Novel Approaches in English Science Education

Michael Akeroyd, Bradford College, BD7 1AY, UK

Email: m.akeroyd@bradfordcollege.ac.uk

Theme: *Assessing Contextual Approaches to the Teaching of Science*

The National Curriculum for England and Wales introduced a new science specification for the 14-16 year old cohort as from September 2006. This includes a novel component "How Science Works". In particular, the Edexcel "360Science" specification adopts a hierarchical spiral philosophy resembling the ideas expressed by A. N. Whitehead (1), this writer (2, 3) and Franz Riffert (4).These topics are analysed in detail in reference (5), included as an appendix at the conclusion of this summary. In addition, the Edexcel specification includes polymer chemistry and astrochemistry *before* traditional inorganic analytical chemistry, in line with the *process model* of introductory chemical education proposed by Joseph Earley, Snr., (6).

The March 2006 ACCN issue (pp. 12-13) contained extracts from a longer document published by the American Chemical Society entitled "The Chemistry Enterprise in 2015", authors W. F. Carroll Jnr. and D. J. Raber. These authors stated:

"The success of the Chemistry Enterprise in the framework of multidisciplinarity will require that our scientists will be deeply trained in the core of chemistry but also be able to communicate and collaborate with those in related disciplines."

No mention was made in the ACCN extract of the role of school chemistry teachers in preparing pupils to think more flexibly, but in the ACS document there is the briefest of references to "New approaches to the chemistry curriculum" (p. 11).

Many course developers adopting a *contextual* philosophy often assume that merely designing a course that is *interesting, relevant,* and *process orientated* is sufficient for success in increasing student academic attainment. However the work of Ramsden (7) suggests that merely evoking the pupil enjoyment of *chemistry* lessons is not in itself a recipe for success if there is no attempt also to modernise the associated theoretical *chemical concepts.*

Recently Eric Scerri (8,9) has advocated adoption of the Janet or "left-step" Periodic Table. A similarly unconventional table was advocated previously by this writer (10) and is also included as a teaching aid in the distance-learning program of the Honolulu Community College, Hawaii. So far the author's proposals for a new *sigma-pi* bonding notation in organic chemistry curricula (11) have not borne fruit.

Recommended reading: Berry van Berkel: The structure of school chemistry: A quest for the conditions of escape. CD-B press, University of Utrecht and J. E. Earley, FOCH 2004, 6, 137-160, cited below.

Literature Cited

1. A. N. Whitehead, *The Aims of Education,* Chaps. 1-3, available on the Internet.
2. M. Akeroyd, *J. Chem. Educ.,* 1983, **60**, 559-560.
3. M. Akeroyd, *Canadian Chemical News,* 1992, **44**, **(3)**, 23-24.
4. F. Riffert, *Alfred North Whitehead on Learning and Education*, edited by F. Riffert, 2005, Cambridge Scholars Press, pp. 89-119, (54 refs)
5. M. Akeroyd, *Interchange*, 2007, **38, (2)**, 167-173.
6. J. Earley, *Foundations of Chemistry*, 2004, **6,** 137-160**.**
7. J. Ramsden, *Int. J. Sci. Educ.,* 1997, **19, (6),** 697-706.
8. E. Scerri, *Education in Chemistry*, 2005, **42**, 135-136.
9. E. Scerri,*The Periodic Table: its story and its significance,* 2006, Oxford University Press.
10. M. Akeroyd, *Education in Chemistry,* 1983, **20,** 19.
11. M. Akeroyd, *J. Chem. Educ.,* 1982, **59,** 371.

****

Reference [5], appended below for convenience.

APPENDIX

The paper below was submitted to INTERCHANGE in December 2006, and was available electronically before the Conference started, entitled 'A Novel 'Whiteheadean' Science Program for 14-16 year olds in England and Wales'. It had originally been hoped that a special 'Whiteheadean' education symposium might have been arranged. The actual presentation on June 24, 2007 was based on the summary above.

