee to help do the task. Your group is that committee.

If at all possible, conduct your review in a real teaching situation. Decide how to do it first, who to report your findings to, and how to present them.

Your Chapter Review

Make up a checklist of management practices and safety procedures/principles you want to keep in mind when teaching science. How can you make these easy to refer to when needed, to jog your memory?

Further Reading

Classroom management

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Laboratory work

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10

Assessment and Reporting

What This Chapter **Asks You** To Do
During this chapter you will:

- Consider the different purposes of assessment in science.
- Explore how to male effective use of performance assessment and outcomes-based teaching in science where these impinge on work practices.
- Consider the range of assessment techniques available in science, and make choices appropriate to your own teaching context.
- Examine ways of effectively recording assessments in science for all students.
- Review the reporting of students' science progress in your sector of schooling and/or school context, with a view to improving communication with parents and guardians.

Assessment has, for some years, been a neglected area in science education. At early childhood and primary levels, it quite often receives a low priority, and is mostly used to provide guidance for teachers when preparing reports for parents. At secondary levels it receives a high priority, but tends to be treated in an unproblematic way. If this happens, it can exert considerable influence on the curriculum and may consist mainly of written tests. With recent trends toward mandated outcomes-based science programs, assessment is assuming greater importance and requires careful consideration. Before proceeding, it would help you to establish what you already know about assessment and reporting, which Learning Project 49 will help you to do.

Learning Project 49

When you think of assessment in science, jot down what comes to your mind. What ways of assessing in science are you familiar with?

Why, in your opinion, do teachers give students assessment tasks in science?

In thinking about these questions, were you thinking of your own science learning experiences or your teaching in your sector of schooling?

When you think of reporting students' progress, what comes to mind? How important do you think reporting is?

If you have contact with some parents, ask for their thoughts about reporting students' progress in science.

In your group share your ideas about assessment in science, such as reasons for doing it, and effective ways of assessing.

Also share views about reporting, including any views of parents which you managed to obtain. What picture of reporting emerges from your discussion?

If you were unable to obtain some parents' comments, what do you think parents might want to know about their children's progress in science in your sector of schooling?

Assessment

Firstly, I had best clarify what I mean by assessment. When I think of assessment, I think of gauging the progress of students' learning. I see it as different from testing, and different from evaluation of the curriculum program, though some people tend to use these terms interchangeably. I see testing as using some task designed to measure students' performance or attainment. It often results in a numerical value, but does not include making value judgements about the significance of the test results. Assessment does. The way I see it, then, is that a test is an assessment technique — a way of gathering information about students' learning. Assessment may therefore involve testing, but does not have to since there are many assessment techniques other than tests.

The other term I mentioned was evaluation. I see evaluation of the science program as making value judgements about its worthwhileness. In doing this, use may be made of information obtained through assessment, that is, about students' progress in learning, in order to make judgements about the value of the curriculum or parts of it. You may well find other books which use these terms differently from me, which is fine. I have simply defined what I mean when I use them.

The next thing I think about regarding assessment in science is why do it?

Purposes of assessment

There are several obvious reasons for assessing. Some are to do with the teaching process, and some are more to do with providing information to interested people. Fortunately, the information obtained from assessment can usually serve most purposes. You may come across the terms formative assessment and summative assessment. Formative assessment refers to assessment conducted during teaching to improve learning, and summative assessment refers to assessment conducted at the end of a piece of work to gauge the level of achievement. These two broad purposes for assessment subsume a number of other possible purposes which I will look at below, to help you focus more explicitly on your own situation.

Assessment to identify existing preconceptions. This has become a well established component of many teaching approaches in science based on constructivist thought (see Chapters 4 and 7), so teaching can proceed from what the students actually know. Such assessment may occur prior to the commencement of the unit of work, or could be done early in the unit as it is taught.

Assessment to identify learning problems. During the progress of a unit, the teacher will want to ascertain whether students are making sense of the work to date, and whether any misunderstandings are developing. This information can then be used to frame the next teaching actions. The assessment can occur moment by moment during interaction with students in a lesson, perhaps during a discussion, practical work, or a teacher explanation. The teacher uses a number of informal techniques to gauge the sense students are making of the work, and if difficulties are noted may choose, for example, a different analogy to explain a point, or ask a question to challenge a developing misconception. Continuing difficulties evidenced by a number of students may cause the teacher to change his/her plans for the future development of the unit.

This form of "diagnostic" assessment may occur at different stages during the progress of the unit, such as when groups report their work to the whole class. Information about the progress students are making toward the unit goals will influence whether the teacher's original plans for the unit proceed, or whether they need to be revised in the light of difficulties students are experiencing. For instance, if there is evidence.that students are interpreting a segment of practical work in an unanticipated way, the teacher may have to introduce a new lesson to deal with this.

Assessment to guide the student's learning. This type of assessment is to provide feedback directly to the students so they may monitor their own learning progress and modify their learning behaviour as appropriate. For this to be effective, they need to be aware of the desired unit goals and share the desire to achieve them. They also need to be reflecting on their learning behaviour so they are aware of their own practices, in order to effect necessary behavioural changes. They also need to have a repertoire of effective learning behaviours. While this has obvious applicability to older students, it is also relevant to younger ones. If their goal is to find out how a caterpillar moves (as, for example, decided by a student's question in the *Interactive Approach),* they need feedback as to whether they are making progress toward getting an answer, or whether they should use alternative information sources or strategies. For maximum effect the assessment feedback should be immediate, and offered in a warm, supportive, constructive environment.

