SCOTTISH QUALIFCATIONS AUTHORITY

Chemistry Review

Progress Report August 2003

As part of the NQ Review of Chemistry in 2001, it was decided that SQA should begin a long-term project to update and revise Chemistry courses to address the relative difficulty and decline in popularity of the subject.

The aims of this work were to:
- identify contemporary themes and topics around which chemistry courses could be constructed
- identify suitable skills that could be developed through chemistry
- examine the role of practical work
- develop proposals for practical assessment
- embed data handling and problem solving in practical and theoretical contexts that will support skill development
- create opportunities to use ICT and interfacing
- develop proposals for assessment strategies that are appropriate for a new approach
- consider new learning strategies within the context of proposed changes
- consider how chemistry courses could limit fragmentation and have continuity, coherence and progression of concepts that link Intermediate 2, Higher and Advanced Higher
- consider progression issues from 5-14 Science to Access 3 and Intermediate 1 Chemistry.

The following is a proposed set of principles which would be used to guide future developments in chemistry.

1. Content and concepts

It is proposed that any changes should take account of the needs of learners and the needs of society. There should be a reduction of existing content, greater articulation of remaining content, and the introduction of new ideas that give a view of the nature of modern chemistry. The aim should also be to reduce fragmentary concept development in the courses and to develop a sense of progression among learners. A reduction of content would allow ideas to be explored more thoroughly and in greater depth allowing candidates the time to assimilate them more fully.

In order to explore issues in more depth it would be necessary to reduce existing content quite considerably so long as what was removed did not hinder progression to further study. This in turn presents an opportunity to add material reflecting more recent developments in chemical knowledge although overall the expectation is that there would be a reduction in content. New content at Higher or Advanced Higher could include:
- Fuel cells
- DNA and the genetic code
- Green chemistry
- Biotechnology
- Liquid crystals.

2. Themes

Learning is most effective when it proceeds from the familiar to the unfamiliar and it is the applications of chemistry that have greatest relevance to everyday life. One solution might be to build a course around a set of universal themes under which chemical knowledge can be grouped.

A model suggested here is that chemistry addresses five themes that are relevant to everyday life:

- Food
- Health
- Energy
- Environment
- Lifestyle (or Materials).

Chemistry has made an enormous difference in these five areas and addressing these themes in a course could challenge the perceived view that chemistry is not relevant to everyday life.

It is not the intention that the above aspects would replace concepts conventionally encountered in chemistry courses but rather that issues like these be woven as seamlessly as possible into the fabric of the courses. Nor is it suggested that it would be necessarily appropriate to construct thematic courses with these five topic headings but they do give a focus for much greater emphasis to be placed on the relevance of chemistry by the use of appropriate introductions to areas of study or by the use of different approaches to learning, for example, short case studies or discussion. Where possible, setting the issues within a Scottish context would be valuable.

In revising courses the emphasis should be on considering issues which are likely to have long term currency and the avoidance of scientific ephemera. Stress should also be placed on the positive contributions that chemistry has made and is making rather than purely negative considerations such as pollution, although these aspects should not be sidestepped.

Table 1 below shows which themes could be addressed by which units in the existing Higher course. There are a number of courses based on themes or applications already in existence[1] and they seem to be effective but no particular model is being advanced for adoption. The emphasis would be on an amalgam of good practice.

Energy Matters	The World of Carbon	Chemical Reactions
Energy Lifestyle Environment	Food Health Lifestyle	Environment Food Energy

Table 1 Higher Units linked to themes

Each one of these themes is surrounded by an air of controversy for, although great benefits have occurred through the application of chemical knowledge, there have also been problems, largely unforeseen and unplanned. A complaint of science courses is that they are constructed in such a way that discussion of controversial issues is avoided. Discussion of issues would be one way of introducing certain topics. It would not be possible to devote a great deal of time to such an activity but it should provide a stimulus to candidates.

[1] eg Salters Chemistry
Chemistry in the Community, American Chemical Society

3. Skills

Employers have long urged the education sector to equip candidates with a range of transferable skills that would make them more effective in their chosen field of employment.

The following five skills:

- Communication
- Team working
- Numeracy
- Use of IT
- Critical thinking

have been identified as particularly desirable for those working in science related disciplines.

Any review of chemistry courses should take the issue of skills seriously. Syllabuses should be constructed in such a way that they explicitly develop these skills in parallel with the more usual demands of the syllabus ie the development of chemical understanding and the acquisition of a body of chemical knowledge.

Communication, numeracy, and use of IT can all be developed by normal coursework. Communication should be understood to include speaking as well as writing. The former can be developed by requiring candidates to give verbal reports on suitable activities, for example case studies. Problem solving and data handling both in practical and theoretical contexts are suited to developing team working and critical thinking, in addition to the other three.

4. Data Handling and Problem Solving

It might be argued that data handling and problem solving are inseparable from other components of any chemistry course and need no separate discussion. However an opportunity presents itself to tackle these aspects while at the same time developing skills through the use of a number of brief case studies forming part of the formal content of the course.

The sort of skills objectives that case studies could involve are:

- analysing, interpreting and evaluating data from a variety of sources
- presenting data in a variety of appropriate ways
- identifying trends and projecting outcomes from data
- using data, in conjunction with chemical knowledge, to solve problems
- working both independently and collaboratively as part of a group
- preparing and presenting a written report from given information and researched information
- preparing and presenting an oral report from given information and researched information
- making appropriate use of information technology.

