# Overcoming learning impediments

This chapter is concerned with the issue of looking at 'failures to learn', and in particular with developing a perspective and approach designed to see such 'failures' as an opportunity for the teacher to learn about how to help the learner.

## The learning-doctor

A useful metaphor here might be to see part of the role of a teacher as being that of a learning-doctor. In other words although it is disappointing when the desired learning has not taken place — the teacher's role here is to:

a) diagnose the particular cause of the failure-to-learn; and
b) use this information to prescribe appropriate action, designed to bring about the desired learning.

Two aspects of the teacher-as-learning-doctor comparison may be useful. Firstly, just like a medical doctor, the learning-doctor should use diagnostic tests as tools to guide action. Secondly, just like medical doctors, teachers are 'professionals' in the genuine sense of the term. Like medical doctors, learning-doctors are in practice. (The 'clinic' is the classroom or teaching laboratory›. Just as medical doctors find that many patients are not textbook cases, and do not respond to treatment in the way the books suggest, so many learners have idiosyncrasies that require 'individual treatment'. And just as General Practitioners in medicine may find interesting cases worth reporting to The Lancer or the BMJ, learning-doctors may well find interesting aspects of learners' ideas or their responses to teaching worthy of reporting to the profession in Education in Chemistry or the School Science Review.

The best science teaching, like medicine, is a research-based activity: both in terms of the teacher's craft being informed by published educational research, and in the sense that every new class (and every new learner) arriving to be taught a topic is a unique 'case' that needs to be approached as a problem to be solved using professional knowledge and skill.[1][2][3][4][5][6][7][8]

## Obstacles to learning

There are many types of obstacle that can prevent a student learning as the teacher intends. Some but not all of these are — to a significant extent — within the teacher's control. Similarly, some of these obstacles ‹me largely outside of the teacher's control, and of the focus of the present materials.

However, it is useful to consider the various types of factor that can prevent students learning from teachers (if only to remind us how skilful successful teachers must be).

## A hierarchy of obstacles

At a fairly basic level of analysis, we can identify the following reasons why a member of a class does not learn the material the teacher hoped would be learnt. These ideas owe a great deal to the psychologist Maslow[9], but they are now familiar enough to count as common sense.

1.Absence If the student is not present, then no matter how wonderful the teaching, they will not learn anything. Although most of us do not suffer from Newton's attendance rates, (in some years no-one' came to his annual lecture, on which occasions he felt justified in only lecturing for half the allotted time!), this is a common frustration for most teachers.

Clearly there are ways of trying to help students who miss classes, but we would not generally hold the teacher responsible for those 'learners' who were not in class.

2.Physical **conditions** If a student cannot see the board or demonstration, or cannot hear the teacher, then effective learning from the lesson is unlikely. The student may have a physical problem (such as needing spectacles or a hearing-aid), which the teacher may not be aware of. bad hand-writing on the board or a class allowed to make too much noise would be the teacher's responsibility, but often conditions are outside the individual teacher's control (eg when the laboratory is not intended for such a large class, the teaching room assigned is next to a noisy drama studio, there is no screen available for the OHP, etc).

3.**Distractions** There may be more pressing issues in the learners' life than identifying the oxidising agent or calculating mole ratios. Clearly if a student is hungry, worried about a sick relative, scared of being bullied at break-time, apprehensive about the day's BCG inoculation, or in love with a classmate (or the teacher!) even the most skillful teaching display may not focus attention on the science. Often our teaching is not seen by class members as being the most important thing to think about, and in some circumstances this may even be a reasonable attitude for them to take.

4.Motivation As we all know, effective learning is only likely to take place if the students are motivated. Most students want to do well, want to feel good about their academic progress, and want to please teachers and family. Many are motivated to enter particular jobs or courses and are aware of the examination results they need. However, there are also many students in schools and colleges for whom there seems little reason to put in the effort to do well. And, sadly, there are some who are strongly motivated to be seen not to be valuing learning. Good teachers can sometimes get the best out of otherwise unmotivated students through the quality of their personal relationships with them. Similarly, by involving students in active learning (see Chapter *5j,* and presenting lessons in more interesting ways, much can be done to improve levels of motivation. However, sadly, there are some in our classes that are unlikely to be strongly motivated to learn from lessons even by the most gifted teachers.

Clearly all of the above are going to be substantive factors with some students in some classes, and these are not trivial issues. Indeed these factors are not entirely distinct, so, for example, improving motivation can reduce absenteeism. However the main purpose in outlining the problems above is to provide a demarcation between these issues and the main concern of the present chapter. Without wishing to underplay the importance of the problems discussed above (which will clearly be more significant in some institutions than others, and in some classes within institutions than others) the present chapter is mainly concerned with the reasons why students who attend classes, who are able to see and hear proceedings clearly, who are concentrating on the lesson and who are motivated to learn from it, should still often fail to do so.

