Assessing ethics in secondary science

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ABSTRACT An increasing number of science courses now include consideration of the ethical implications of science. However, there is little agreement about how ethical reasoning in science should be assessed. This article highlights the conclusions of a seminar on the assessment of ethics in science that was organised by the Nuffield Foundation Curriculum Programme and the Nuffield Council on Bioethics. It includes the eight recommendations of the resulting report. These relate to the differences between ethics and science, the demands placed on science teachers, the importance of student progression, the design of examination questions, the design of mark schemes, and teacher development.

Over the years there has been much discussion about the extent to which ethics should be addressed in school science lessons. An increasing number of science courses, both in the UK and in other countries, now include at least a modest consideration of the ethical implications of science. However, one problem has been that there is little agreement, or even discussion in the literature, about how such ethical reasoning in science should be assessed.

In 2008, the Reaching out to Young People Advisory Group of the Nuffield Council on Bioethics therefore decided to hold a one-day seminar on the issue, which I chaired. As Angela Hall (director of the Nuffield Foundation Curriculum Programme) and Hugh Whittall (director of the Nuffield Council on Bioethics) wrote in their Foreword to the resulting report:

The intention was that the seminar would provide an opportunity to discuss why teaching ethics in science is important and would examine approaches to the assessment of ethics in science. It was hoped that it would lead to the development of some tangible outcomes for curriculum developers, assessors and the Nuffield Council on Bioethics and Curriculum Programme. (Reiss, 2009: 4)

This article highlights the conclusions of the day and includes the recommendations of the resulting report.

Why engage young people in ethical issues in science lessons?

One of the major debates in science education in recent decades has been the extent to which its scope should be broadened and, specifically, whether ethical aspects of science should be addressed (Reiss, 1999).

One argument in favour of addressing ethics in science education is that ethics is inevitably intertwined with much of science. The subject matter of science itself to some extent reflects the interests, motivations and aspirations both of the scientists who carry out such work and of those who fund them. Much funding provided for scientists, both currently and for some considerable time past, has been provided with the hope that particular applied ends would be met, not simply that pure scientific knowledge would result.

A second argument for addressing ethics in school science stems from the consideration of what school students would like science lessons to include. It is generally the case that students enter their secondary schooling with high expectations of science and a positive attitude towards it. Over the succeeding years, though, students' interest in science in industrialised countries generally wanes (ROSE, 2009). Discussions with both students and their parents suggest that one of the principal reasons for this is that much of what students learn is not perceived to be 'relevant' (Osborne and Collins, 2000; Reiss, 2000). 'Relevance' encompasses a number of things but in the 21st century it is perhaps unsurprising that for many young people the ethical issues raised by science too often seem to be missing from their science lessons.

In a student review of the science curriculum in England, with a sample size of 1493 14- to 19-year-olds, the first of the students' ten recommendations was:

The science curriculum should include more ethical and controversial issues. These should not be hived off into occasional discrete topics but included throughout the curriculum. (Murray and Reiss, 2005: 91)

However, there are arguments against including ethics in secondary school science. One stems from a consideration of the nature of science and has its roots in distinctions between forms of knowledge (see, for example, Donnelly, 2002). It can be argued that science concerns itself with what is whereas ethics concerns itself with what ought to be. In other words, the two disciplines of science and ethics occupy separate spheres of knowledge. In claiming that ethics should be taught in science, one might as well claim that science teachers should teach aesthetics. The job of a physics teacher is to explain how we get rainbows, not to pontificate on whether rainbows are beautiful or to suggest what we should do on seeing one.

A second, pragmatic, argument against the teaching of ethics in science goes something like the following. Science teachers are generally educated in science and very rarely in moral philosophy. It is therefore unrealistic and unfair to expect them to teach ethics. If such teaching is required, it would reduce the time they have available to teach science and lead to lower quality teaching, since science teachers will be teaching outside their sphere of competence.

Recommendation 1

When teaching about ethics is included within science curricula, it should be made clear that there are differences between ethical reasoning and scientific reasoning and that the methods used to arrive at scientific knowledge are therefore not the same as those used to reach ethical conclusions.

The rise of ethics in school science curricula

Whatever the arguments about the role of ethics in school science curricula, there is no doubt that ethics is finding a more prominent place in secondary school science. In England and Wales, this has been particularly noticeable in biology specifications. For example, Salters-Nuffield Advanced Biology, from its first pilot version,

incorporated a considerable amount of ethics uniformly distributed among its topics (Hall, Reiss and Scott, 2002). Also at A-level (age 16–18 years), two specialised courses – Science for Public Understanding (Applin *et al.*, 2000) and Perspectives on Science (Taylor *et al.*, 2007) – paid particular attention to ethics. Indeed, in the Perspectives on Science course, ethics constituted fully one-third of the course.

