Introduction

Clarification of terms

Giftedness in individuals can be used to describe adults or children that have a capacity for high levels of expertise. Giftedness in children could be thought of as 'expertise in development'.[1] They may or may not be currently high achievers and their potential may emerge at any stage in their development. The Department for Children, Schools and Families (DCSF) uses the term *gifted* to mean the most able in academic subjects like English, maths, history *etc*. The term *talented* has come to refer to those with abilities in areas such as sport, art, music or drama. The gifted and talented students can be thought of as the top fraction of the ability range. Young Gifted & Talented (YG&T) – the new national programme for gifted and talented education – encourages the top 10 per cent to join their membership. Other organisations also take the top 10 per cent as gifted and talented. *Severely gifted* children are exceptionally able and represent a much smaller fraction of the population.

Why something special should be done for the most able students

It is axiomatic in education that *every child matters*. All students deserve an education that gives them the opportunity to maximise their potential. Children need to be challenged by tasks that take into account their abilities and prior knowledge. Gifted provision in the classroom is about meeting the individual needs of the most able along with the other students. Able students, in common with others, can get bored and disaffected by lessons that have an inadequate level of demand or interest for them. Some gifted students become difficult and uncooperative in lessons where they have felt de-motivated by the lack of demand in the tasks set.

Some people involved in education are wary of special provision for the most able. Among their concerns is that such provision may be elitist and lead to lower ability students being less well provided for. They are likely to comment that, if an activity for gifted students is worthwhile, it should be made available to all students. Gifted provision is not elitist – it is not motivated by a belief that some students matter more than others, but by a belief that what is needed to meet the needs of some students differs to that which is needed for others.

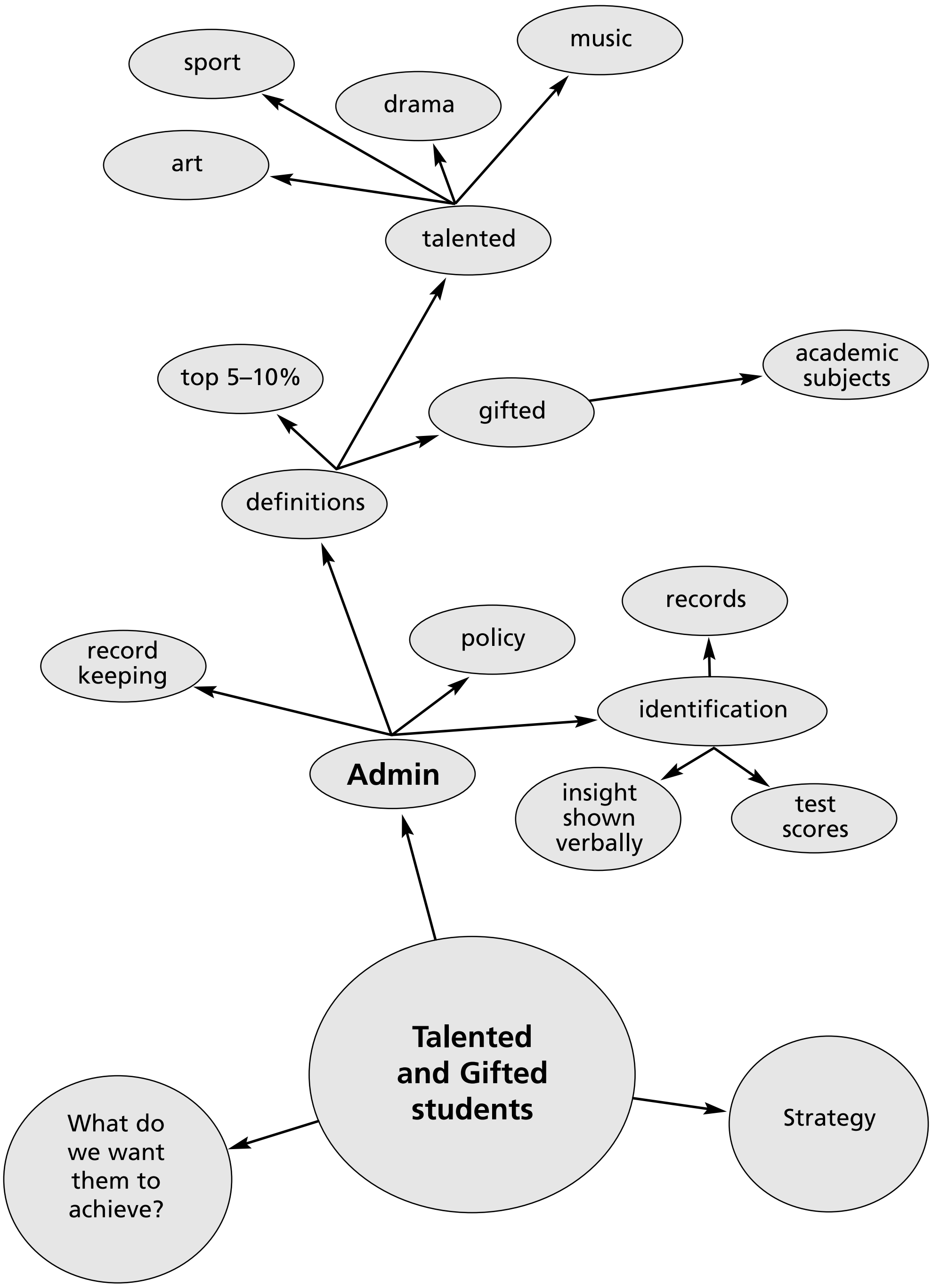
Contrary to the belief that the other students suffer when provision is made for gifted students, there is evidence from OFSTED that when the needs of the able students are met, standards of achievement are raised for all students.[2]

