A11. A science module for Level 1 Primary BEd trainee teachers based on sustainable development principles

Keith Ross and Mike Littledyke

One of the main aims of teaching science in primary schools must be to help the next generation come to an understanding of how the planet functions and of humankind's influence on it. In a democracy it is important that the electorate understands the issues sufficiently to enable them to act in a way (and to accept government action) that permits development, without depriving future generations of the ability to sustain themselves. This chapter describes a science module for trainee primary teachers, whose aim is to provide this scientific understanding of sustainable development, as well as imparting fundamental scientific principles more generally.

Aims

The module aims to reactivate an understanding of and interest in science by trainee teachers, based on the need to understand the science behind sustainable development, and to challenge the misunderstandings of scientific concepts that may have built up during their formal education.

Rationale

Many students become 'switched off' science during their school years. Even those that are not may have serious misconceptions that prevent a good understanding of how the world works. It is essential that teachers enter the profession with a clear understanding of the way that scientific ideas help us to see how this planet works and the pressures that humankind is putting on it. We have written a CD-Rom, *Science Issues*, which we have used, very successfully, to address the science subject knowledge component of the first level of a three-year BEd degree, a primary teaching qualification. We use an issues-based approach to teaching of this module, to enable student teachers to see how their everyday and wider environment can be understood through the

application of scientific ideas. The course has a number of important active learning elements: the initial and final audit of students' understanding; the use of group concept maps and learning logs for formative assessment; the use of the CD-Rom for lead lectures and self study; and the use of practical workshops to enable the students to embed new ideas.

Often students arrive in higher education with misconceptions of basic scientific ideas, despite having achieved a grade 'C' at GCSE science (the UK's subject-based examination at the school leaving age of 16+). These misconceptions form a barrier to their understanding. When we changed from a four year BEd degree which included science as a specialist study, to a three year general course, we took the opportunity to reactivate all students' interest in science through this new issues-based course based on the two aims above. The module:

- Identifies some of the main misconceptions impeding conceptual understanding in science
- Uses sustainable development to provide the context for students' learning.

Implementation

Examination of the module unit 'Matter' demonstrates how the pre-course audit provides information about student misconceptions and how these are then addressed in the lecture and workshop sessions.

Box 1. Matter audit question and pre-module responses

Matter can be divided into 5 categories: metals, rocks (ceramic), polymers (giant structures based on carbon, including natural and man-made materials), volatile materials and ionic materials.
Which of the following are *'polymers'*?

1.	Steel	38%
2.	Salt	20%
3.	Granite	33%
4.	Petrol	52%
5.	Leather	32%
6.	Nylon	69%
7.	Wood	32%

In Box 1 are some of the audit questions with the % of students choosing each option (n=120) on arrival at university (the pre-test). Following each question is a commentary on how the issues are addressed through the use of the CD-Rom, *Science Issues*, and other activities.

A third of students have a very blurred view of the elements that bond together to construct the world they live in. Only last three materials are polymers (leather, nylon and wood). The CD-Rom explores the history of the periodic table, and shows that most elements are metallic (with a unique set of properties). Rocks are giant structures based on silicon and polymers are giant structures based on carbon, either derived from living matter, like wood and leather, or manufactured from petroleum, such as nylon. Volatile materials (which evaporate easily or are already gases at room temperature) are made from non-metallic elements. Finally, ionic materials are combinations of metals with non-metals. This simple (and simplified) picture of the materials around them helps to understand what happens to materials we discard into the environment.

Box 2. Mass audit question and pre-module responses

When you pump air into a football, will the football……?

1. Get heavier 30%
2. Stay the same 46%
3. Get lighter 24%

Box 3. Combustion audit question and pre-module responses

When you burn rubbish
Compared to the rubbish, will all the materials produced during burning (smoke, fumes, ash, char ...) ?

1. Be heavier 12%
2. Be the same 26%
3. Be lighter 62%

In Boxes 2 and 3 the example questions examine ideas about the conservation of matter. The mass question requires understanding of the concept that gases are real matter, if in a rather spread out form, so that adding air to a football will add to its weight. Without this idea that gases are massive forms of matter (i.e. matter with mass) students find it difficult to understand that burning is a constructive process (Box 3). Most people think that burning makes things lighter but they do not appreciate that the gases produced are 'heavy' nor do they appreciate that oxygen from the air *joins* with the material being burnt, so the products, although they are mainly gaseous, are *much* heavier than the original rubbish. Without this understanding, students will go out into the world thinking that burning rubbish, or fuels, is a way of getting rid of them. The idea that carbon dioxide is a heavy product of combustion is far from their thoughts, and it makes understanding the concept of greenhouse emissions difficult to comprehend.