At lower age ranges too, there is now a greater emphasis on ethics. At key stage 3 (age 11–14 years), the section on 'key concepts' talks about pupils '*examining the ethical and moral implications of using and applying science*' and a hyperlink to 'ethical and moral implications' reads:

Scientists, individuals and society need to think about the balance between the advantages and disadvantages of new developments before making decisions (eg examining issues related to selective breeding and genetic engineering of plants and animals, to the production of potentially hazardous chemicals, and to the use of nuclear energy). The way scientific developments are achieved can also raise ethical and moral issues, for example experiments on animals to produce drugs that may prolong human life. (see QCDA: *National Curriculum – Science Key Stage 3* in *Websites*)

Similarly, at key stage 4 (age 14–16 years) there is a requirement within 'How science works' that pupils should be taught '*to consider how and why decisions about science and technology are made, including those that raise ethical issues, and about the social, economic and environmental effects of such decisions*' (see QCDA: *National Curriculum – Science Key Stage 3* in *Websites*). Of the various GCSE science courses (age 14–16 years), it is the Twenty First Century Science suite of specifications (see *Websites*) that has paid particular attention to ethics because of its particular commitment to scientific literacy for all.

Nor are such developments restricted to England and Wales. Zeidler and Keefer (2003) summarise developments about the role of moral reasoning and the status of socio-scientific issues in science education in a number of countries, including Australia, Canada and the USA.

The demands that teaching ethics places on science teachers

Teaching ethics within school science, even if relatively little time is spent on this, so that science

still drives the agenda, places considerable demands on the teacher. For a start, there is the specialised knowledge that is required (although students, at any rate, may have been taught some or much of this in other lessons such as religious education, citizenship or philosophy). More pressingly, there are additional pedagogic demands. A great range of teaching approaches may be needed, including more student discussion, occasional formal debates and the use of role play. And then there is the fact that, for all that certain arguments in ethics are valid and others invalid, it remains the case that much learning is more open-ended than in conventional science teaching. This approach is unfamiliar for many science teachers and can be unsettling.

Recommendation 2

Those responsible for devising science courses with a significant component of teaching about ethics should be considerate of the demands placed on teachers, for instance by providing clear guidance about what is and is not expected, carefully prepared worked examples, and materials that can be used for professional development.

The current assessment of ethics in secondary school science

The aim of this section is not to provide a comprehensive overview of the assessment of ethics in secondary school science. Rather, it is to look at examples of how ethics is currently assessed in two courses, one for 14- to 16-year-olds (Twenty First Century Science) and one for 16- to 17-year-olds (Science for Public Understanding). These examples are used to raise more general issues about the assessment of ethics in secondary school science.

Twenty First Century Science

Ethical issues feature quite strongly in the various specifications of the Twenty First Century Science suite of courses (OCR, 2009). One of the aims of these courses is to encourage candidates to:

... evaluate, in terms of their scientific knowledge and understanding and their understanding of the processes of scientific enquiry and of the nature of scientific knowledge, the benefits and drawbacks of scientific and technological developments, including those related to the environment, personal health and quality of life, and considering ethical issues where these arise. (p. 6)

This aim is reflected at a number of points in the specifications, particularly in the biology modules. Interestingly, when it comes to the grade F, grade C and grade A grade descriptions, ethics does not feature at grade F and features in precisely the same way at grades C and A, namely:

They demonstrate good understanding of the benefits and risks of scientific advances, and identify ethical issues related to these. (pp. 79–80)

The fact that the same ethical demand seems to be placed on candidates at grades C and A, and none at grade F, contrasts strongly with the grade descriptions for practical skills and for scientific knowledge and understanding, where there is clear progression from grade F through grade C to grade A.

Recommendation 3

Science specifications that include ethics should indicate what progression in knowledge and understanding is expected, for example when grade descriptions are provided.
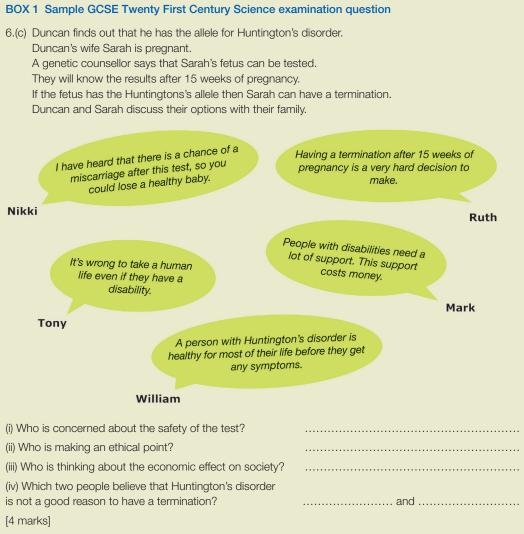
An example of the assessment of ethics in the course is shown in Box 1.