Overview of talented and gifted provision

The mind maps below summarise some of the generic topics discussed in the literature on gifted and talented education. There are three maps shown for clarity, but they really form one large whole.

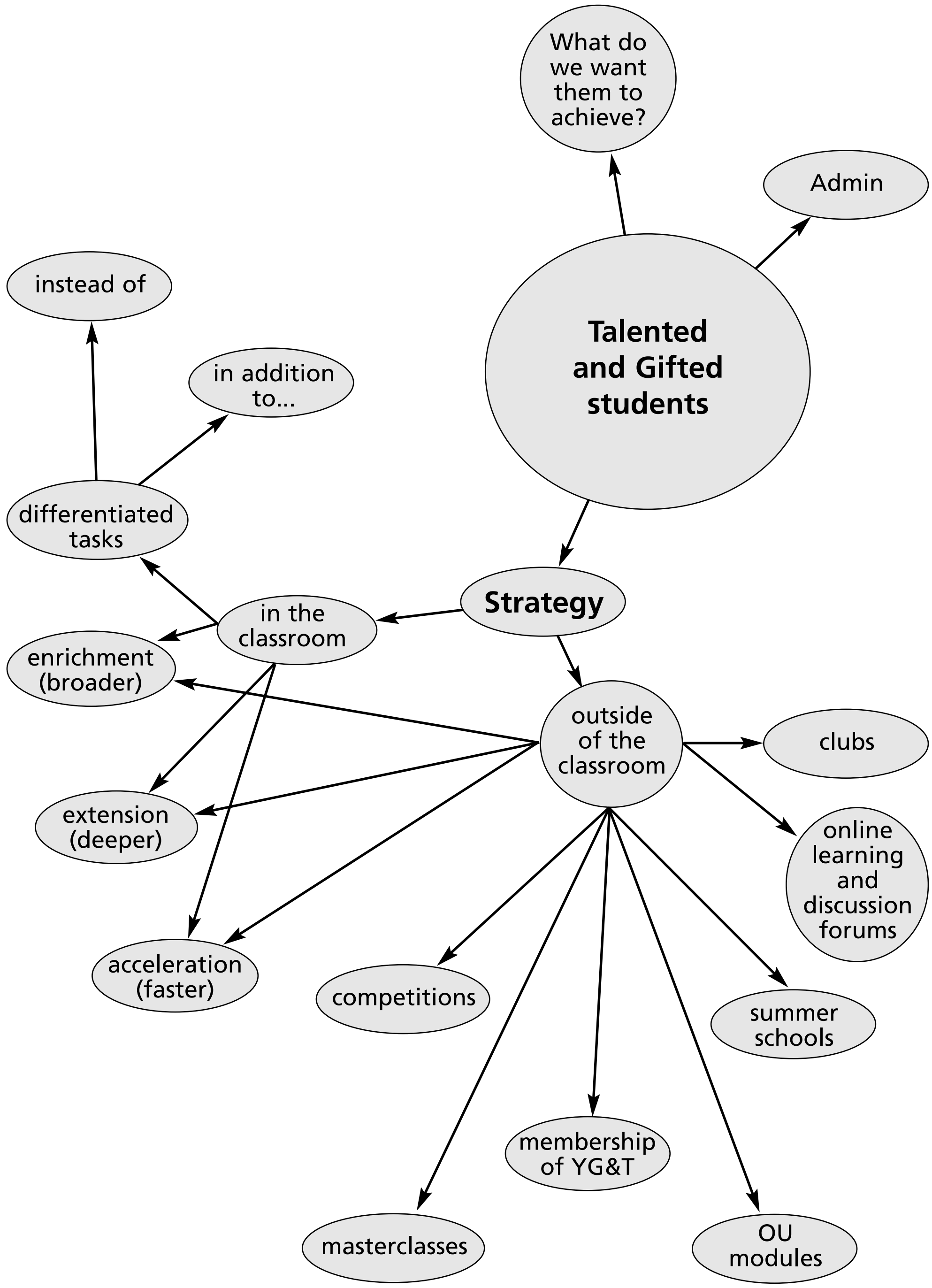
Administration

Schools in England are expected to have produced policies for the gifted and talented and to have put them into practice. Further information about such generic issues is available from *www.standards.dfes.gov.uk/giftedandtalented/* (accessed April 2007).