Assessment for accountability. This is to provide others such as school administrators, parents, or politicians information about the progress students are making in learning science. It is often comparative in nature, perhaps with other students, classes, or schools. Whether such comparisons are appropriate or even ethical is an issue I will not engage in here, though you may wish to consider this question. In some places, standardised testing programs have been introduced to make it easier to draw comparisons. Unfortunately such data, if made public, can easily be misinterpreted and even misused. On the other hand, it is quite valid for those with public responsibilities, such as administrators, to ask for some assurance that students are making reasonable progress toward expected goals. It is preferable that such assessment be negotiated between the teacher and administrators so it is acceptable and meaningful.

Another aspect of assessment for accountability is to determine whether the student should progress to the next academic level. This is rare now in most schooling situations, except in the final year of secondary school, where assessment results are often used to determine whether students may progress to University. Another way of looking at this, is assessment for accrediting a student as having achieved a particular level of schooling, such as Year 12 Biology in the Australian system, or A level Chemistry in the British system.

Assessment to report progress to **parents or guardians.** Parents and guardians naturally want to know that their children are making good progress, even in science. The greatest challenge for teachers is to make the reports of progress meaningful to parents/guardians. The easiest form of progress report for many people to understand is a comparative one, where students are matched against other students. This is often done either as a rank order (place in class), or as a percentage, on the assumption that 50% has some real meaning of a "pass" mark. Such marks or ranks unfortunately give the *appearance* of providing information about progress, without actually providing the meaningful information desired. Some teachers therefore succumb to using this form of reporting. However, it is preferable if assessment showing students' real progress can be formulated and couched in a form understandable by parents/guardians.

Learning Project 50

Explore the purposes for assessment in science that pertain to your own teaching situation. Examine sources such as the curriculum, syllabus, any textbooks, and school policies. Also consider other influences such as requirements by the school administration, political demands for accountability and the like, parental expectations, and the students' expectations.

In your group discuss which of these purposes tends to dominate the thinking of a teacher in your sector of schooling.

Also consider the issue of whether the dominating assessment purposes are determining what is taught in science, and if so, how.

When and what to assess

Planning assessment for the science program over the year involves assessment of each of the objectives areas in the syllabus, usually concepts, process skills, attitudes, and manipulative slulls. Development of process skills and attitudes are long-term goals, so it is unrealistic to expect noticeable progress in these during a unit. Therefore, assessment for a unit/topic would usually focus on assessment of concept development and/or perhaps a manipulative skill (if appropriate). The assessment may also address a key process skill and key attitude but the assessment in these would not necessarily be for all pupils in the same unit. For instance, the teacher might plan to assess each student three times a year (say) in each process skill and attitude.

For each unit then, assessment techniques would normally be planned to gauge progress toward the concept objectives for the unit and any manipulative skills for all students. There may also be techniques selected for gauging progress in particular process slulls and attitudes for some students. Such techniques are commonly noted on the unit plan. It is much easier to select appropriate assessment techniques if the unit objectives are specific.

Performance assessment

Performance assessment has become an important issue in recent years. Although by and large not welcomed by many in the teaching profession, it has been introduced into several education systems worldwide. In some instances it has extended to the science program, sometimes even to the lower primary levels. It mainly arises from the “assessment for accountability” purpose outlined above. Since this is a pervasive issue, I have included a few extra comments about performance assessment, even though it should be merely one small aspect of assessment.

It seems that in some political and public forums there is distrust of teachers and the education system. A consequence has been legislated requirements for outcomes-based teaching, formal standardised testing programs, or both. Such a framework can alter considerably the curriculum and context of teaching. I will mainly focus here on the issue of using assessment linked to outcomes.

Using outcomes as a basis for assessment. Performance outcomes are usually couched in terminology which states what the students are to do — what they are expected to be able to perform. As such, outcome statements tend to focus on observable behaviour, and avoid terms which are difficult to observe. This is problematic, since it goes by the assumption that the only way to decide if learning has occurred is to see if there has been a change in behaviour. While this is a reasonable assumption, it implies that, if a particular behaviour occurs, then the student has learned something. However, there is often a tenuous link between behaviour and learning. A student may have learned what was expected, but for some reason does not display the required behaviour. The converse, where the behaviour may be apparent but the desired learning may not have occurred is also possible. Despite this problem, performance outcomes can be useful tools in planning and assessing. This is because they are used to focus the learning and teaching onto specific outcomes. Their use in planning was considered in Chapter 8.

Since the objectives are stated in terms of student behaviour/performance, then appropriate techniques for noting the desired behaviours need to be selected (see the next section). A detailed recording system is also needed to keep an ongoing record of the performance of each student. The only difference between required performance objectives and a teacher's normal assessment program is that the objectives or outcomes are predetermined, with a potential loss of flexibility in the curriculum.

Learning Project 51

If you have to deal with performance objectives in science, it is a useful exercise to plan a unit based on a topic without referring to the performance objectives, then repeat the exercise using the performance objectives. You can then compare the content and form of the two units.

In your group share the similarities and differences between two such units you have planned.

