Developing a science curriculum to foster scientific literacy

Robin Millar

University of York, UK
Overview

• Introduction: clarifying terms
• An opportunity
• Design
• Outcomes
‘Scientific literacy’

• A widely used term in the recent science education literature
  • but with a variety of meanings
  • and hence a variety of implications for curriculum content and emphasis
Scientific literacy

For some:

“To speak of scientific literacy is simply to speak of science education itself.”

(deBoer, 2000: 582)
A more common view

[Scientific literacy] stands for what the general public ought to know about science.

(Durant, 1993: 129)

A change of emphasis:

• the kind of understanding of science that citizens need
• rather than the kind of science that only scientists need
A key distinction

• Very few of us will ever be producers of new scientific knowledge

• We are all consumers of scientific knowledge and information
  • Science education should aim to help students become more discerning consumers

Note: ‘all’ includes scientists.
A scientifically literate person
(National Science Education Standards (NRC, 1996))

A person who is scientifically literate can:

• read with understanding articles about science in the popular press
• engage in social conversation about the validity of the conclusions in such articles
• identify scientific issues underlying national and local decisions and express opinions that are scientifically and technologically informed
• evaluate the quality of scientific information on the basis of its source and the methods used to generate it
• pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately
A central tension

The school science curriculum has to provide:

- Access to basic scientific literacy for all
- The first stages of a training in science for some (a minority)

The problem:
Different kinds of science courses are needed to do each of these well.
Creating an opportunity
Towards a science curriculum for public understanding

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A frequent justification for 'science for all' is in terms of the need to improve scientific literacy and promote better public understanding of science. But there is much evidence that many school students and adults have little understanding of basic science ideas or processes. The five-year moratorium on change following the Dearing review of the National Curriculum provides an opportunity for a fundamental review of science education, of the structure and content of the science curriculum, as a vehicle for promoting public understanding.

Concerns about science education

Within the past ten years science has joined English and mathematics as core subjects in the school curriculum in the UK. There is broad consensus, both within and beyond, that all students should receive throughout, from relatively few, they are, I think, the visible signs of a wider and more general unease and concern about science education prevalent.

A major cause of this unease is the accumulation of evidence, not just in Britain, but throughout much of the developed world, that little scientific understanding is actually assimilated by most students. The TIMSS studies [3] showed that only around 15% of 5-year-olds could apply scientific concepts to simple problem situations. Students' learning is still oriented towards rote learning in specific knowledge. Most students are in the same direction at the age of 16, making a case for new ideas about the structure and content of the science curriculum.

School Science Review, March 1996

Proposals for the content of a science curriculum with ‘public understanding of science’ as its primary aim
An unexpected challenge

• Can these ideas be used as the basis of a one-year optional course for upper secondary school students?

• The positive response to this course created the opportunity to develop a similar approach for younger students.
“The science curriculum from 5 to 16 should be seen primarily as a course to enhance general ‘scientific literacy’.”

How can we achieve this, whilst also catering for the needs of future specialists?
Changing the curriculum for 15-16 year olds

• In 2000, the Qualifications and Curriculum Authority (QCA) invited tenders to develop and consult widely on ways of making the science curriculum for 15-16 year olds more ‘flexible’
  • Contract awarded to University of York Science Education Group and Nuffield Curriculum Centre
  • Report submitted in February 2001
• After further development work, QCA decide on a pilot trial of a more flexible curriculum model, from September 2003-June 2006.
Previous curriculum model for 15-16 year olds (years 10-11)

Double Award GCSE Science
20% of curriculum time in Years 10 and 11
Counts as 2 GCSE subjects

Taken by most students
Some do just Single Award Science GCSE
Some (<10%) do 3 GCSEs in Biology, Chemistry, Physics
Proposed new curriculum model

- GCSE Science
  - 10% curriculum time
  - Emphasis on scientific literacy
    (the science everyone needs to know)
  - for all students

- GCSE Additional Science
  - 10% curriculum time

or

- GCSE Additional Applied Science
  - 10% curriculum time

  for many students
Flexible combinations

<table>
<thead>
<tr>
<th>Science only</th>
<th>A clear ‘scientific literacy’ rationale, unlike previous Single Award Science.</th>
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<tbody>
<tr>
<td>Science + Additional Science</td>
<td>Equivalent to previous Double Award Science. At least as much content as before, with a more stimulating approach.</td>
</tr>
<tr>
<td>Science + Additional Applied Science</td>
<td>A new option, welcomed by many schools as a more appropriate science course for many of their students.</td>
</tr>
<tr>
<td>Biology + Chemistry + Physics</td>
<td>Achieved by adding some further content in each subject area. So all students follow courses which have a common core.</td>
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Testing the model

- Pilot trial in 78 schools from September 2003
- Teaching materials developed by *Twenty First Century Science* project
- Revised in the light of this pilot
- Published June 2006
Design

How can we design a science course to foster scientific literacy?
The central aim

- To provide students with a ‘toolkit’ of ideas and skills that are useful for accessing, interpreting and responding to science, as we encounter it in everyday life
What science do we meet everyday?

- a lot about health, medicine, environment
- risk and risk factors
- claims about correlations and causes
- issues that involve science and technology, but also involve other kinds of knowledge, and values
What do you need to deal with this?

• Some understanding of major scientific ideas and explanations

• Some understanding of science itself:
  • the methods and processes of scientific enquiry
  • the nature of scientific knowledge
  • the interface between science and society
Science Explanations

• Focus on the ‘big ideas’ of science
  • The idea of a ‘chemical reaction’ as a rearrangement of atoms; nothing created or destroyed
  • The gene theory of inheritance
  • The theory of evolution by natural selection
  • and so on …

• Aim for a broad, qualitative understanding

• Depth of treatment: only as much as a citizen requires
Ideas about science itself

Ideas that help you to:

• assess the quality of data (know that all data are uncertain, how to assess and deal with this)

• evaluate claims about correlations and causes (controlling variables, comparing groups, matching samples, etc.)