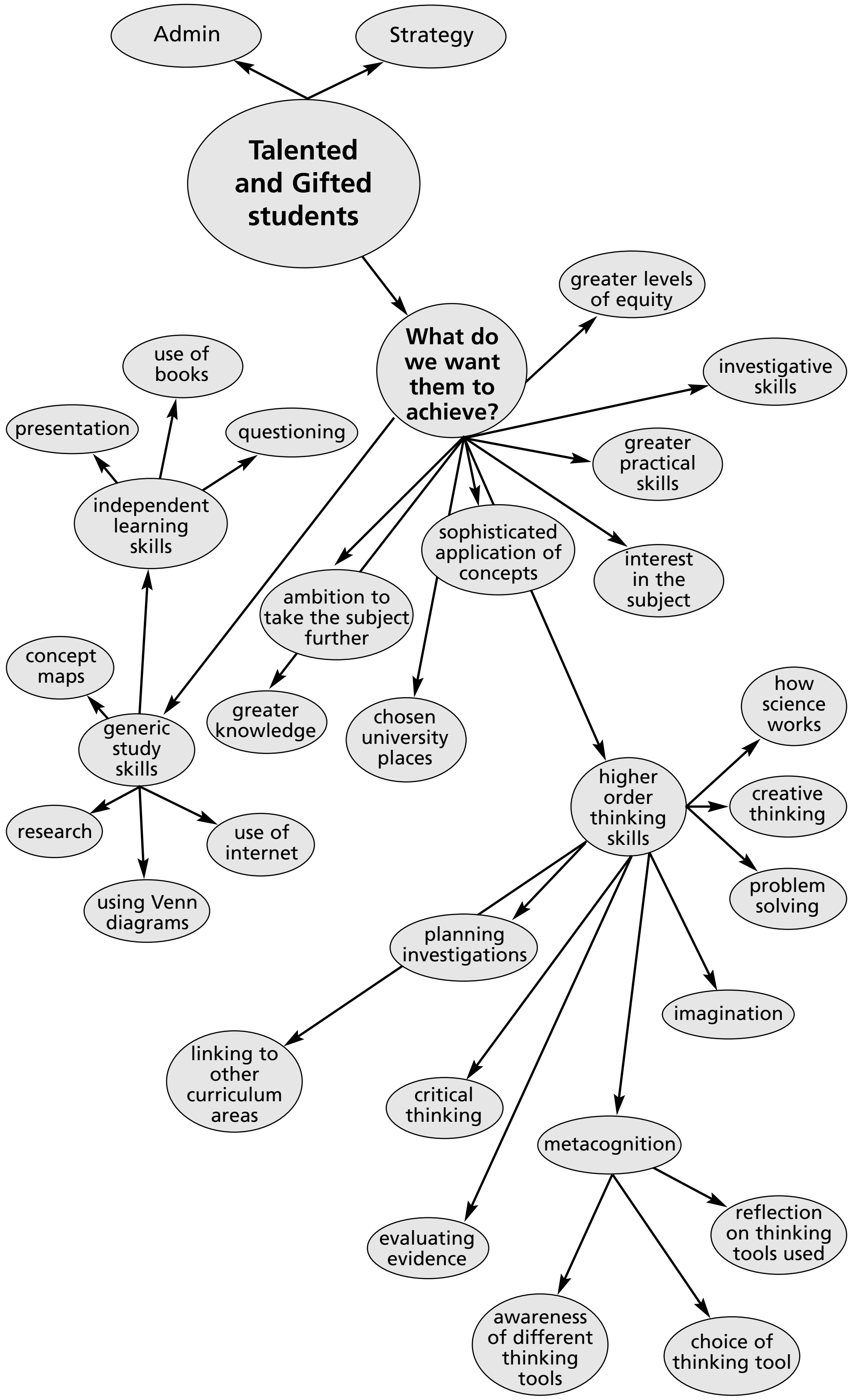
Strategy

This includes an overview of the types of additional and alternative learning experiences that students can benefit from.



The aim of provision for gifted students

The focus here is on educational aims in a narrow sense. There are many possible emotional, social and spiritual benefits for giving a very able child appropriate learning experiences. These underpin the ethos of gifted provision but are omitted because of the risk of 'preaching to the converted'.



What we should do with gifted students

Materials are available to help whole science departments consider the issues around provision for gifted students at
www.standards.dfes.gov.uk/keystage3/downloads/agt40_mod4_sci.pdf
(accessed April 2007).

If giftedness is 'expertise in development' then we need to pause and ask what expertise in our subject is like. We need a vision for what high levels of performance means in chemistry. That vision depends on the developmental stage of the student. What we should aim to achieve with a student who is finishing their chemistry education at age 16 differs from the aims we may have for a student who follows a post-16 chemistry course.

Aspects of a vision for expertise in chemistry which are common with other subject areas:
- good independent learning skills;
- the ability to make links to other knowledge and concepts;
- communication skills;
- teamwork skills;
- generic study skills such as revision techniques, use of concept maps, Venn diagrams, flowcharts and other tools for ordering thoughts;
- higher order thinking skills – creative and critical thinking;
- metacognition – an awareness of the different thought processes that students use; and
- problem solving skills.

Aspects of expertise in students more specific to chemistry (or science):
- spatial awareness that enables students to visualise, in three dimensions, models of molecules, atoms and ions;
- appreciation of the nature of models as used in chemistry and an ability to choose the appropriate model for the situation in question;
- application of abstract models;
- use of published data, such as thermodynamic data, and awareness of its limitations;
- evaluation of the usefulness and reliability of models and data;
- practical skills;
- investigative skills;
- breadth and depth of knowledge of chemistry;
- ability to apply the fundamental concepts of chemistry to novel situations; and
- mathematical skills applied in a chemical context.

For post-16 students on a chemistry course there may be *fundamental* concepts that are not currently taught as part of the specification they are following. It is clearly detrimental for gifted students to miss out on these and they should be encouraged to find out about them and use them. Principally: *curly arrow mechanisms, entropy* and *the second law of thermodynamics* but others might want to add topics such as *molecular orbitals* to that list.