Assessment techniques

To make judgements about students' progress in learning science, data must be available on which to base those judgements. A range of techniques can be used to gather this data, though the techniques used are mostly determined by the purpose/s of the assessment, the learning outcomes for the work being assessed, and the time available. In other words, the techniques are chosen because they will provide the information, or data, about which judgements need be made, in the time available,

Learning Project 52

Make a list of the assessment techniques which you would consider useful in science for your sector of schooling. Which techniques would be used most often? Why?

In your group make a combined list of science assessment techniques, with those used most frequently indicated. Be prepared to justify the selection to others in your group.

Compare your list with the list of techniques below. What would you change? Which on your list have I omitted? Which techniques would be best for assessing concepts? Processes? Attitudes?

The following is a brief summary of the main techniques for science that I have seen teachers use. If you are not familiar with any of these, you may want to find out more about them.

Portfolios. These are collections of examples of a student's work. The examples may include a variety of products derived from other testing techniques. The student may collect and select the items for inclusion in a personal portfolio, or the teacher may do this for a group or class portfolio. A personal portfolio provides information about a student's progress over a period of time, though it may be designed to show only the best aspects of the student's performance. A class portfolio serves as a record of the science program the class has been engaged in over a period of time.

Journal. A journal can be considered as a special kind of diary. In it, the student records his or her personal thoughts and feelings during the progress of a science unit. The focus of the recordings would be on the student's learning, ideas being developed, and feelings associated with these. Students do not spontaneously know how to write a journal, so this needs to be taught, and can be an important part of the language program worked out in practice in science. Who is supposed to read the journal is also an important consideration: journals can be very useful learning tools for students, if they write them for themselves and their own benefit. If they are used for assessment the teacher will be the key audience. The students will therefore carefully frame their writing for the teacher, and try to provide what they think the teacher wants. In this case it is essential for the teacher to provide guidelines about his or her expectations.

Tests. Although the most common form of test is some written variety, other forms are also possible.

- *Written tests* tend to be used as soon as students exhibit sufficient writing ability for the type of test. Hence some teachers use simple forms as early as year one. Although written tests are a convenient and efficient way of gathering assessment information, they do not necessarily provide reliable information about students' understanding of science phenomena. I have found that written tests need to be used with care, with the form of test and its construction considered in detail.

  Forms of written tests used in science include:

  - *Essays.* These tend not to be used in science very often as they test a limited amount of content and take a fair time to mark. The student is usually given a topic and asked to write a lengthy account on the topic. Headings are sometimes provided to ensure the students address required aspects of the topic.

  - *Multiple choice.* A statement or question is provided, with four or sometimes five possible answers. Only one answer should be correct, but the other choices must be reasonable options, possibly derived from knowledge of common student misconceptions.

True/false. **A** statement is provided, and the student is asked whether it is true or false. Since there is a fifty percent chance of getting these correct by guessing, they should be used sparingly.

Short answer. The student is asked to answer a given question in a paragraph, possibly up to half a page. Care should be taken that it is possible to answer the question in the available space.

Matching. The student is asked to match items from each of two lists. The lists may consist of words, but can both be pictures, or one of pictures and one of words.

Fill in the blanks. **A** sentence or paragraph is provided with words omitted, and with the omissions shown by underlined spaces or similar. The student is expected to insert the missing words.

- *Oral tests* are conducted in structured one to one or one to small group situations, where students' responses are made verbally, perhaps accompanied by some action or limited writing. Many of the structured techniques used in written tests listed above can be conducted verbally. **A** major advantage is that the student can be prompted to say more, and ambiguities can be probed and clarified.

- *Performance or practical tests.* Students are given a practical or laboratory task to perform, with the purpose and expectations made clear. The students' actions and eventual success or otherwise are observed, and recorded.

Product. Students are required to produce a product according to predetermined criteria. The students may be involved in the preparation of the criteria. If criteria are not provided, or are ambiguous, students may feel that any grades resulting from the assessment are unfair. **A** variety of products is possible:

- *a laboratory report/activity worksheet.* This is usually completed during an investigation or laboratory session, but may also include a section to be done afterwards. Headings, questions or incomplete sentences are often provided as prompts.

- *a picture.* This is usually a drawing or sketch, but could include paintings and the like. If the teacher is expecting a realistic representation of what is to be drawn, this should be made clear. If the teacher is expecting a stylised sketch typical of those used in some scientific publications, the students should be taught the conventions of the style beforehand. For example, a beaker or similar container would have the following stylised form:

- *a model.* This may be a three-dimensional model or a diorama. Models are usually constructed to represent key features of some object or phenomenon. For example, a model of rock strata may be constructed using strips of coloured plasticine. This can then be used to show strata folding and the like.

- *a display or collection.* Some things, such as rocks and insects, lend themselves to displays as collections. If biological items are being collected, ethical issues about capture and killing need to be explored first.

- *a play.* Plays can be generated for historical events related to science, or as simulations of physical phenomena, such as meiosis. They can be mimes or include dialogue. Care needs to be taken in setting the assessment criteria, so science elements and dramatic elements are clearly distinguished, and students are aware of the requirements.

- *a story, narrative, or poem.* These offer considerable scope for those students who find other forms of assessment daunting. They can also appeal to younger students. Again, care needs to be taken in setting the assessment criteria. A useful variation of this is to have each student write a statement about their ideas before the unit commences, and write another at the conclusion.