• distinguish data (evidence) from explanation, and recognise that all explanations are to some extent tentative

• appreciate the important role of the scientific community (critical scrutiny of claims, peer review)

• interpret data on risk, and evaluate specific actions in terms of risks and benefits

• recognise the issues raised by specific applications of science (technical, economic, social, ethical), evaluate views expressed by others, and express your own views rationally
Content selection

• Using ‘different drivers’ (Fensham, 2003)
A modular course

• A series of modules, on topics that are likely to catch and hold the interest of students
  • Used to introduce and develop understanding of a chosen set of Science Explanations and Ideas about Science
Course structure

Science
Explanations

Modules

Ideas about
Science

etc.
Module titles

- You and your genes B
- Air quality C
- The Earth in the Universe P
- Keeping healthy B
- Material choices C
- Radiation and life P
- Life on Earth B
- Food matters C
- Radioactive materials P

- Detailed teaching scheme to show how each module can be taught in 12 hours of lesson time
- This allows time for extension, and for coursework tasks
- Supported by textbook, photocopy masters, ICT resources
How is it different?

• More obvious links to the science you hear, or read about, out of school
• Some new content
  • risk
  • evaluating claims about correlations and risk factors
  • clinical trials
• More emphasis on *Ideas about Science*
  • in the context of evaluating scientific knowledge claims
• More opportunities to talk, discuss, analyse, and develop arguments
  • about science
  • and about its applications and implications
Outcomes

Evidence from the pilot
Internal evaluation: Pilot teachers’ views

- Data from Questionnaires completed by pilot school teachers

Main findings

• Most pilot school teachers thought the core Science course was successful, or very successful, in improving students’ scientific literacy

• Most thought it was significantly different from previous science courses
  • Relates to students’ experiences
  • More discussion
  • More emphasis on students’ ideas and views

• Almost all thought their students’ response in science classes was better
Positive features  
(teachers’ views)

• Everyday relevance of content, up to date, links to science in the media
• Use of case studies
• Opportunities to discuss and debate, develops critical thinking
• Inclusion of ethical issues, links to citizenship
• Less emphasis on factual content, more emphasis on Ideas about Science
• Range of learning styles and skills required; encourages independent learning
Challenges identified by teachers

- Amount of reading and language demand of resources, especially for weaker students
- Managing discussion activities in class
- Students find activities which require them to reason and debate challenging
- Fitting everything into the time available
- Finding your way around new resources; recognising what is essential
What we did in response to feedback

• Worked with pilot schools to:
  • develop new or alternative materials for some activities with lower reading demand
  • add more practical activities to some modules
• Simplified some of the assessment procedures and reduced the amount of assessment to make this more manageable
External evaluation of pilot: Three studies

- Student learning compared with other science courses
- Students’ attitudes towards science and school science
- The classroom implementation of the Science course
  - and teachers’ and students’ views of it
External evaluation of pilot

• Overview of main findings available at: http://www.21stcenturyscience.org
  • click on ‘Rationale’ (in left-hand panel)
  • then ‘Evaluation’
External evaluation of pilot: Main findings

• Generally positive teacher and student response
• Students report greater interest in reading about science
• Level of conceptual understanding similar to more ‘traditional’ courses
• Teachers need continuing support and training to improve understanding of course aims, and confidence with the new teaching styles involved
Evaluation of pilot: Practical outcomes

- Revised specifications for all *Twenty First Century Science* courses from 2006
  - plus specifications for Biology, Chemistry and Physics
- Fully revised editions of all textbooks and course materials
  - Including 2 versions of the Science course textbook with different reading levels (*Foundation* and *Higher*)
Twenty First Century Science
Uptake from September 2006

- Around 1100 schools (~25% of maintained schools in England) have chosen *Twenty First Century Science*
  - One of four GCSE specifications on offer
  - Generally seen as the most innovative
What have we learned?

• A better understanding of the curriculum implications of ‘scientific literacy’
  • We learn by trying to put our ideas into practice

• How to bring the ‘nature of science’ into the science curriculum
  • Not as a separate element, but integrated with science content

• That many teachers and students respond very positively to a ‘scientific literacy’ approach

• That considerable support and training for teachers is needed to make it work well

• That assessing it through written examinations is still problematic
Issues

- Implementation
  - Getting the classroom realisation closer to our aspirations
- Assessment
  - Developing written assessment that reflects the course aims and encourages good teaching
- Dealing with the reaction to ‘scientific literacy’
  - From some sections of the media and the scientific community who see change as ‘dumbing down’
  - Criticisms often based on little real knowledge of the course, or the school context
Letter from a pilot school
Head of Science

“Twenty First Century Science is harder to teach, you need to be more creative in producing practical activities, you need more access to ICT and the coursework takes a good, strong teacher to manage well. But from the eyes of students it is a universe ahead of anything else.”
The final activity in P3 Radioactive Materials saw groups furnished with identical information about potential replacement power stations considering that nuclear power stations built in the 50’s and 60’s are coming to the end of their life. If I was to write a letter to the Prime Minister advising him what to do, what would I say?

It was wonderful. As if by magic seven groups reached seven different conclusions, all based on exactly the same evidence. When I asked what they would suggest we do, Lee put his hand up and said: “I think that we should tell him that everyone in the country should have to do an exercise such as this so that they would understand the complexity of the issue.”

Marvellous.

Helen Reynolds, Gosford Hill School, Oxford in Institute of Physics Education Group Newsletter, February 2008