This suggests that there must be at least one more type of obstacle to effective learning. It is helpful to label this as a communication problem, in the sense that the teacher's attempt to 'transfer' an understanding of some idea is thwarted

5.Not grasping the teacher's meaning It is a common experience of teachers that an apparently logical, clear and coherent presentation of a topic, pitched at an appropriate level, to keen and capable students, who should have previously mastered any pre-requisite material, does not guarantee that the intended learning will take place. A whole gamut of evidence (such as homework, test responses, class questions) shows that communication often fails.

Even for the best teachers, the task of helping learners gain an acceptable understanding of some scientific ideas is often problematic. (Whilst this can be frustrating, it is also true that if the communication of concepts was a trivial process, then teaching would lose much of its challenge, and its potential for helping learners and so providing the teacher with job satisfaction.)

The remainder of this chapter is concerned with the nature of this 'communication breakdown', and how teachers should respond to such failures to achieve learning.

## Barriers to effective communication

It is helpful to begin our analysis of why science teachers' skillful expositions often fail to communicate the intended meaning to learners by considering an extreme case.

Imagine you have a new student in your class: a keen, intelligent student who has to date studies a curriculum comparable with the rest of the class, and who joins as you set out on teaching a new topic. Als‹› consider, as sometimes happens, that this young person does not speak the language of instruction in your class, and that you do not speak the students' native tongue.

It would seem that there is little chance of even the most skilled teacher being able to effectively teach new science concepts to this student. Communication is about sharing understanding, and this is only possible if a common language can be found.

Even such a drastic case is not hopeless if at least one party is prepared to learn the language of the other (and I can recall one such case from my own teaching with a successful outcome due to the student's efforts with a translating dictionary, and a somewhat bilingual classmate acting as interpreter). The point is, that without a common framework for sharing meaning, a common language, effective communication will not occur.

The reason for presenting such an extreme case is to suggest that it stands as a suitable metaphor for all our int.=r-personal communication. It is what we — in science — might call the limiting case. Yet it is a potent metaphor for all our conversations with others: they are only successful to the extent that there is a common language for making sense of ideas.

By talking of a language I am not thinking so much of grammar, because most experienced teachers know how to keep their sentences simple enough for the age and ability of the classes they teach. * Although this may be a factor, far more important are the words we use. Nut only which words, but what we mean by them.

Clearly science teachers know a great deal of technical vocabulary, and this has to be introduced sparingly and in a non-threatening way. But even with those words that are familiar to students, the meanings students have are often very different to those intended by the teacher.[11]

It is well recognised, for example, that technical terms used in science (acid, force, energy, momentum, plant, chemical...) often have much less rigid and tightly defined uses in common parlance.[12] Students also often have vague or inaccurate meanings for non-technical terms (such as omit, initial or abundant).[13]

What is perhaps given le5s thought, is how the meanings of a word vary from person to person according to all the manifold ways in which they experience it and use it. Indeed, there is a sense in which each individual English-speaking person speaks a subtly different language: as no two individuals share exactly the same set of word-meanings.[14]

### What do *you* mean by a covalent bond?

Consider as an example a term like 'covalent bond'. Probably most students entering secondary school have no meaning for this term. As they pass through school, and possibly college chemistry and beyond, they construct a meaning, as they meet the term in a range of contexts.

Even ignoring students who get the 'wrong' meaning (perhaps mixing up covalent and ionic bonding) there is a whole spectrum of meanings to be developed. Perhaps initially 'covalent' bond might be understood as a pair of electrons 'shared' between two atoms (see Chapter 8), and this may originally be restricted to a few isolated examples (H—H, Cl—Cl, ...) until the concept is better mastered. It might be strongly associated with a line drawn between two chemical symbols, or a dot-and-cross type Lewis diagram. Perhaps it comes to have further meaning by being contrasted with the ionic bond.

The expert chemist, of course, brings a different and much richer meaning for the same term. For the teacher covalent bonds are at one end of a spectrum of bonds with varying degrees of polarity; perhaps they are associated with molecular orbitals formed by the linear combination of atomic orbitals; they are seen as bonding pairs which influence the shape of molecules in a slightly different way from 'lone' pairs of electrons, they imply something about the physical and chemical properties of the substances to which they are ascribed, etc.

A young student who has just learnt the notion of a covalent bond in a very limited context does not share the same set of meanings for the term as the teacher. This is not a case of the teacher being right and the student wrong, but of them having different concepts of covalent bond. The teacher and the student use the same word, but it is not clear that they refer to the same thing. The teacher's meaning is not only extended, it is more sophisticated, more subtle, and more deeply integrated into a framework of chemical ideas.

Now this situation is fairly obvious to teachers, and we all recognise that it is our responsibility to allow for the difference in meanings. The teacher tries to bear in mind the student's likely meanings for a word, and to hone his or her own language to both fit with, and ultimately to develop, the student's meanings. (This will be described in Chapter 5 in terms of seeing chemistry at the resolution available to the learner.)