Opportunities for developing critical thinking can present themselves where problems have incomplete data or unfamiliar methods or unclear goals. New skills in working collaboratively and in thinking in creative and divergent ways are developed with these types of problems and the effect is one of mental stimulation not normally associated with learning.

Practical problem solving

Predictability of practical work could be tackled by the use practical problem solving exercises. With these exercises the ability to group problem solve is developed by applying existing chemical knowledge to an unfamiliar problem. The problem could be introduced and discussed with the whole class if necessary so that the problem is fully understood. A number of possible strategies could be evaluated and tried. Alternatively, separate groups could be given the problem to solve without prior class discussion.

Practical problem solving is more challenging when the problem has an answer to be found which goes beyond simple observation. Having a measurable result gauges the extent to which the problem was solved. Examples of this type of activity might involve candidates finding out as much as they can about three different solids, or preparing a volumetric standard and then comparing three antacid tablets.

5. ICT

The revised chemistry courses would maximise the use of ICT. Opportunities for ICT include:

- using software to present information on paper and on screen
- using databases and spreadsheets to process data
- gathering data using sensors
- gathering relevant information from the internet
- gathering relevant information from CD ROMs.

ICT in chemistry involves three basic processes:

- sourcing data
- organising data
- presenting data.

6. Practical Work

Practical work is a key aspect of chemistry and hence should be an essential component of chemistry courses. It serves a variety of purposes:

- it shows that the principles of chemistry are based on observable results, even although the underlying explanation must be inferred using a set of chemical theories consistent with the observations
- it allows candidates to experience chemical phenomena as real events
- it allows candidates to apply theoretical principles to arrive at solutions to real problems
- it allows candidates to develop a range of communication, numerical, manipulative, organisational, and critical thinking skills which are useful and, in the main, unique when in the context of chemistry.

The practical work that chemists do falls mainly into these categories:

- preparing and characterising pure substances
- collecting and processing data
- quantitative analysis
- volumetric analysis
- spectrometric analysis
- qualitative analysis.

All of these techniques would be of little value were they not carried out according to a set of generic principles which define the essence of scientific practical work and are known collectively as experimental method. These are:

- understanding the need for risk assessment
- selection of the most appropriate method
- exclusion and control of variables

- the importance of working methodically and accurately
- the ideas of standards and calibration
- understanding the reason for taking multiple readings
- the importance of repeatable results

- correct handling of data
- appropriate presentation of data
- the idea of uncertainty and confidence in results
- interpretation of results.

The first three are related to experimental planning and design, the next four are concerned with carrying out the experiment, and the final four have to do with evaluating results. The above list of principles is not exhaustive but they are central to practical work in chemistry. Rather than making specific experiments the focus of attention, conducting practical work around these principles might do much to counter the view that it is trivial and undemanding.

7. Practical Assessment

The question of how practical work should be assessed is one which will need careful consideration and broad discussion.

Some issues are whether:

- practical work should be assessed in a formative manner or in a summative manner
- assessment of separately identified manipulative skills is valid or reliable
- a written experimental report is a more valid assessment of practical work than recall of experimental method in a summative assessment
- drawing of experimental apparatus is valid assessment of practical work in a summative assessment
- Prescribed Practical Activities should be retained or not
- assessing the underlying principles of practical work is more valid than a number of selected experiments being assessed
- the principles of practical work should be embedded into the course in a more integrated way.

8. Assessment Strategies

External examination

In considering the external component of assessment, it is important that performance in the final examination should be a valid measure of chemical expertise. There is a need to discuss:

- the type of questions: use of multiple choice, short answer, free response, data handling, problem solving based on case studies
- use of language eg use of general terms or the need for specifc names and implications for syllabus content
- ways of increasing the validity of the examination including a consideration of the number of marks available within the specified time limit.

Unit assessment

The opportunity is presented for different approaches to assessment to be taken which need not parallel the external examination. Internal assessments could have a greater focus on skills rather than content, particularly written communication and critical thinking. A report on a case study might form part of the assessment, or an open book report which had been researched previously, or more open ended problem solving involving evaluation of practical data, or a short written account of a particular concept.

9. Articulation of Access 3 and Intermediate 1 Chemistry with 5-14 Environmental Studies

A more suitable treatment of chemistry in revised Access 3 and Intermediate 1 courses might be found in the "Public Understanding" courses that exist[2 3] in which the issues of science are discussed. Such courses might give greater focus on the benefits and problems that chemistry brings to everyday life and how the responsible citizen should relate to them. There could be content on how to interpret data and how to read and deal with information. There could be some experimental work, possibly to do with environmental monitoring, but treated mainly at a macroscopic level, and there should be opportunities to use ICT. The general skills listed in the main body of this report should apply to this course as much as to others.

10. Comments

Comments on any aspect of this report should be addressed to:

Mary Hoey
Qualifications Manager
Scottish Qualifications Authority
Hanover House
24 Douglas Street
GLASGOW
G13 1SE

Telephone 0141 242 2329

e-mail: mary.hoey@sqa.org.uk

---

[2] OCR GCSE Science Single Award Pilot (Science for the 21st Century – project title)
[3] Science for Public Understanding, AS Level, AQA