The matter topic considers the nature of living matter and explores why some materials are biodegradable, whilst others are not, and why some may also be toxic. The issue is explored again later in the 'Home' unit, where students audit the materials entering the home, and account for them all as they leave it again (often in a changed form), again emphasising that although materials change, the atoms from which they are built do not.

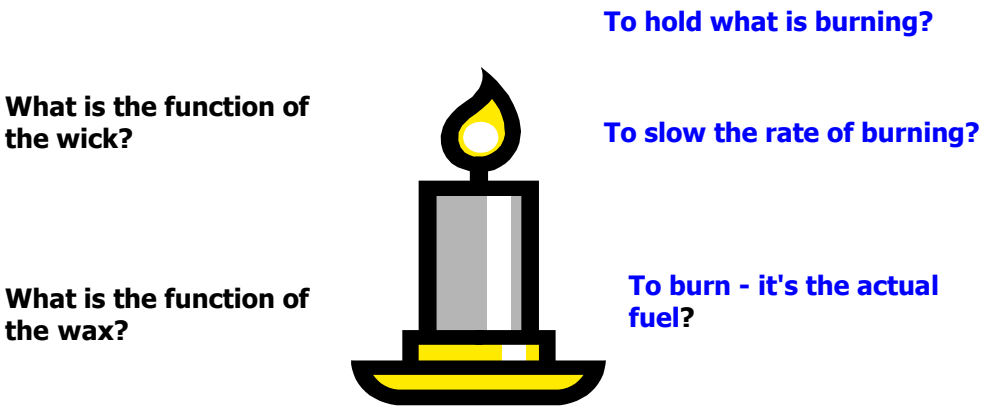

Figure 1. The candle questions (Source: Ross *et al.* 2004: Fig 5.3)

The candle questions (see Figure 1) again diagnose limited understandings of the material nature of fuels. In the workshop students experiment with a candle by lighting the white smoke given off when a candle is blown out. By comparing the candle with an oil lamp and a Bunsen burner, they quickly see that the wax is a fuel, and that the condensation above the flames of all three burners is water, one of the combustion products.

During the module students are able to reformulate their understanding of how the planet functions and of humankind's influence on it. Our hope is that they will go onto teach science in school with the aim of helping the next generation come to a similar understanding, and hopefully to take better care of the planet than the present generation have done.

Brenda and Friends (West 1984: 38) was published several years before the first science National Curriculum for UK schools, but it is an inspiring attempt to describe how a pupil would think who has experienced an education in science – in effect their *minimum entitlement*. The science is set in a real world context, and it has taken the curriculum world twenty years to put this in practice.

> *Rebecca appreciates that the sun is the ultimate source of nearly all the Earth's energy and when she visited relatives in Israel she saw that by means of solar cells .... the sun's radiant energy can be converted into electrical energy for domestic needs. By experimenting with different conditions in primary school when growing bean shoots in jam jars, Rebecca knows that sunlight is needed to make plants grow .... (and) that animals cannot make their own food but have to eat other animals or plants for this purpose.*

In an attempt to show how science has often been learnt by heart, rather than understood, here is an extract from a physics topic where the scientific words have been exchanged for nonsense words. It helps the teacher appreciate what the text would seem like to a new learner of the topic. Even so it is still possible to answer the question posed (Ross *et al.* 2004: 28).

Markobine gando
When an orbal of quant undual to the markobine bosal passes through a dovern mern it is deranted so as to cosat to a bart on the bosal called the markobine gando

What happens to the deranted orbal when it passes through a dovern mern?

For an acceptable answer to this question, after trying it for themselves, readers should see the end of this chapter.

We try to show our student teachers that science is *not* something to be learnt by heart, but rather a set of ideas and models which attempt to explain natural phenomena. The approach outlined here relies on two important principles: the need to identify misconceptions (in this case which have survived from students' GCSE science) and the need to address these using an everyday 'real' context.