### The class from Babel

Now in any real teaching session, this difference in meaning is multiplied by the number of concepts being discussed. Every word the teacher uses referring to some idea is associated with a different range of meanings for each learner in the class. For each idea used in an explanation there may be thirty or so different understandings of what is meant, some quite close to what was intended, some less so. When this potential for understanding differently is taken over a whole class, over a whole lesson, it becomes clear why teachers have to become such effective communicators. Each classroom is a diluted version of the Tower of

Babel. The student who does not speak the language of instruction is just the limiting case, in effect, every person in the class speaks a slightly different language.

### How do we make sense of what people say to us?

Slaving described the problems of effective communication in the classroom, it seems appropriate to turn the discussion around, and consider how we ever manage to understand each other.

Each of us has a highly evolved and well developed tool for making sense of the world — our brains! The human brain (although it obviously has other functions) is a complex instrument for making sense of the world.

To a 'first approximation' it is useful to think about two different aspects of the learners' brain (although the distinction is certainly not an absolute one). One aspect of the brain that is clearly important is how it functions, what we may call the cognitive apparatus. Although our knowledge about how the brain functions to process information is far from complete, we know that different human brains tend to he generally rather similar in terms of how (for example) visual information is processed, or how memories are laid down and accessed.

The processing of human language is also said to be very similar despite the apparent wide variation in human language. Brains obviously vary
— whether through genetic predisposition, developmental maturity, or prior experience — but they seem to generally work the same way.

The second aspect of the brain that is important shows much greater variation. This is the individual's frameworks of understanding and knowledge, built up through a lifetime's wealth of experiences.

Each eleven year old in a class has an enormous store of ideas, beliefs, images, memories, *etc,* that have been constructed in their brains through their personal life experiences. This complex framework of notions may be labelled as the learners' cognitive structure (see Chapter 3) and it is unique to that learner. Whenever a person listens to another, their ability to make sense of what is said will depend upon their unique cognitive structure, ie their existing frameworks of meaning.

### Constructing knowledge

One of the ways that brains tend to operate similarly, is that it is human nature to try and make sense of what is seen and heard. Indeed many common illusions depend upon the brain's ability to fit together a meaning from quite limited data. (So there may seem to be figures moving in the shadows; clouds may seem to take the shape of something familiar, such as a weasel {Shakespeare} or Ireland (Kate Bush}; and we readily recognise what quite minimal patterns (0) are meant to represent).

Human memory is notoriously unreliable. Human memories are not accurate records of events experienced, but reconstructions. The brain is potentially swamped by vast quantities of data every second, yet actually only has the ability to consciously process a very limited amount of information at any time. The cognitive apparatus filters the vast majority of input before it reaches consciousness.

The signals that do get through are not close to being raw data (except perhaps in cases of sudden pain!), rather they are already meanings that are imposed on the data to simplify it

so the high level processing can cope. This is why we see figures moving in the shadows when no one is there. (In evolutionary terms, there is clearly an advantage to over-interpretation in this example, it is better to play safe and be alert.)
Consider two simple examples. What do you see below? (Figure 4.1)

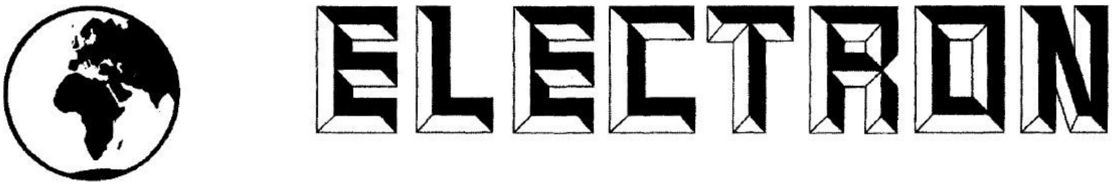


**Figure 4.1 Two recognisable patterns?**

It is easier to describe what you interpret the two patterns to represent (a recognisable image and a familiar word) than to describe what you actually see. We find this type of effect in many aspects of life. Stereotypes are readily maintained as it is easy to find examples that seem to fit our prejudices. In science we soon learn to ‘see’ cells through a microscope, to ‘see‘ isotopes on an NMR chart, or to see ’hysteresis’ in a load-extension graph. It is human nature to develop more and more intricate conceptual frameworks to enable us to quickly make sense of increasingly complex phenomena.

Each of our students has constructed an extremely rich structure of conceptual frameworks through which he or she effortlessly interprets the wbrld. This cognitive structure acts as the filter through which our teaching is heard. It is the substrate on which the learner builds a meaning for what the teacher has said. Often students construct meanings which are close enough to that intended for effective communication, but certainly not always. The teacher has to find ways to anchor new learning on the bedrock of the student’s existing conceptual structure. To use a biochemical metaphor, the molecules of the teachers’ message will only bind to the substrate (of existing conceptual frameworks) if they closely match the available target sites. If a binding site has the wrong structure (or is already occupied by an existing conception) then the intended synthesis cannot occur.