How the use of this resource fits in with the wider provision for gifted students

The model of gifted provision adopted nationally in England has a pyramid like structure, with classroom provision as a foundation to everything else. The bolt-on experiences outside the classroom should not be seen as sufficient provision for gifted students on their own.

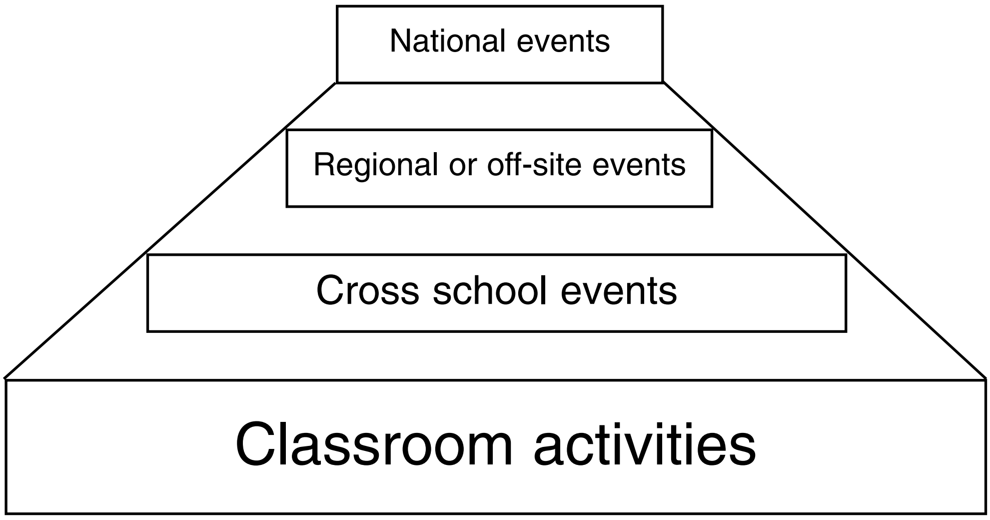


Figure 1 Structure of gifted and talented provision

The main purpose of this publication is to provide resources and ideas for *classroom activities* that might be used as differentiated tasks or whole class activities. Some of the teachers using this resource may be involved with chemistry provision for the very able beyond lessons, so it is worth considering what some of the opportunities might be outside of the classroom. Some of these are listed towards the end of this chapter under the heading *Opportunities for gifted students*.

Strategies

In general, provision for gifted students uses three approaches: enrichment, extension and acceleration. These are also referred to as broader, deeper and faster.

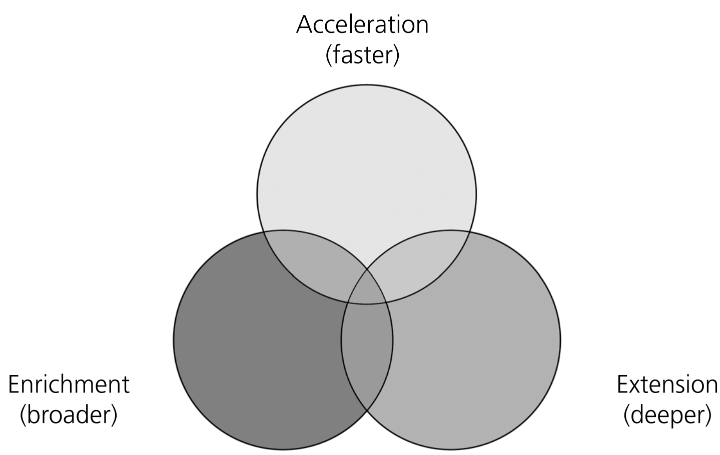


Figure 2 Three types of gifted provision

Enrichment, acceleration and extension

Enrichment activities are those that are outside the normal curriculum. Thus the learning experience is broadened beyond the scope of the standard provision.