- *a video or audio tape, or a sequence of photographs.* These are ideal to show physical or biological changes which occur over time. They can also be used to record a play performance, but the time involved in doing this may not be worthwhile.

- *an experiment devised by the student to test or show an idea.* A key component of this technique is that the student devises the experiment, rather than finds one from a book, On the other hand, ideas for experimental tests are often adapted from others' suggestions, so the emphasis here needs to be on the student tailoring the experiment to the actual test of the idea under consideration. This technique can be used for almost all ages except the very young, if the task is kept at the level appropriate to the age.

Concept maps. Care needs to taken in using concept maps for formal assessment and grading, though they can be very useful for formative assessment. Concept maps are most effective when they are used to explore the students' actual ideas, such as at the beginning of a unit. Students tend to become reticent about using them if they know they will be graded on them. They are also difficult to mark fairly.

However, I have seen reports where concept maps have been used as a data source in summative assessment with apparent success.

Observation of work in progress. Teachers are observing students at work all the time. One reason they usually do this is to obtain feedback about the progress of the lesson so decisions about pedagogy and management can be made. However, if the teacher uses some predetermined observation criteria while looking at students, this can contribute to the formal assessment information being collected about students. Two considerations when using this technique are to keep the observation workload manageable, and to have a simple and easy to use recording system. In any lesson, it is best if a limited number of observation criteria are used, and only a small number of students are observed at the one time. Recording is best done at the time of making the observations, as doing it after the lesson often results in incorrect recording or even data being omitted. Observation techniques can be used to gather data about concepts, processes and attitudes.

Self assessment. Many teachers are reluctant to try this in the belief that students cannot be trusted to grade themselves, or that they, as teachers, are entrusted with the responsibility of awarding grades. While this is true, information from student self assessment can be one factor in arriving at grades. The assessment criteria need to be discussed carefully beforehand, and how the information will be used needs to be clear to the students. In practice, students tend to grade themselves more harshly than the teacher might have. Self assessment is most effective for middle primary to secondary grades.

Group assessment. In this technique the students in a small group grade each other's work. This is particularly useful for assessing group projects. However, it needs to be done sensitively, with the issue of whether the assessments will be public or private clearly resolved. Public assessments, where the group discusses each student's performance in turn, can work very well. However, some students may be threatened by this, or members of a group may be reluctant to publicly state that one of them did poorly. In this case it is best for each group member's grading to be done privately and kept confidential.

Recording of assessment data

It should be self-evident that assessment data, particularly that which will be used for summative assessment, need to be recorded systematically. This is not difficult when the data are derived from written tests and the like, but can become a problem for other techniques, and for keeping long-term records of students' performance over a year. It can be particularly problematic for recording data from observational techniques used during class time. Such problems can be reduced considerably if the recording system is planned carefully at the outset.

Learning Project 53

Make a list of the forms of recording assessment data that you know about. Obtain examples of each. Compare your list with that below.

Which would be used most frequently in your sector of schooling? Why?

Explore ways of using computers in record keeping.

In your group discuss ways of making records of students' behaviours observed during class. Talk about how this can be managed while the teaching is going on.

Consideration must initially be given as to what to record. This will usually be determined by the purpose/s of the assessment. For example, Senior High School teachers record scores and/or grades from formal assessments to arrive at an overall judgement about each student's performance at the end of high school. By comparison, early childhood teachers record students' behaviours and examples of work to show parents or guardians the progress the students are making.

Forms of recording may include mark books or sheets, checklists, and anecdotal notes. These can be kept in loose leaf folders, bound books, or computers. Databases or spreadsheets are the most commonly used software packages for record keeping. The advantage of computer packages is that they can speed up calculation of scores; but a disadvantage is that they are usually desk bound and data often have to be handled twice — manually recorded first, then entered into the computer. Hand written forms like checklists are very versatile, as they can be used for collating test or similar information, and during class time to note observed behaviours. Anecdotal records can provide a wealth of detail, but are time consuming to prepare. Using codes can speed up recording anecdotes, provided the codes do not have to be looked up on a master list all the time. Recording of students' behaviours and the like during teaching can also be demanding, and takes some practice to achieve. Care should be taken to avoid lengthy checklists, or the taking of copious anecdotal records, or they can dominate the lesson.

Reporting

Teachers usually have to report their students' progress to school administrators and to parents/guardians. The former type of reporting is not normally important in lower Year levels, but assumes greater significance in higher Year levels, where there would be predetermined procedures and formats for doing this. I shall therefore direct my attention to reporting to parents and guardians.

In my experience, parents and guardians want to know to what extent their children are progressing. They find it easier to understand this if the report states how their child is performing in relation to others. The two ways of doing this that are often preferred are a percentage, and a position in a rank order of the class or group. Unfortunately, neither is necessarily a valid way of reporting a student's progress, and both reflect traditional practices. A percentage is not necessarily valid, since the score obtained depends on the questions or tasks set in the assessment. Judgements about progress are usually based on the assumption that 50% is a pass or satisfactory mark. This assumption rarely holds unless the percentages have been scaled according to a statistical distribution, which can only be done reliably when hundreds of students are involved. Similarly, rank position in class not only relies on test scores, but the students in the group that year. Groups of students vary from year to year in ability and application, so a rank position of, say, 5th may mean different things in different years. However, the use of a rank order can be more meaningful if there are hundreds of students being compared. In practice, few teachers outside of senior high school would have access to these comparative numbers across hundreds or thousands of students. We therefore need other ways of conveying to parents the progress of each student, in terms they can understand.