## Talking in code

One analogy for the teaching process is that of communicating through code. If the communication takes place between two people who share the same codebook then the message can be successfully passed on. Human minds work through a form of electrical communication (mediated by chemical processes of course), yet communicate externally through signs and language (such as writing and talking). The brain has to re-code the electrical activity that is ’our thoughts’ to be transmitted through speech or writing, to form a signal detected at another person’s ears or eyes, where their brain will try and re-code the signal into the original meaning. Yet, despite strong similarities in cognitive apparatus, no one is born with the codebook in place![15] Each of us has to construct our own codebook by a process of trial and error; a process which is complicated by the fact that no two people we talk to are using exactly the same codebook as each other.
Luckily, it is often (but not always) clear when communication is not working, and in normal conversation we are usually allowed to have several attempts at making sense of each other until satisfied that a meaning has been communicated. The perceived social pressures of a classroom may however lead to less than optimum opportunities for this ‘transactional calibration’.[16]

Often, however, the failure to communicate effectively may go unrecognised. If the listener does not re-construct the speaker's meaning, but still makes sense of what she hears, then neither speaker nor hearer will be aware that the message has been misconceived! Teaching can easily become an unintentional game of Chinese Whispers!

## Learning impediments

This way of thinking about communication (or lack of it) during teaching suggests a way to analyse 'failures' to communicate. Such failures to communicate can be frustrating for teachers and students, whether they are clear at the time or only become apparent later. The following way of classifying learning impediments is intended to help the teacher decide how to respond effectively when such communication breakdowns are detected.[17] Sometimes this will help with the immediate problem detected with the current student or group, and sometimes this will be more useful in planning future teaching.

Successful communication occurs when the teacher's explanations are interpreted by the learner as having meaning sufficiently close to that intended by the teacher.[18] Apart from the more obvious barriers to this communication considered at the start of this chapter (the student is absent, not able to hear clearly, not paying attention etc), communication can also break down when the learners' 'coding apparatus' is sufficiently different from the teachers. The teacher 'codes' his or her explanations from a background of chemical knowledge that is often much broader, deeper, more sophisticated and accurate from that of the students. However, the teacher uses her experience of teaching and of students to tailor the explanation to fit their current level of knowledge and understanding. Most of the time this is successful, but inevitably there are often occasions when at least some of the students 'decode' the explanation in ways that are not intended, or are unable to meaningfully make sense of the teacher's words at all.

In these situations we may think of the learning impediment being due to a lack of match between the actual knowledge and understanding of the learners, and that assumed by the teacher. This 'failure to match' can occur in different forms, and the teacher's next step depends on the particular type of mis-match.

The basic distinction is between the student failing to make any sense of the teacher's words, and in misinterpreting them.

## Null learning impediments - causes of not understanding

A null learning impediment describes the situation where meaningful learning does not take place because the learner does not make a connection between the presented material and existing knowledge. In this case the teacher is assuming that the explanation will be interpreted in the light of some existing knowledge and understanding, but this does not happen, and the teacher's words do not make sense to the student. The learner does not make the intended connection.

## Substantive learning impediments - causes of misunderstanding

The second type of situation is where the learner does make a connection with existing knowledge and learning, but not a useful connection from the point of view of the teacher. This usually means that the learner holds some alternative conceptions of the topic area, and understands the teacher's words in this inappropriate context.

It is important to distinguish between these two types of problem, because the teachers' appropriate response is different in the two situations. In one case, new information needs to be added to the learner's existing knowledge base. In the other case some existing ideas needs to be challenged or developed (see Chapter 10).

Moreover, each of these two main types of learning impediment can be further sub-divided.

### Two types of null learning impediment

Learners fail to make sense of the teacher's exposition because they have not been able to connect the teacher's words with their own existing knowledge. This could mean the learner does not have the prior knowledge, or that he or she just fails to realise what is being talked about! (So if a new teacher gives an explanation in terms of 'the valency shell', the learner may not realise this what the previous teacher referred to as 'the outermost shell'.) Deficiency learning impediment Sometimes learners will not have the assumed prior knowledge.

They may have been absent for some reason, or perhaps a previous teacher/school did not cover the material. (Or they may have made no sense of the teaching on an earlier occasion so that no significant learning occurred.) In this situation the appropriate response is to provide some form of suitable remedial input so that the learner acquires the 'missing' learning. Fragmentation learning impediment However, it may be that relevant material is held in cognitive structure, but that the learner does not appreciate its relevance, so the new material is treated as an unrelated fragment of knowledge. I will describe this case as a fragmentation learning impediment.

The most appropriate response from the teacher is to work to make the connection. This may simply mean asking the learner about the assumed prior knowledge and explicitly showing how the new ideas fit. Sometimes a more creative approach may be needed, with the teacher using analogies, metaphors and models to show that the new information is just like something already familiar to the learner. (Although important, this approach can lead to new alternative conceptions unless carefully planned. The example of modelling the atom as a tiny solar system is discussed in Chapter 7.)

### Two types of substantive learning impediment

Learners come to classes with all manner of alternative conceptions, deriving from various source[19] and so there is great scope for new teaching being misconstrued in terms of existing knowledge and understanding. Substantive learning impediments are more serious than null learning impediments for two reasons:

(a) it is easier to 'fill' a 'gap' in knowledge than to challenge and replace an existing conception (see Chapter 10);
(b) 'gaps' in knowledge are often easily detected as learners and teachers can readily spot that no meaningful communication has occurred. Misconceptions may go undisclosed for long periods as both parties believe they understand the matter in hand.