Sustainability focus

The module is divided into eight sections which together cover the broad spectrum of scientific concepts through a series of topics related to sustainable development and everyday life (there is a ninth section dealing with 'being scientific'):

- Matter (pollution and re-cycling);
- Biodiversity (loss of habitat);
- Health (how the human body works);
- Agriculture (plants);
- Genetics (genetic engineering);
- Energy (use of fossil fuels);
- Transport (forces, navigation, space);
- Atmosphere (ozone, greenhouse, acid rain);
- The Home (materials and energy).

In order to give a flavour of the approach we have adopted, both in terms of active learning and sustainable development, examples of the methodology of working with students on their ideas about humankind's use of fossil fuels and approaches to recycling will be given, drawn from the sections on matter and energy.

Active learning

The module begins with an 'electronic audit', which is re-administered at the end of the tuition and is itself divided into the same sections as the module. The audit is based on research undertaken by a group of science education tutors. There are over 100 items which are based on research into students' misconceptions. The audit is available as a text file, but also in various formats including Blackboard, WebCT and Qmark, and is available from ESCalate (see references).

Each of the eight module topics begins with a lead lecture, based on the CD-Rom. This is followed by a practical workshop, and private study by students. Students then meet up in study groups to prepare a 'concept map' and 'learning log'.

The 'learning log' is an individual response by each student identifying the changes in their understanding during the module. The 'concept maps' are constructed jointly by groups of about five students and display their overall understanding of how the concepts link together. The map score is shared, but the log score is personal to the actual student. Both are brief, covering no more than one side of A4 each.

- The 'concept map' is to identify how the main concepts of each unit are linked. Students are asked to be colourful!
- The 'learning log' is to evaluate the changes that have taken place in students' thinking and understanding as a result of the unit and subsequent reading.

Here are two extracts from students' learning logs:

> *I was always confused by the word energy. I always knew it was useful but could never explain precisely to anyone what it is.*
>
> *I now realise that energy can be described in two ways ... that its usefulness can be used up ... yet the amount of energy remains the same.*
>
> *I gradually came to realise how much of a part 'atoms' do play in matter. I have always assumed that as materials go though the process of change, the atoms from which they are made up, change too. However, this unit helped me to understand that*

> *atoms are indestructible and I can look at any substance now and judge that, regardless of what change it goes through, the atoms will remain the same.*
>
> (Ross *et al.* 2004: 88)

An implication of the first extract is that we need a constant supply of high-grade energy to drive both natural and human system on this planet, but that this energy then needs to be radiated away as waste heat. An implication of the second extract is to justify the need for recycling – that matter is indestructible at an atomic level. From these two ideas we develop the idea that on this planet matter is cycled and these cycles are driven by high grade energy that gets degraded.

Figure 2 is a section of a concept map for energy, constructed by one of our student teachers. Students get feedback from tutors using a 'numbered comment' system. Students have access to a set of numbered comments for each of the eight units at the start of the course – these are amended as necessary each year. Note the tutor's star numbered comment bottom right (*33) in figure one. The tick shows that the student has addressed this concern. Here is number 33 from the numbered sheet of comments for energy:

**33 Be careful how you use the word chaos. The arrow of time dictates that the universe will become more and more chaotic (heat death - the chaos of the second law), but that does not stop some systems (e.g. ecosystems) from maintaining a high degree of material order - importing high grade sunlight and 'exporting' it as waste heat to their surroundings - this allows them, with positive feedback, to evolve quite unpredictably. This is the chaos (complexity) of the butterfly effect which refers to systems that are highly ordered but behave in ways that it is impossible to predict (see Biodiversity *21 and *25).*