Learning Project 34

For your sector of schooling, obtain two examples of reporting to parents/guardians in science.

Do you think it tells parents/guardians what they want to know? Why/why not? If you have an opportunity, ask a few parents what they think.

In your group brainstorm about ways of reporting about science to parents/guardians in your sector of schooling, that parents would find helpful. Which is the best idea? Why?

Try working with the idea suggested below, as a group. Make up an imaginary report based on some actual outcome statements. If you have access to assessment data, use this to prepare a report. Explore different ways of presenting the information.

Effective communication in reporting. This is really what is needed when reporting to parents. We need to give them the type of information they want, in a form they can understand. As I said before, they want to know how their child is progressing. Progress is always stated in terms of a comparison to something or somebody else. If comparisons against other students (position in class) and using percentages are not necessarily valid, what alternatives are available? An obvious alternative is progress toward achieving objectives, provided the significance of the objectives is also known.

What I am saying, then, is that an effective means of communicating students' progress is to use outcome statements or objectives outlined in syllabus or curriculum documents as a basis. These outcomes are usually stated as expectations to be achieved at a particularly year level. Progress toward achieving those objectives provides one view of each student's progress. You have probably noticed already the flaw in this proposal: whether the outcome statements or objectives are valid in the first place. Hopefully the ones you use have been prepared carefully so they are valid, or at least there is a feedback mechanism in place so they can be modified as errors are detected.

Reporting in this way needs to have two sets of clear statements. The first is the outcome or objective; the second is the progress made by the student toward achieving it. Some principles to keep in mind are:

- state each outcome or objective in a way that non-teachers can understand. That is, avoid jargon;
- ensure the expected level of performance or criteria for the appropriate year level is indicated;
- state the student's actual progress toward the outcome/objective, based on your professional judgement derived from your assessment;
- keep the number of outcomes/objectives being reported to a manageable number, preferably not more than six; and
- ensure the information is presented in a clear unambiguous way.

I do not intend to suggest that this is the only valid or appropriate way of reporting, but under the current political climate in many countries, it is worth considering.

A Case for You to Work on

A novice teacher working next door has called on Joan/Sally/Julian to help with assessment in science, and how to report to parents. Think of a particular context where this might be happening (or make one up). What should Joan/Sally/Julian say and/or do?

In your group share ideas about what Joan/Sally/Julian should do to help the novice teacher. Include a description of the context.

Use this discussion to arrive at a "Code of good practice" in assessment and reporting in science for your sector of schooling.

Your Chapter Review

Use the "Code of good practice" emergent from your group discussion above, and evaluate it in terms of your own personal teaching situation. What would you change, and why?

If you were unable to obtain this from a group, make up your own personal code of good practice.

Further **Reading**

Criterion based assessment

Christofi, C. (1988). *Assessment and profiling in science.* London: Cassell.

Pallett, R. & Rataj, J. (1991). Criterion based assessment and school science: Part 1. *Australian Science Teachers Journal, 37* (4), 48-55.

Note: The whole of this issue was devoted to assessment in science, and there are many worthwhile articles to look at.

Pallett, R. & Rataj, J. (1992). Criterion based assessment and school science: Part 2. *Australian Science Teachers Journal, 38* (1), 54-56.

Assessment practices

Doran, R.L., Lawrence, F., Helgeson, S. (1994). Research on assessment in science. In D.L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 388-442). Washington, DC: National Science Teachers Association.

Fairbrother, R., Dillon, J., & Gill, P. (1995). Assessment in science: Teachers' attitudes and practices. *Australian Science Teachers Journal, 41* (4), 30-36.

Robinson, J.T. (1979). A critical look at grading and evaluation practices. In M.B. Rowe (Ed.), *What Research says to the science teacher, Vol 2* (pp. 1-31). Washington, DC: National Science Teachers Association.

Assessing concepts

Glynn, S., & Duit, R. (1995). *Learning science in the schools: Research reforming practice.* Mahwah NJ: Lawrence Erlbaum. Part IV, pp. 299-364.

Loughran, J. & Corrigan, D. (1991). Do you know your body: Assessing understanding. *Australian Science Teachers Journal, 37* (4), 44-47.

Stanbridge, B. (1993). Towards an alternative mode of assessment in senior chemistry: Using cognitive criteria. *Australian Science Teachers Journal, 39* (3), 69-72.

Assessing practical work

Cavendish, S., Galton, M., Hargreaves, L., & Harlen, W. (1990). *Observing activities.* Assessing science in the primary classroom series. London: Paul Chapman.

Russell, T., & Harlen, W. (1990). *Practical tasks.* Assessing science in the primary classroom series. London: Paul Chapman.

Schilling, M., Hargreaves, L., Harlen, W., & Russell, T. (1990). Written tasks. Assessing science in the primary classroom series. London: Paul Chapman.

Rosier, M. (1991). The assessment of science practical work. *Australian Science Teachers Journal, 37* (4), 32-39.