Examples of ways in which curriculum topics can be enriched:

Contextual enrichment – approaching a topic via an application or situation, *eg* corrosion on the Titanic rather than just rusting.
Historical enrichment – studying the development of ideas, how models are changed and refined, *eg* role play around Priestly and Lavoisier as part of a topic on combustion.

Enrichment activities do not need to closely relate to the general curriculum. For example the activity *Norbert Rillieux and the sugar industry* in the RSC publication D. Warren, *Chemists in a social and historical context*, London: Royal Society of Chemistry, 2001.

Acceleration is covering concepts or knowledge earlier than would otherwise be done. Careful consideration needs to be given to acceleration as a strategy. You do not want to cause subsequent frustration by teaching the most able something which they are then going to be taught again.

Extension means taking a deeper look at current topics, using higher order thinking skills and applying theory to understand concepts to a greater depth than would otherwise be done. For example, relating chromatography to the particle model, planning experiments instead of following a recipe and evaluating different explanations of the same observation. A topic could be extended by approaching it via an egg race or problem solving scenario.

Many activities incorporate aspects of more than one approach as indicated in *Figure 2*.

The rationale for these resources

These resources focus mainly on extension activities. This was done partly to complement the scope of existing resources. Many of the materials already produced by the RSC and others offer opportunities to enrich the curriculum. Some suggested resources are listed later in this chapter under the heading *Other resources suitable for gifted students*.

Many of these resources are designed to be an episode that could fit into a lesson on a regular topic. The resources are designed so that they can be used to differentiate for the more able in a class or, if appropriate, for whole class use. Differentiation can put extra demands on teachers' time in class so for every activity there is a discussion of the answers and issues raised that are appropriate for the students. The *Discussion of answers* sheets are written for the students and can be given to them to review their own work or as guidance to help peer review and discussion.

Some of the activities are designed to develop study skills in a chemical context – *eg Organising your thoughts* and *Atoms, elements, molecules, compounds and mixtures*.

Some of the activities are designed to develop critical thinking skills – *eg Boiling point* and *Solutions*. Here the students are asked to evaluate a number of alternative explanations or ideas.

The *Covalent bonding* activity attempts to address the over reliance on 'filling the octet' as a model for bonding, as identified by a previous RSC Schoolteacher Fellow, Keith Taber.[4]

It is important that students develop an understanding of the nature of models in science. The activities *Bonding models* and *Formal charge* give them the opportunity to evaluate and refine models used in chemistry.

The concept cartoons – *eg Candle investigation* and *Ionic bonding* – are an easily reproducible way of adding a more challenging episode in a lesson. By offering new ways of looking at a situation they make it problematic and provide a stimulus for developing ideas further.[5] They can be used to develop critical thinking (evaluate several alternatives), creative thinking (produce several alternatives) and enquiry (asking several questions). They are easy for teachers to produce themselves and have the great advantage that there is not too much to read before you can start thinking.

Lateral thinking skills are important. *Rust* introduces lateral thinking problems to the students, where they search for the solution by asking questions that can be answered 'yes' or 'no' by the teacher.

Chemistry at its best is an interrelated web of concepts, practical skills, models and facts – each supporting and gaining support from the whole. Gifted students particularly appreciate a sense of overview of the subject and some of the activities in this resource – *eg Rates and equilibria* and *Entropy and equilibrium* – are written to show the connection between subject areas.

Students are often aware that examination questions have clear cut definite answers which the question, if read carefully enough, will point them towards. They are expected to reproduce well rehearsed thoughts and arguments. Examination questions ask students to state, account for, explain and describe. We do not often ask them to speculate about situations where the possible solutions are not well rehearsed and may not be known by the questioner or indeed at all. The activities *A new kind of alchemy* and *A question of thinking* encourage this type of speculation. Speculation involves *creative thinking skills* and helps to dispel the myth that everything interesting or exciting in chemistry is already known and understood.

Many students (especially gifted ones), when faced with a question, are able to leap to an answer without having to explore their thinking about it (as illustrated by the top part of *Figure 3*). The result is sometimes that they do not have the explorative skills to consider a problem if they do not see an answer immediately and then tend to declare 'I don't get it'. Toddlers will sometime pick up objects and explore them. They will turn them over in their hands and scrutinise them from every angle, try tasting and hitting them and establish whether they will fit in their nostrils *etc*. I believe that students need identified thinking tools to help them explore questions in science.