In terms of helping individual learners it is important to identify and then challenge alternative conceptions,[20] and it is not that significant how the alternative ideas developed.

However, taking a more long-term view, it is useful to identify when alternative conceptions have developed from previous teaching. This makes little difference to those learners misunderstanding this year's lessons - but it may be possible to avoid the problems recurring with future classes. To revisit my notion of the learning-doctor, the medical doctor's immediate task is to diagnose and treat the patient's problem - but individual cases may also provide more generic information to improve public health. The slogan ’prevention is better than cure’ can apply to teaching as well as to medicine.

Intuitive science conceptions - ontological learning impediments This is a (rather awkward) term for those alternative conceptions that arise from the learners’ experiences of the world.[21,22,23] best example (because it has been found to be so widespread) is the naive physics conception that objects stop moving unless constantly pushed. This is an understandable deduction from everyday experience (as it is actually what happens in practice!), and causes many students difficulty when they study Newton’s laws in school.

As students are not taught Newtonian mechanics until after they have experience of pushing objects around in a gravity-rich and friction-rich environment, it is inevitable that many will come to school science holding an ‘impetus’ framework (ie that when pushed objects move so far until the ’push/force/ ...’ is used up). Physics teachers just have to accept this, be aware of it, and deal with it!

Mis-learnt science conceptions - pedagogic learning impediments There are doubtless many such alternative conceptions that arise outside of school, and which teachers can only tackle after they have been acquired. However, it has been suggested that in chemistry many of the alternative conceptions learners hold are ’pedagogic learning impediments’ that derive largely from the teaching they have received.[24,25] learner’s personal beliefs about force and motion may be due to early life experiences, but it is much harder to explain why a learner would come to school believing that the sodium chloride lattice is comprised of diatomic molecules. Such ideas clearly develop from the way the subject is taught (see Chapter 10).

Sometimes these ideas are the result of students working beyond their level. Keen students may read ahead and can misinterpret material for which they have inadequate background knowledge. (Consider, for an example, what a typical 13 year old recently introduced to a basic model of atomic structure, might make of a laboratory poster showing the shapes of atomic orbitals.) Often, however, the teaching may not take the students’ existing ideas into account sufficiently. If learners lack the expected prerequisite knowledge (see Chapter 3), or if the complexity of presented material overloads working memory, or contains logical steps that are too large for the learners to construct the teacher’s meaning (see Chapter 5), then the learnt version of the ideas will not match what is intended.

If learners have alternative ideas of this type, the teacher needs to address them in the same way as intuitive science conceptions. However, it may be possible by re-thinking teaching (the order of topics, the emphasis given to certain ideas, the stage at which formal definitions are introduced, etc) to reduce the extent to which these problems are found in future year groups. Knowledge of how this years’ learners have misunderstood concepts can be very useful in planning how to introduce those topics in future years.

The typology of learning impediments described above is represented in Figure 4.2. These characteristics of the types of learning impediment, and the actions indicated, are summarised in Table 4.1.

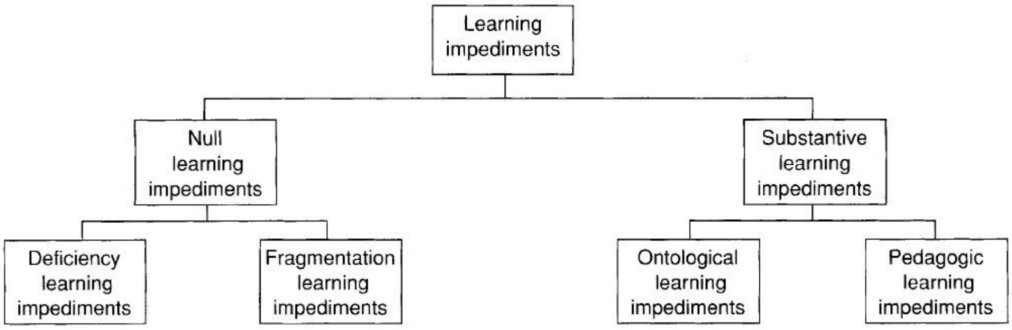


**Figure 4.2 Types of learning impediment**

| Type of learning impediment | Nature of impediment | Action required |
|---|---|---|
| Deficiency impediment (missing knowledge) | No relevant prior knowledge and understanding | Remedial teaching of prerequisite learning (if available), or restructuring of material with bridging analogies *etc.* |
| Fragmentation impediment (disconnected knowledge) | Learner does not see relevance of existing knowledge to presented material | Teacher should make connections between existing knowledge and new material explicit |
| Ontological impediment (intuitive science) | Presented material inconsistent with intuitive ideas about the world | Make learner's ideas explicit, and challenge them where appropriate |
| Pedagogic impediment (mis-learnt science) | Presented material inconsistent with ideas deriving from prior teaching | For individual learner: treat as ontological impediment; for future: re-think teaching of topic – order of presentation of ideas, manner of presentation, *etc.* |

**Table 4.1 Types of learning impediments**

## Applying ideas about learning impediments in the classroom

The section above discussed how failures to learn may sometimes be seen as breakdowns in communication due to a mis-match between the ideas the teacher expects the students to bring to class, and their actual knowledge and understanding. The purpose of discussing such ideas, and in particular of suggesting a way of classifying different types of learning impediment, was to provide a way of thinking about learning difficulties that may be a useful tool for teachers.