Gender-based assessment preferences

Rennie, L., & Parker, L.H. (1991). Assessment of learning in science: The need to look closely at item characteristics. *Australian Science Teachers Journal, 37* (4), 56-59.

Teaching Aids and Resources

What This Chapter Asks **You** To Do

During this chapter you will:

- Consider the uses computers can be put to in science programs, and apply these ideas to your own situation.
- Explore ways of managing equipment for the school and/or laboratory.
- Consider guidelines for using helpers in science classrooms and on field trips.
- Identify potential local science informal learning sites and how they might be used.

This chapter deals with several issues clustered around the use of aids and resources in teaching science. Each, while important in itself, is essentially an extra consideration to the basic thrust about science teaching derived from earlier chapters.

Learning Project 55

This chapter covers several types of aids and resources: computers, equipment management, classroom and laboratory helpers, and informal learning experiences.

For each, write down briefly what you know about them, in relation to science teaching. How would you use each in your teaching of science?

Using Computers in Science

Computers are increasingly available in all areas of schooling, How they can be used depends on the age of the computer, the amount of memory installed, and the availability of peripherals such as a printer, a modem (for connecting to phone lines) and a compact disc (CDROM) player. **A** fairly modern computer could have any or all of the following uses:

1. Data **gathering.** There are add-on packages available which include probes and measuring devices (e.g. a thermometer) which can be connected to the computer, and the software to enable the probes to be used effectively to, for instance, take observations over a period of time. Instead of the students sitting around measuring temperatures every five minutes for two hours, the

computer can take over after the first few times. Probes are available for a variety of tasks ranging from measuring temperature and pH, to monitoring velocity and acceleration.

2. **Data processing.** Spreadsheets are a form of normal commercial office software which can perform arithmetic calculations and plot graphs quickly from data entered into the spreadsheet, or from data gathered by the computer. Some special-purpose spreadsheets are available, such as those used for calculating overall grades from several tests.

3. **Databases.** There are many databases available now, most of which use CDROM technology. These are fully indexed encyclopedic information, usually available in picture, text, sound and film. There are some excellent astronomy databases which give "planetarium" type displays, and others which provide photograph images of planets and the like. **A** large number of topics is available now for all age groups, from mammals and dinosaurs to geological sites and forms. Many programs for young children have been tailored to appear as games. Some databases are available for teachers' use to generate examinations and tests.

4. **Simulations and models.** These are computer programs which simulate real or imaginary problems that the students are asked to solve. Older programs put lines of text on the screen and wait for the student to respond, but more powerful ones are interactive in real time. For example in an old program piloting a lunar lander was done by typing in periods and direction of fuel burning, and being told the results of the action in text on the screen, but more recent versions show a lunar lander control board and viewer on the computer screen and have operating controls which give immediate visual and other feedback to the student's actions (flight simulators). Simulations of science experiments can allow long-term or dangerous experiments to be "conducted" quickly and safely. Data presentation in table or graphical form is often available in such experimental simulations. Recent developments in simulations are in virtual reality, where a particular environment can be explored as if the operator were really in that environment, such as on the surface of Mars. However, these have not yet become generally available as they require considerable computing power.

5. **Drill and practice.** This has traditionally been done in the form of a quiz. While more recent programs tend to make them more "fun" to do, many of these programs are hardly worth the money. **A** more useful form generates examination questions for upper secondary students to practise answering examination questions.

6. **Word processing.** This is an excellent way for students to integrate writing with science if posters, charts, or reports are prepared using a wordprocessor or publishing package. **A** printer is absolutely necessary. There are also many

uses the teacher can make of a word processor, such as preparing worksheets and writing reports.

7. Tutorials. Some computer programs provide a structured teaching program where information is provided in small pieces and tested progressively. While some of these types of program can be useful, they are often quite bad! I would urge you to exercise caution in buying or using such programs.

8. Programming languages. These are languages written to allow students to "drive" the computer — the students control the computer rather than being controlled by the computer program. The best known example is the *Logo* program, used to teach mathematics, and also used as a control language for the *Lego Technics* computer controlled sets. The main point is not necessarily to learn how to program a computer, but to use the computer and the process of programming as a learning tool. Programs like *Logo* can be used by quite young students, provided proper use is made of the remote "turtle" robot. This is a device which runs freely over the floor, but is controlled from the computer program, linked by a ribbon cord or an infrared light beam.

9. Communication. Computers can be used very effectively to communicate with other computer owners through electronic mail (email) or through the World Wide Web (WWW). There have been some excellent trials of students interacting with others across the world in joint projects. If using the WWW, care needs to taken about which sites are accessed, as there are sites unsuitable for student use.

Consideration also needs to be given to the use of computers as part of the overall curriculum program. Many schools have established a computer room, which has to be timetabled for use. While this has advantages of efficiency in maintenance and security, it limits the use of the equipment to the few occasions per week when the class can be timetabled into the room. This requires careful planning so that maximum use can be gained from the computers during scheduled periods. On the other hand some classrooms have computers located in them, but, at best, only a few are usually available. This is most common in early childhood and primary classes, where there is greater flexibility for students to take turns during the day, and there is a fair measure of security fox the equipment. Another alternative is to use laptop computers which can be issued to students for particular purposes or periods of time.

Learning Project 56

If you had access to computers for your science program, what topics would they be most useful for? In what way/s would you use computers for these topics?