Abstract

A novel 'Whiteheadean'[1] science program was initiated in England & Wales in September 2006. Following a critical House of Commons report in 2002, the Government altered the National Curriculum targets and thus forced the Examination Boards to alter their specifications in order to come 'in line'.

Assessment at GCSE level (i.e. the 14-16 year cohort) was criticised for:

- failing to inspire students to continue with science
- discouraging students from thinking for themselves
- neglecting contemporary science

- lacking flexibility
- making practical work into a tedious and dull activity

The Government has insisted that ALL pupils in state funded schools must know the names of some modern scientists and their work. They must discuss some current scientific problems. History and Philosophy of Science is included under the topic heading 'How Science Works'. In Chemistry these objectives have destroyed the traditional linear 'top-down' sequential approach of teaching into an approach based more closely on Whiteheadean lines (cf. the ideas expressed in *The Aims of Education*, Chapters 1-3).

Introduction

In the late 1980's the UK Government introduced the 'National Curriculum' into organisation of State funded schools in England & Wales and forced the various examination boards to make their specifications conform to general national criteria, thus increasing standardisation. The original proposals envisaged twenty three (!) Attainment Targets, including the last one entitled *The Nature of Science*, worth 3% of examinable content and containing historical and philosophical topics. (see Akeroyd, 1989). Alas, there was a back reaction from teachers and the Press to the multiplicity of targets and the paucity of this 3% examinable content and *The Nature of Science* was relegated into becoming an optional non-examinable component of a much larger attainment target. As such, it was easily evaded by textbook authors, teachers and students.

In 1997 New Labour won the UK General Election by a landslide majority and one slogan was 'Education, Education, Education'. A House of Commons Select Committee was set up to investigate the whole of Science and Technology teaching from 11 years old to first degree level and was chaired by Dr Ian Gibson, a former university science academic turned politician. His report, based on evidence from scientists, educators, teachers and pupils, was a damning indictment of the successful resistance of the examination boards to the *spirit* of the objectives of the original National Curriculum for Science Education. The report (2002) found:

Assessment at GCSE level (i.e. the 14-16 year cohort) was unsatisfactory for:

- failing to inspire students to continue with science
- discouraging students from thinking for themselves
- neglecting contemporary science
- lacking flexibility
- making practical work into a tedious and dull activity

The result was that tougher, more coherent National Curriculum targets (now renamed 'objectives' were constructed for Key Stage 4 (the curriculum for 14-16 year olds who will be entered for the GCSE examinations at 16+). GCSE is an acronym for General Certificate of Secondary Education. *The Nature of Science* now becomes *How Science Works*, with examinable content weighting of about 15%. No chance of successful evasion of HPST topics now!

Dr. Gibson stated:
'Science should be the most exciting subject on the school curriculum……GCSE science students currently have no time to explore interesting ideas, and slog through practical exercises that are completely pointless. This is a disaster: we need to encourage a new generation of young scientists and ensure the rest of the population has a sound understanding of scientific principles.'

As a result of Government enforcement the Examination Boards came up with new science specifications in Sep 2005, and these were implemented in Sep 2006. The Science Suite of modules contains modules for the subject Science, 3 hours per week for one year, to be taken by *all* pupils. These contain equal proportions of Biology, Chemistry, Physics. Then follows the subject Additional Science, recommended to be taken by 85% of pupils, with more advanced modules, again totalling 3 hours per week. Finally there are Extension modules offered, allowing pupils to convert to separate full Biology or Chemistry or Physics awards. About 15% of pupils in State schools are expected to follow this route. Although possession of just Science plus Additional Science is a minimum requirement for progression to an Advanced Level Science course, students are advised that possession of appropriate extension modules

is highly desirable if they wish to study the single subjects Biology or Chemistry or Physics at this level.