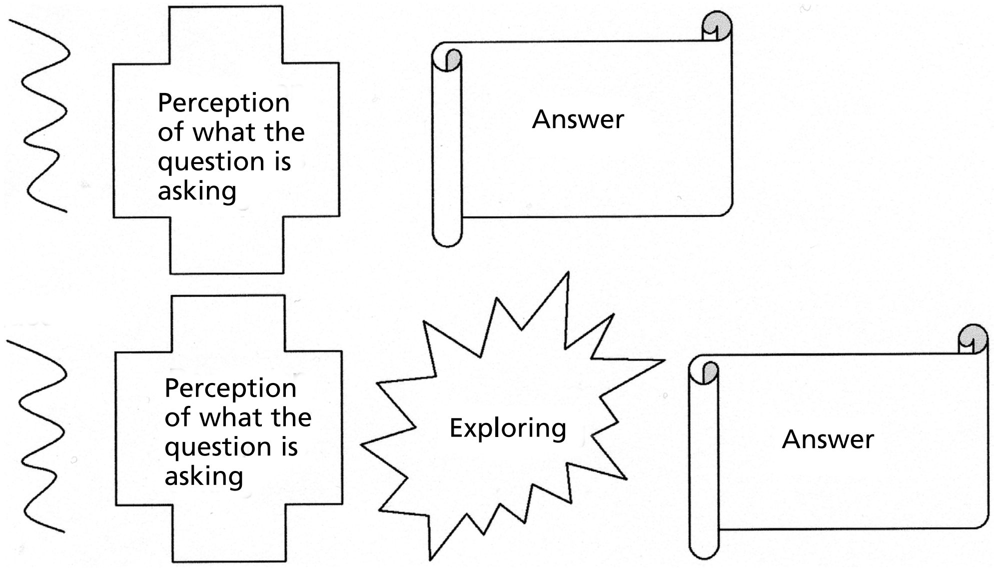


Figure 3 A diagram showing the place for explorative thinking skills in problem solving

Part of the answer lies in the students developing **metacognition** (thinking about thinking) skills. There is a good case for frequently discussing with students what kind of thinking strategies they employed in answering questions and identifying specific thinking procedures they can use when they meet a question where the answer is not readily apparent. Instead of supplying the answer in response to the declaration 'I don't get it', it is better to discuss what thinking procedures could be employed when searching for understanding.

Some thinking procedures might be:

- organising the question into what we know and what we need to find out;
- rewording the information given;
- listing all the facts and concepts that might have a bearing on the question;
- developing a flowchart from the information given – *eg* information A tells us that trend B will be true *etc*.
- developing a flowchart back from the answer – *eg* to be able to give a value to Z I will need to know Y which will be determined by X;
- brainstorming alternative suggestions;
- 'mind mapping' out from the original problem;
- fishing for a similarity with a familiar fact or concept in chemistry;
- briefly exploring, or identifying an intuitive feel for, which direction a brainstormed suggestion might take;
- evaluating alternatives and prioritising the most likely suggestions;
- having arrived at an answer go back and ask if it seems reasonable; and
- acting as a critic of your solution. Are there identifiable problems (sources of error, dubious assumptions *etc*) with the solution?

The activities *A question of thinking*, *Mixing drinks* and *Volume changes* are designed to develop students' metacognition.

The Chemistry Olympiad questions, which have been selected from the RSC Round 1 selection papers for the *International Chemistry Olympiad*, are carefully written to test and develop the problem solving skills of the most able students. They often introduce an interesting context in which the chemistry is explored. By providing a more detailed discussion of the answers it will hopefully encourage teachers to give these out as part of the work on the relevant topic without fear that it will demand lots of time from them to explain or work out the solutions. More students will hopefully feel encouraged to sit the Olympiad Round 1 paper having tackled past paper questions.