Look at some software produced for science in your sector of schooling, and decide how helpful it would be. What are good points about it? What bad points are there?

Equipment Organisation

This section is treated fairly generally, as the requirements for different sectors of schooling differ considerably. You may therefore want to be selective in what you look at in this section.

School equipment organisation

Use of equipment at the classroom level depends in part on good organisation at the school level. At the school level, there are three areas of consideration:

1. **Obtaining equipment.** This is usually obtained through education system ordering systems, and depends on the procedures in place. It is usually for more specialised equipment such as laboratory glassware and the like. Not all equipment can be ordered this way, so some may need to be obtained from local suppliers like supermarkets or hardware shops. Early childhood units and primary schools may also consider linking to the local high school/s to borrow specialised or expensive material. Students can also be invited to bring everyday equipment from home.

2. **Packaging and storing equipment..** High schools are usually well provided for with special storage rooms and containers, but it can be a problem in early childhood and primary schools. Packaging can be in any available containers which suit the purpose, such as tote boxes, ice cream containers, toy boxes, plastic basins, fruit boxes, margarine or yoghurt containers, shoe boxes, or cardboard cartons. Where to store containers is more problematic, since storage space is often at a premium, and in larger schools the equipment must be readily accessible. Possibilities range from a dedicated science room if space exists in the school, a central “store” cupboard, several decentralised “store” cupboards located around the school, **to** a fully seif-equipped classroom. A central store may work well for a small school of up to a dozen teachers, but this is ineffective for larger schools. If several grades at the same year level are in the school, the teachers may cooperate in obtaining and storing equipment. Secondary school storage areas need to conform to the legal safety requirements, particularly for storage of chemicals. For instance, strong oxidants must not be stored near reducers. Safety equipment also needs to be stored in an accessible place.

3. **Maintenance.** All systems must be maintained. That is, new equipment ordered, broken items repaired or replaced, and consumables kept current. Safety equipment must be checked regularly and kept in good operable condition. High schools usually have specially employed staff to help

maintain and organise equipment. Early childhood and primary schools must manage the best they can. The only options for them are to use teacher aides, parents, students, administration staff, or teachers. It usually falls to the lot of the teachers, so if care is not taken, the maintenance program can get crowded out with the other responsibilities of teaching.

Organising equipment in the classroom/laboratory

As a preliminary check, at least a week before the lesson, it is wise to check whether what you are planning to use is available. Consider hardware, consumables and perishables, and the quantities of each required. This will obviously depend in part on your grouping system and the number of groups you intend to form. In high schools, the laboratory assistant needs plenty of notice to arrange your needs. You would also need to conduct health and safety risk assessments for any planned laboratory exercises using any hazardous material, or including any potentially hazardous process. Fortunately, curriculum materials now contain very few suggested investigations or laboratory exercises involving hazardous materials or situations, but if you are using old material for ideas take extra care.

Possibilities for distribution of equipment include:

- Set up activity posts around the room, with the materials already there.
- Distribute materials yourself to each group.
- Have student monitors distribute the material to each group.
- Students collect the materials themselves.

Each has advantages and disadvantages, and your choice will depend on the context and the topic. If the chosen method involves a lot of student movement around the room, care must be taken to avoid congestion, and groups obtaining more than one set of equipment.

Always allow adequate time for collecting equipment and cleaning up. Use a similar system as used for distribution.

Learning Project 57

In your group discuss the advantages and disadvantages of the different ways of organising equipment for a selected topic for your sector of schooling. Each person in the group could be assigned a particular method to "defend."

Teacher Aides, Laboratory Assistants, and Other Helpers

Many schools have people whose task is to help the teacher, even if their availability might be somewhat limited. In some education systems, early childhood centres have assistants, primary schools have teacher aides, and high schools have laboratory assistants. Parents may also be available to help in some situations. If you have the opportunity for them to help you, you need to be able to relate to them in a professional way, and to maximise the time you have them for. The suggestions I have included here are some guidelines for working with such helpers.

- If the person is employed as an assistant, aide, or laboratory assistant, make sure you know what hisker job is about. There should be a job description somewhere which you can refer to. He or she may also have defined the job by simply getting in and doing things, so it is a good idea to have an informal chat to clarify what his/her perception of the job is. It is also useful to chat with any parent helpers to find out their strengths, weaknesses, likes and dislikes. Make sure that you know the sorts of things that you can ask of your helper, and the sorts of things that you cannot ask.

- In your planning, identify exactly what you want the helper to do. If the task involves interacting with students, you will also need to decide the nature of that interaction, and what criteria or expectations the helper should use to judge success or otherwise in his/her assistance.

- Decide when and how to convey all of this to the helper. It is best if this is not done in front of the students, especially if they are waiting to commence work. Advanced notice may be important for some tasks, particularly for laboratory or equipment preparation. Often written instructions can help, but be aware that even the most carefully worded statements may be interpreted differently from what you intended.

- If the helper has had some experience, invite and listen to her/his suggestions.

- Monitor the helper at work, though be careful not to be too obvious. The main thing you want to establish is that the task is progressing satisfactorily, and, if students are involved, they are on-task with no misbehaviour. Remember that the teacher has the ultimate legal responsibility. If equipment is being prepared, check a couple of days before it is needed to see that the preparation is progressing.