Whitehead and *The Aims of Education*

In the first chapter of *The Aims of Education*, (a Presidential Address to the Mathematical Association in 1916), Alfred North Whitehead severely criticised then current English educational practice. He complained about the terrible burden of "inert ideas" that was foisted on pupils: ideas that were merely received into the mind without being utilised, or tested, or thrown into new combinations. He asked: if an education is not useful or does not convey some understanding of present day problems, what use is it? He stated that in scientific training, the first thing to do with an idea is to prove it. But he extended the meaning of "prove" to include not just narrow deduction but "prove its worth". If an idea is currently accepted by scientists and coheres with the world view of the pupils then it should be utilised and tested in interesting practical situations until further theoretical discourse is required. He denounced the "concept-led" approach in mathematics teaching and would surely have denounced even more emphatically "concept-led" approaches in courses of theoretical chemistry where students undertake some thirty hours of pure chemistry as a "foundation" which "sharpens the mind" allowing the subsequent practical work to be rapidly assimilated as merely the corroborating instances of the theoretical system.

In a follow up essay, *The Rhythmic Claims of Freedom and Discipline*, published as Chapter Three in the book, Whitehead examines the conflicting demands of education and training. He states:

'There can be no mental development without interest.'

'Unless the pupil is continually sustained by the evocation of interest, the acquirement of technique and the excitement of success, they can never make progress and will certainly lose heart.'

'It is an unfortunate dilemma that initiative and training are both necessary, and that training is apt to kill initiative.'

In this essay Whitehead mentioned the three stages of intellectual progress: Romance, Precision, Generalisation. He gives some readers the impression that Romance generally occurs in children up to the age of 8, Precision between 8-14, Generalisation later. But the quotes indicated above show that 14 year science pupils are not to be starved of romance as they are expected to be stimulated by the introduction of fresh new ideas. As developed by Franz Riffert (2005), Whitehead was obviously proposing a *hierarchical spiral method* of teaching with *linear sub-units*, i.e. interesting idea, practical application and testing, generalisation, new interesting idea etc. etc. Once the process has started, it becomes meaningless to refer to this method as "concept-led" or "context-led": both concepts and contexts are interacting.

The Edexcel Chemistry specification

Four main Examination Boards offer several different Chemistry specifications in England & Wales. All at GCSE level are "Whiteheadean" in the sense that they introduce several *modern* contextual elements into the specification: reference to living scientists, polymers introduced at a very early stage, topics like pollution and global warming included. These address the problem relating to the original Whiteheadean strictures about the 'terrible burden of inert ideas' associated with a traditional "concept-led" approach that has changed little since 1920.

All specifications include the history and philosophy of science, introduced as *How Science Works.* The aim of this requirement is to help students to:

1. identify questions that science can, and cannot address, and how scientists look for answers
2. evaluate scientific claims by judging the reliability and validity of the evidence appropriately
3. question scientific reports they see in the media, and to communicate their own findings
4. consider scientific findings in a wider context – recognising their tentative nature
5. make informed judgements about science and technology, including any ethical issues that may arise.

The specifications highlight a range of contemporary and historical science contexts to explore this requirement. This basic introduction to how modern science currently works is not imposed simply as a component to *educate* the majority of students who will cease science studies at 16+, or as a 'taster' to attract more potential students to consider a scientific career but also as a *foundation* for the already committed students who will find that *How Science Works* is examined in much greater depth in the higher level of examinations from September 2008. The actual specifications of the GCE AS and A2 courses are currently being constructed but the Government sponsored Qualifications and Curriculum Authority has already decreed the outline structure in September 2006.