Some post-16 chemistry courses currently leave out important topics such as curly arrow mechanisms, entropy and the second law of thermodynamics. Several activities refer to these topics and *Curly arrows and stereoselectivity in organic reactions* and *The second law of thermodynamics* are designed to develop students' understanding of these topics.

Many gifted students have good memories and recall facts with little effort. However, they do not all recall facts well and some may have a tendency to categorise factual information as trivial and therefore not worth committing to memory. The puzzles and Su Doku activities encourage students to engage with factual information in a problem solving context. All kinds of puzzles – *eg* crosswords and Su Doku – are attractive, almost addictive, to some, and can be a more exciting approach than being told to learn facts for a test. The logical problem solving skills developed are useful in themselves. For example, they are similar to the skills used to assign NMR spectra or identify an unknown.

How to use these resources

As many of these activities are designed to add a more challenging episode to regular topics, they could be given to students who finish the general tasks early. However, some students can be discouraged by the perception that the reward for staying on task is yet more work. A preferred option is to use these activities **instead** of some less challenging work for those students who will not be sufficiently challenged by the alternative task. Teachers may wish to select which students do the extension activities on the basis of general ability, recent good work, or the students demonstrating that they have a good grasp of the topic already. It is often beneficial for teachers to find out at the start of a topic what the students already know; students who demonstrate a sufficient knowledge or understanding at the start could then be asked to take on the extension activity. Another model for consideration is **self selection** – ask the students to make a judgement as to how well they understand a topic and to select the level of challenge that they believe they are ready for.

Many gifted students learn well and are most creative when they discuss ideas. It is not always necessary for their answers to be written down and there is a positive benefit in offering a variety of methods of reporting back their thoughts. Many of the activities ask several questions which can discourage students if they are expected to produce written answers for all of them. If there is more than one student working on an activity it is recommended that at least some of the questions are simply discussed.

Assessment of the students' responses can be done at several levels. There is often a good case for peer review, particularly among gifted students. This gives them some feedback and also develops their listening, empathy and communication skills. They should be encouraged to read through the *Discussion of answers* and may indeed decide that they disagree with them. The activities may well stimulate questions that they will want to discuss with their teacher.

Some personal reflections by the author

Over the course of the fellowship year I have read and thought about the teaching and learning of students (gifted and otherwise) to a greater degree than I had done previously. I go back to teaching with several resolutions about how my teaching can be improved and I record them here in the hope that they will be helpful for other teachers.

- Avoid 'experiments to show...' where the student can already predict the outcome.
- Set more open ended tasks and encourage a greater diversity of reporting methods.
- Do more investigation work (with a sigh of relief that it is not coursework) where the students (and teacher) do not know what the outcome is.
- Allow gifted students to learn more by discussion and less by writing.
- Repeatedly ask students if there are other additional possible solutions when they have arrived at an answer.
- Foster enquiry by asking what questions could be asked.
- Adopt a must, should, could model in the scheme of work which gives examples of relevant extension and enrichment activities.
- Use more of the problem solving activities in *In search of solutions* ***www.chemsoc.org/networks/learnnet/solutions.htm*** and *In search of more solutions* ***www.chemsoc.org/networks/learnnet/more_solutions.htm.***

'Often there has been too much reliance by the teacher upon absolute right answers related to some sense of truth, or sometimes too much control on the student's thinking within a set paradigm.'[6] Appreciate whatever thinking or logic might lie behind an answer even when the answer is wrong.

Edward de Bono[7] divides thinking into 'reactive' and 'pro-active', where reactive thinking is in response to a defined problem but pro-active thinking is more open ended, creative and diverse. I would like to give students greater opportunity for pro-active thinking. I hope to risk setting some very open ended tasks such as: producing presentations on an application of chemistry; coming up with fundamental questions they think would have important answers; describing a day in the life of someone in a world suddenly deprived of man-made materials; predicting how chemistry will transform our lifestyles in 40 years time; describing the biochemistry of life evolved on a planet with as much sulfuric acid or bromine as we have water *etc*.