- Always treat the helper courteously, and provide encouragement and praise when appropriate. Even **if** something goes wrong, avoid placing blame or giving the cold silent treatment — just get on with salvaging the situation. If the helper is a continual problem you will have to decide whether to continue using the person. Finding a more manageable task may be best. If the person is a school employee, you should seek advice from the school administration.

Learning Project 58

Use a science curriculum plan prepared in an earlier chapter, and decide where a helper normally available in your school situation might be used productively. Decide how to prepare for the helper's involvement, how to brief him/her for the task, and how to monitor his/her work.

Informal Learning Experiences

These can be obtained through informal learning sites such as museums, and special events such as sponsored science projects.

Informal sites

Informal learning sites vary in availability and suitability. Science centres and museums are often located in larger cities, and environmental study centres and the like are often found in regional areas. They can all offer a valuable extension to the curriculum (not just science), but can also be wonderful time-wasters if their use is not planned for carefully. I offer some suggestions about using informal sites:

- If at all possible, visit the site well beforehand.
- Establish whether the site has static displays, interactive displays, or provides special educational programs run by their own staff.
- Structure your science program to take maximum advantage of the type of program available at the site. Integrate with other subjects if at all possible. Set clear goals. The visit should be part of an overall teaching approach, so that it fits well into the current learning program, with meaningful previsit and postvisit experiences.
- Arrange organisational aspects of the field trip (see Chapter 9). Consider the length of the stay at the site in terms of travel time and what might be achieved.

Static displays are difficult to use effectively, since they tend not to hold students' attention for long. These are best used in conjunction with a worksheet outlining a series of questions for investigation, preferably ones which the students have helped construct. An adult helper for each small group, who takes an active role in focusing the students' attention to each task, can maximise the use of static displays. This is imperative for younger students.

Interactive displays hold students' attention very well, but the interaction can be superficial and transient. If merely let loose in a site, students tend to try each display quickly to see what it can do, in search of the spectacular. Maximum benefit can be obtained if the students are directed to particular displays to investigate predetermined questions. Adult helpers for each group are most useful, as they can encourage students to interact with the display in a reflective way, and ensure they know what the display is portraying or modelling. Sometimes the site provides specially trained staff to introduce displays.

Special education programs are usually offered only at sites with some education authority involvement or which have some special funding for providing educational programs. Some science centres provide special programs, but they are most common at environmental study centres. Staff offering special programs are most often teachers appointed to the centre, so previsit collaboration and joint planning are essential to obtain maximum benefit. The teacher bringing the students may be asked to be involved in the teaching program.

Special events
These can range from science fairs to science projects sponsored by education authorities, districts, or businesses. They are usually competitive, with fairly specific rules laid down. Work submitted is expected to be the student's own work, though some assistance may be provided by the teacher or parents. The following guidelines may help in using these effectively:

- Find out what projects, fairs, and the like are available for your sector of schooling from the local science teachers association. There tend to be more opportunities for upper primary and secondary students, so projects can be organised for younger students at the school level, perhaps in association with a school fair.

- Obtain copies of the rules and requirements. If you are helping organise a school competition, the organising committee should draft the rules, perhaps using other set of rules as a model.

- Encourage the students to participate. Make sure they understand the rules and requirements — particularly about getting assistance from adults.

- Set aside part of the normal science program where they can do some preparation for their project, if this is allowed in the rules.

- Schedule a class display or presentation of the projects being undertaken, as they near completion.

- Ensure the entries are submitted by the due date, with any necessary papenvork.

- If there is local judging, the organising committee should ensure the judges know the criteria for assessing projects.

Learning Project 59

Find out what informal learning opportunities in science exist in your local district which might be useful for your sector of schooling.

Decide the types of topics and situations which might make use of these sites most effective.

A Case for You to Work on

In your group choose one of the following:

Joan, our early childhood teacher, has been asked to prepare a set of guidelines for using helpers (aides and parents) in her section of the school. You are a group of friends she has asked to help her. Assign one person to be Joan, and draw up the guidelines.

Sally, our primary teacher, has been asked to review the equipment organisation in her school, and suggest ways of making it more effective. She has called together a group of colleagues to discuss the options. Assign one person to be Sally and propose a way of organising equipment. You will also have to clarify details of the school, such as architecture and size.

Julian, our secondary teacher, has been thinking about introducing the use of computers in laboratory work for the Year 10 classes. He has called his staff together to discuss the possibilities and decide if it could be done, and if so, how. Assign a person to be Julian and decide what could be done. You will also need to clarify details of the school facilities and curriculum program.

Your Chapter Review

What new insights have you gained for using each of the aids and resources? Could you suggest some things which I have not mentioned, which you think I should have?

In your group share experiences in using some of the aids and resources described. Consider writing a manual as a group to provide guidance for a colleague intending to use a particular aid or resource.

Further Reading

Computers

Scaife, J., & Wellington, J. (1993). *Information technology in science and technology education.* Buckingham, UK: Open University Press.

Equipment organisation

Knox, M. (1994). Let's organise the science store. *Investigating, 10* (3), 26-29.

Science museums

Butler, S.V.F. (1992). *Science and technology museums.* Leicester, UK: Leicester University Press.

Science projects, fairs & field trips

Collette, A.T., & Chiappetta, E.L. (1994). *Science instruction in the middle and secondary schools.* New York: Macmillan. **pp.** 259-286.

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