Only the Edexcel specification, labelled "360 Science", contains further Whiteheadean principles. It gives teachers a choice of content-orientated or context-orientated approaches, and the opportunity of centre designed internal assessment for some components. (meeting another Whitehead recommendation). Each of the modules in the specification contains a *Guidance for Students* sheet that contains the headings "Have you ever wondered?" followed by eight questions designed to capture the students' interest, "Learning Objectives", a brief outline of the main requirements and a "Glossary" of words and phrases that the student is expected to be able to recall, explain and use appropriately in the module examination. Although within a module the designers allow for concept-led or context-led approaches, the design of the first three modules making up the chemistry component of the subject *Science (2101)* does not allow for a traditional 'heavy' conceptual introduction. The first module allows for a minimal subset of concepts relating to atomic structure and the Periodic Table sufficient for chemistry contexts that will be studied. Only in the chemistry modules of *Additional Science (2103)* does Ionic and Covalent bonding occur in detail and the Periodic Table in more detail. The Mole and Avogadro's Law is left to the *Extension Units* that allow for an award of single subject Chemistry (2107). Whitehead, if still alive, might have objected to this tight modular arrangement and tyranny of the 6 monthly examinations, but in fact this tightly organised modular system *enforces* the hierarchical spiral method advocated by him and refined by Franz Riffert (2005).

The problem outlined above by Whitehead due to the conflicting demands of initiative and training is addressed in the *Extension Units.* Students opting for these units are by this time presumably enthusiastic about the prospect of further study. Full intellectual rigour is introduced alongside interesting contexts. Students undertake qualitative analysis, titrations, balance equations, calculate reaction yields and are introduced to the Mole and Avogadro's Law and the General Gas Equation. In another unit they study industrial processes.

Whitehead was once asked "Which are more important, facts or ideas?". He replied "Ideas about facts." (Price, 1984, p. 337, cited by Birch, 1988). This gives an important insight into the "concept-led " and "context-led" approaches to science teaching. Once the hierarchical spiral of interesting idea-interesting contexts-interesting idea- interesting contexts-interesting idea-interesting contexts gets under way it becomes irrelevant to think in terms of "leaders" and "subordinates".

NOTE

1. I use the adjective 'Whiteheadean' advisedly. The anonymous authors of the Edexcel specification neither publicly claim nor privately admit any influence from Whitehead's writings. However this writer claimed in Akeroyd (1983, 1992) to be influenced by Whitehead, and he also claims that the Edexcel specification is in the *spirit* of Whiteheadean thought. The specification can be accessed through any Internet search engine: "Edexcel + GCSE + Chemistry + 2107 + specification + UK". Approximately 100,000 pupils aged 14+ started the Edexcel Science specification (including introductory chemistry units) in September 2006, about 14% of the total cohort. Neither Dr Ian Gibson (2004) nor Sir Anthony Greener (2005) mention Whitehead in their Internet publications, but all their criticism of the conventional education system fits Whitehead's like a glove.

References

Akeroyd, F. M. (1989). Philosophy of Science in a national Curriculum. In D. E. Herget (Ed.), *Proceedings of the First International Conference on the History and Philosophy of Science and Science Teaching,* 15-22. Tallahassee:University of Florida Press,.

Akeroyd, F. M. (1983). Chemical Education and the Year 2000. *Journal of Chemical Education,* 60, 559-560.

Akeroyd, F. M. (1992). Theoretical Applied Chemistry. *Canadian Chemical News,* March issue, 23-24.

Birch, C. (1988). Whitehead and Science Education. *Educational Philosophy and Theory*, 20, (2), 33-41.

Gibson, I. (2004). Lighting the fire. Fabian Society document dated 23/09/2004 (available on the Internet).

Greener, Sir A. (2005). Moving towards a modernised curriculum. QCA Futures (available on the Internet).

House of Commons Science and Technology Committee (2002). *Science Education from 14-19. Third Report of Session 2001-2. Volume I.* London: The Stationery Office.

Price, L., (1984). *Dialogues of Alfred North Whitehead.* Boston: Little, Brown and Co.

Qualifications and Curriculum Authority, *GCE and A level subject criteria for science*, paragraph 3.6. QCA/06/2864 (available on the Internet).

Riffert, F. (2005). Whitehead's dynamic cyclic theory of Learning. In F. Riffert, *Alfred North Whitehead on Learning and Education,* (pp. 89-119). Durham: Cambridge Scholars Press.

Whitehead, A. N. (1926). *The Aims of Education and Other Essays.* New York: E. Benn.