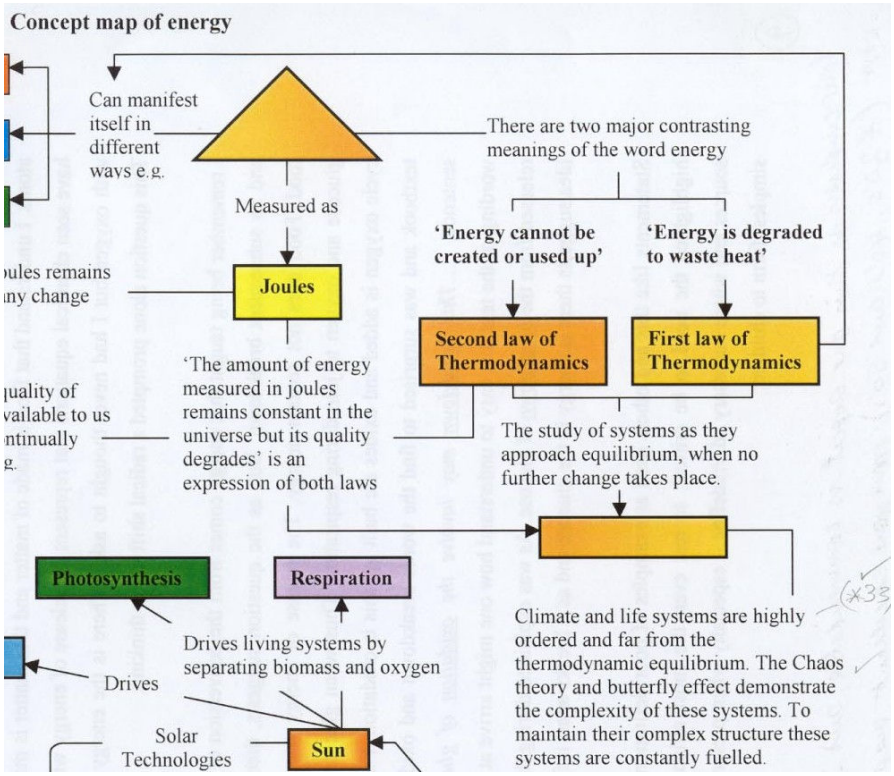

Figure 2 - Section of a student's concept map for energy.

Analysis of the ideas and concepts that the students bring with them from their school experience has formed the focus of our research and several papers have arisen from this work (see Ross 2006; Ross *et al.* 2004; and Littledyke *et al.* 2000).

The CD-Rom and audit have been used in many universities and colleges providing Initial Teacher Training in this country and overseas, including India and Uganda. It has been evaluated by *Curriculum Online* and is available for use in secondary schools as a GCSE resource. It is definitely not a resource for science specialists but rather it is designed to make science accessible and enjoyable for everyone.

Feedback

The module has received consistently good evaluations from those who have used the CD and undertaken the course. It has been used on several very successful short courses for practicing teachers, and was Guardian CD of the week where they said 'this product is quite remarkable. In a crowded field of revision aids, this one is outstanding' (Guardian 2004). Since then it has been upgraded and further developed.

Programmes

Science Issues is a Level 1 15 CATS point module. This is a compulsory module for students of the three year BEd Primary programme. The CD also used as a self-study support for the PGCE Primary, and as a two-week intensive booster course for primary and secondary PGCE science students.

Answer to the question

'It cosats to a bart on the bosal called the markobine gando'

Key words:
Science teacher education; misconceptions; concept maps; learning logs; matter; energy; burning; education for sustainable development

References

Education Guardian (2004) The CD, *The Guardian*, Tuesday 13 July, p11.

Littledyke, M. Ross, K.A. and Lakin, L. (2000) *Science knowledge and the environment: A guide for students and teachers in Primary Education*, London: David Fulton.

Ross, K.A. (1998) 'Science: Brenda grapples with the properties of a mern', *In:* Littledyke, M. and Huxford, L. (eds) *Teaching the Primary curriculum for constructive learning*, London: David Fulton.

Ross, K., Lakin, L. and Callaghan, P. (2004) (Second Edition) *Teaching Secondary Science - Constructing meaning and developing understanding*, London: David Fulton.

Ross, K.A., Lakin, L. and Burch, G. (2005) *Science issues and the National Curriculum'*, CD-Rom, Cheltenham: University of Gloucestershire.

Ross, K.A. (2006) An issues-based approach to developing primary ITE students' subject knowledge, *Science Teacher Education*, 45, pp2-4.

West, R. (ed) (1984) *Towards the specification of minimum entitlement: Brenda and friends*, London: Schools' Council Publications.

Audit:
Available from: ESCalate <http://www.escalate.ac.uk/1141>

Science Issues:
Available from: <http://www.glos.ac.uk/science-issues>

Contacts:
Keith Ross
Faculty of Education, Humanities and Sciences
University of Gloucestershire
Francis Close Hall
Cheltenham
GL50 4AZ
+44 (0) 1633 669609
kross@glos.ac.uk

Mike Littledyke
School of Education
University of New England
Armidale NSW 2351
Australia