## Common and not-so-common alternative conceptions

Give a teacher a probe and you help him or her identify specific conceptions; teach a teacher to be sensitive to students' conceptions and you provide insight for life.[26] The probes and exercises that are included in the companion volume have been written to take account of alternative conceptions that have been uncovered in research. There are some common alternative conceptions that research suggests are found in most classes in most schools and colleges. The materials have been prepared to help teachers diagnose and challenge some of these common conceptions. The two criteria that have been used to select topics for probes are:

(a) the topic seems to be commonly misunderstood in ways that can be readily identified; and
(b) the subject matter is significant for the understanding of basic concepts.

It has not been possible to deal with all of the alternative conceptions reported in the literature. Just as important, every learner is unique, with his or her own individual network of ideas, beliefs etc. So many learners have alternative conceptions that are idiosyncratic, and which cannot be revealed by the use of standard sets of diagnostic tools. So while it is hoped that the materials included in this resource will be useful, they will not provide a universal panacea for identifying students' alternative conceptions.

## The most important diagnostic tool: the teacher's sensitivity

In practice all teachers regularly spot learners' alternative conceptions. Often 'different understandings' are apparent in test responses or homework assignments. It is obviously more useful if the teacher can identify learners' alternative conceptions as early as possible. It would be ideal to have diagnosed and catalogued all relevant alternative conceptions (as well as having checked that pre-requisite prior knowledge is in place) before starting a topic. In practice this degree of auditing prior learning is not usually possible, although techniques such as concept mapping (as discussed in Chapter 3) can be very useful.

However, a good teacher can use classroom questioning to elicit many potential 'failures of communication' in situ, which allows the misunderstandings to be dealt with immediately, rather than when reviewing written work (by which time fanciful interpretations will have been rehearsed and may have taken hold in the learner's thinking). The teacher's sensitivity to learners' potentially unhelpful ideas about science topics may be increased in a number of ways:

(a) with increased teaching experience there are more opportunities to be familiar with the types of ideas students use in their work;
(b) being more aware of the types of ideas that have been found and reported in research;[27]
(c) taking time to sit down with individual learners or small groups and exploring their ideas in a nonthreatening context;
(d) developing a teaching approach that encourages learners to discuss and critique their ideas; and
(e) developing classroom questioning techniques which explore learners' interpretations in more depth, rather than simply evaluating responses as correct or not.

In particular the teacher has to try and interpret the learner's comments in terms of his or her own meanings, and not assume that the learner means much the same as the teacher hoped, or see apparently non-sensible suggestions as necessarily confused or meaningless. (Of course students do often answer questions with a 'random' or confused response, but some comments that seem meaningless may indicate that the student has an alternative conception for the point being discussed.)

The typology of learning impediments discussed above (see Figure 4.2) is meant to be a tool to help teachers think about learners' apparent failures to understand our teaching. The classification is not meant to be absolute, but to provide the teacher with a simple analytical framework. It is intended that using the framework will help develop sensitivity.

Included in the companion volume is a resource to help teachers work through this process, the Learning impediment diary, but the intention is to increase awareness of, and sensitivity to, learners' ideas, rather than to learn to use the typology itself.

The basic format of this 'exercise' is to keep a diary of the 'failures of communication' that you notice in your teaching, and to then try and classify these (and so start to think about their origins, and how they can be overcome and perhaps avoided in future). Some readers may feel that their teaching experience and sensitivity is such that this will not be a useful exercise: but it is offered for those who may find it helpful.

## Keeping a diary of learning impediments

The basic form of the exercise is to keep a record of the learning impediments that you notice in your teaching. It is not necessary that you spot and record every occasion a learner does not understand the work. Indeed it may initially make more sense to decide to look out for one instance in each lesson, or one example per day. It is the analytical process that is important, not the quantity of examples you can spot. If you find this exercise helpful, you may decide to continue the diary indefinitely. Or you may feel you have become sufficiently sensitised to learners' ideas to be able to respond flexibly without needing to continue to use the diary. Or you may feel you only need to use the diary when first meeting a new class, or teaching a topic you have not met for some time.

1. **Spot a failure to communicate**

The first step is to be aware of occasions when a learner has not followed your intended meaning. This is easy if the student looks blank and is waving her arm to tell you she 'does not get it'. When students are (sadly) less concerned to understand, or are embarrassed to be seen *to* not 'get it', or when they misunderstand, then active questioning is needed. The questioning is usually better if conceptual rather than factual ('can you explain why?' rather than 'do you know what?'), and an initial suggestion of a misconception may need to be probed (gently) by a short sequence of questions.

2. **Detail the failure**

The pressures of the classroom make it tempting to respond to any apparent misunderstandings by quickly providing the 'right' answers. However, without exploring the reasons for the misunderstanding such an input is often like 'papering over cracks' and will not correct the problem in the long term. A detailed exploration of what the students thinks, and why, will reveal more about how communication has failed, and, therefore, how to best deal with it.

3. **Apply the framework**

The simple 'key-type' flowchart (Figure 4.3) will help you work through what you need to know in order to respond effectively. In practice you will want to deal with problems as they arise in class, and probably will not have time to document examples at the time. However, it is suggested that it may be useful for you to use the flow chart as an aide-memoire, and to complete the diary entries as soon as possible after the class.

You may find that it is difficult to analyse and record classroom instances of 'communication breakdowns' because of the pressures of working with large, demanding classes. An alternative approach (at least, as a starting point) would be to identify apparent problems from missing/wrong answers in students' work, and then ask to speak to the individuals about the work for a few minutes after class. This would enable the problem to be analysed in detail in a calmer environment, with less potential for embarrassing the learners, or of loosing 'the thread' of the lesson for the rest of the group.

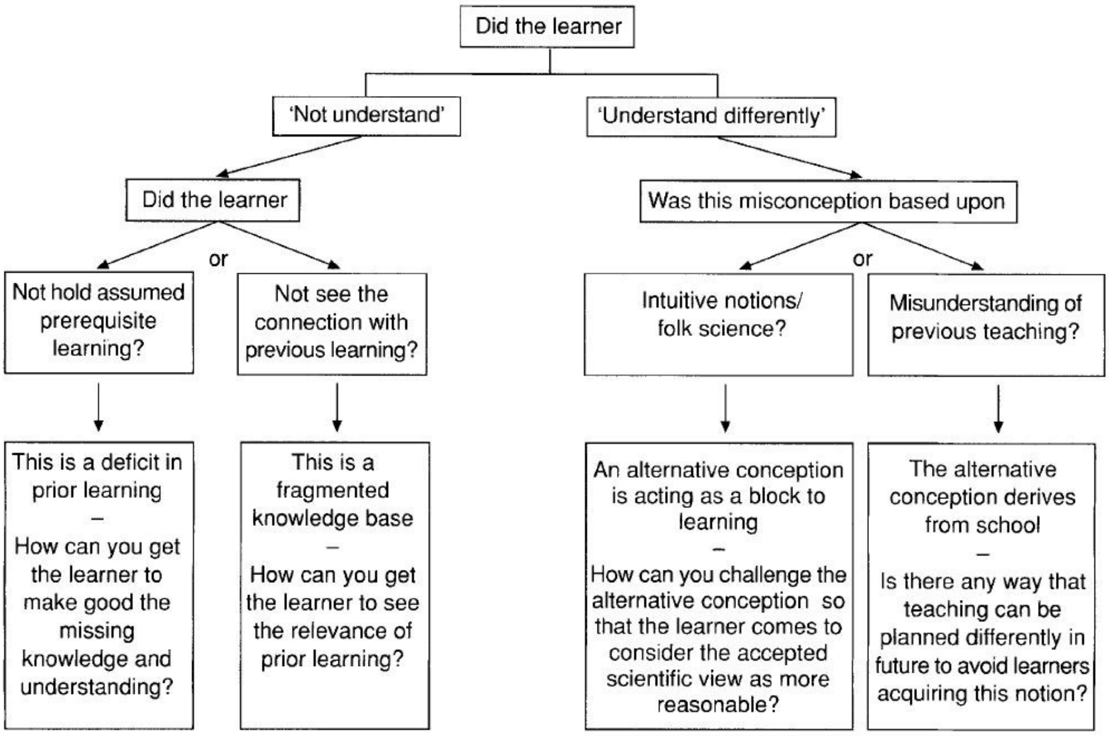


**Figure 4.3 A flowchart for analysing learning impediments**

# Notes and references for Chapter 4


1. Educational research has been criticised for often being irrelevant to practice - a charge that has been strongly resisted by the research community (for example, the British Educational Research Association - see note 2). Within science education, research has been seen as an important way of informing practice for many years (eg notes 3 and 4). A recent book discusses a number of areas where research in science education has significant implications for practice (see note 5). The UK Association for Science Education (ASE) has been concerned about the issue of whether science teachers should be more involved in, and aware of, research for some years (eg see note 6), and there have been calls for science teachers to see their work as research based (see note 7). The RSC Challenging Misconceptions in the Classroom project which led to these present publications was very much seen as an attempt to help teachers adopt research findings in their classroom practice (see note 8).
2. P. Mortimer, letter to the editor, Sunday Telegraph, 28.1 1.99, reprinted in Research Intelligence, 1999, 70, back cover.
3. P. F. W. Preece, Towards a science of science teaching, School Science Review, 1977, 58 (205), 801 -806.
4. P. F. W. Preece, A decade of research in science education, School Science Review, 1988, 69 (248), 579-586.
5. R. Millar, J. Leach & J. Osborne, Improving Science Education: the contribution of research, Buckingham: Open University Press, 2000.
6. K. S. Taber, Communication, motivation, ownership and subversion?: Facilitating the application of research in science education, 1996, available via Education-line, at http://www.leeds.ac.uk/educol/ (accessed October 2001 ).
7. K. S. Taber, Should physics teaching be a research-based activity?, Physical Education, 2000, 35 (3), 163-1 68.
8. K. S. Taber, Constructing chemical concepts in the classroom?: using research to inform practice, Chemistry Education: Research and Practice in Europe, 2001, 2 (I), 43-51, available at http://www.uoi.gr/conf-sem/cerapie/ (accessed October 2001 ).
9. D. Child, Psychology and the Teacher (4th Edition), London: Cassell, 1986
10. Techniques for estimating the reading age of classroom texts and teaching materials suggest that in science lessons reading tasks are often set at too high a level However, it is not clear how definitive such findings are. Some techniques used give words with multiple syllables a heavy weighting as they are assumed to be inherently difficult. Science tends to use a lot of long technical words, and so texts will tend to have a high reading age on such measures. Although long words will tend to be more difficult to read, this may be less of a problem once those words are a familiar part of a students' vocabulary - see the comments in Chapter 5 on 'chunking' information. More significantly, perhaps, measures of reading age assume that such text is intended for lone reading by an individual. If a learner is reading along with peers or a teacher then it may be appropriate for the reading age of a text to be set above the individual's own reading age. (In terms of 'scaffolding learning', discussed in Chapter 5, the reading age of the text should be within the learner's 'zone of proximal development', to provide an achievable challenge that will help the learner develop their reading skills in science.)
11. D. M. Watts & J. Gilbert, Enigmas in school science: students' conceptions for scientifically associated words, Research in Science and Technological Education, 1983, 1 (2), 161 -1 71

12. C. Sutton, Language and communication in science lessons, Chapter 4 in C. R. Sutton, & J. T. Haysom, The Art of the Science Teacher, Maidenhead: McGraw-Hill, 1974,41-53.
13. A. H. Johnstone & D. Selepeng, A language problem revisited, Chemistry Education: Research and Practice in Europe, 2001, 2 (l), 19-29.
14. C. Sutton, Science, language and meaning, School Science Review, 1980, 62 (21 8), 47-56.
15. Although it is conjectured that some brain structure acts as a ‘language acquisition device’, this is meant to channel human language within a general form: it does not provide the specific grammar (or lexicon!) of particular languages.
16. The idea that in dialogue we provide each other with ’constant transactional calibration’ has been discussed by Jerome Bruner. See Chapter 4 of J. Bruner & H. Haste, Making sense: the child’s construction of the world, London: Routledge, 1987.
17. K. S. Taber, The mismatch between assumed prior knowledge and the learner’s conceptions: a typology of learning impediments, Educational Studies, 2001, 27 (2), 159-1 71.
18. Sufficiently close, that is, to be able to give answers that are judged correct in test, examinations, etc.
19. One classification refers to preconceived notions; non-scientific beliefs; conceptual misunderstandings; vernacular misconceptions; and factual misconceptions - Science Teaching Reconsidered: misconceptions as barriers to understanding science, at http://bob.nap.edu/readingroom/books/str/4.html (accessed October 2001).
20. Although it may be necessary to challenge students’ ideas, research suggests that well established ideas are not readily ‘forgotten’, even once they are shown to be inadequate. See Chapter 10.
21. ’Ontological’ being to do with the things that exist in the world and how they are categorised. For example, in some cultures, spirits and ghosts may be seen to be as real as living people (see note 22). In science education it has been suggested that many alternative conceptions are based on students’ ontologies having category errors - such as classing heat as a substance like water (see note 23).
22. K. S. Rosengren, C. R. Johnson & P. L. Harris, Imagining the Impossible: Magical, scientific and religious thinking in children, Cambridge: Cambridge University Press, 2000.
23. M. T. H. Chi, j. D. Slotta, & N. de Leeuw, From things to processes; a theory of conceptual change for learning science concepts, Learning and Instruction, 1994, 4, 27-43.
24. M. Carr, Model confusion in chemistry, Research in Science Education, 1984, 14, 97-103.
25. K. S. Taber, Prior learning as an epistemological block?: The octet rule - an example from science education, 1995, available via Education-line, at http://www.leeds.ac.uk/educol/ (accessed October 2001 ).
26. With apologies to a well known charity slogan.
27. In England there is a government funded initiative to raise standards among the 11-14 age range. This ‘Key Stage 3’ strategy for science is intended to provide opportunities for ’continued professional development’ to all teachers working with that age range in maintained schools. One of the units that is being developed is on ‘key ideas and misconceptions’. There are strands in literacy, numeracy, science, ICT and critical thinking.