Interestingly, the only answer allowed in the mark scheme to question 6(c) (ii), '*Who is making an ethical point?*', is 'Tony' (for 1 mark) (OCR, 2008b: 6). It is often easy to criticise awarding bodies but, while Tony is indeed making an ethical point, surely he is not the only one of the four to do so.

This introduces a more general point in that ethics probably cannot best be assessed by questions worth only 1 mark. The assessment of ethics in GCSE science courses may therefore be helped by the recent Ofqual decision to require the awarding bodies to change the ways in which they assess broader aspects of 'How science works' at GCSE (Ofqual, 2009). This will lead to more open-ended questions, requiring candidates to provide longer answers worth more marks.

Recommendation 4

Assessment of students' understanding of ethics is unlikely to be best achieved when questions are worth only a very small number of marks. Students need to be given time and space to show what they know and to develop an ethical argument.

BOX 1 Sample GCSE Twenty First Century Science examination question

6.(c) Duncan finds out that he has the allele for Huntington's disorder.
Duncan's wife Sarah is pregnant.
A genetic counsellor says that Sarah's fetus can be tested.
They will know the results after 15 weeks of pregnancy.
If the fetus has the Huntingtons's allele then Sarah can have a termination.
Duncan and Sarah discuss their options with their family.

I have heard that there is a chance of a miscarriage after this test, so you could lose a healthy baby.

Nikki

Having a termination after 15 weeks of pregnancy is a very hard decision to make.

Ruth

People with disabilities need a lot of support. This support costs money.

It's wrong to take a human life even if they have a disability.

Mark

Tony

A person with Huntington's disorder is healthy for most of their life before they get any symptoms.

William

(i) Who is concerned about the safety of the test? …………………………………………………

(ii) Who is making an ethical point? …………………………………………………

(iii) Who is thinking about the economic effect on society? …………………………………………………

(iv) Which two people believe that Huntington's disorder is not a good reason to have a termination? …………………… and ………………………

[4 marks]

From OCR *GCSE Science A: Twenty First Century Science Unit 1 Modules B1 C1 P1 (Foundation Tier)* examination paper (OCR, 2008a: 16–17).

Science for Public Understanding

Science for Public Understanding was an Advanced Subsidiary (AS-level; 1 year) course. It has been replaced by an A-level (2 year) course called Science in Society that had its first AS examination in June 2009 and will have its first A2 examination in June 2010. The final Science for Public Understanding examination was in June 2009 (see Science in Society in *Websites*).

Ethical issues featured quite strongly in the Science for Public Understanding course (AQA, 2007). In addition to a number of generic references to '*technical, economic, social and*

ethical constraints' (AQA, 2007: 10) – a phrasing that rather suggested science being held back by such forces – there were specific references in the specification to '*Ethical issues raised by genetic engineering*' (p. 18), to '*Role of ethics committees in regulating the application and further development of scientific knowledge*' (p. 18) and to medical genetics:

New medicines: procedures for testing including use of animals, experimental designs in drug trials, double blind studies. Legal and moral obligations of pharmaceutical companies.

Reproduction: use of routine screening tests during pregnancy (e.g. blood tests, amniocentesis, ultrasound scans), judgements about the quality of life, abortion (techniques, issues and ethical dilemmas). (AQA, 2007: 17–18)

An example of the assessment of ethics in the course, along with the mark scheme, is shown in Box 2.

As this question was worth 4 marks, it rewarded candidates who were able to demonstrate that they could develop a reasoned argument. One criticism of the mark scheme is that, as there were 12 possible marking points for these 4 marks, a candidate needed only to make one-third of these points to be given full marks. It would therefore be possible to gain full marks with rather a shallow or one-sided answer.

The current assessment of ethics in other secondary school subjects

A number of other school subjects, notably philosophy and religious studies, are more used than is science to assessing ethics. An example of the assessment of ethics in religious studies is provided by a question in the AQA June 2008 paper to examine the AQA Advanced Level Religious Studies Unit 4: An Introduction to Religion and Ethics. The question is one of two alternatives and needs answering in 40 minutes (Box 3).

One notable feature of this mark scheme, given that there are 25 marks at stake, is its comparative brevity. Many examiners of science papers would wonder about the consequences of this for the reliability of the marking (that is, the ability of two markers to give the same, or very similar, number of marks as each other to scripts). On the other hand, such an approach does perhaps give candidates considerable scope to express themselves and show originality.

It is also noteworthy that the candidate is expected to write an essay on a single subject (albeit one divided into two parts) for 40 minutes. Good candidates are evidently expected to be able to write at some length and to craft an unfolding argument. Then there is the fact that the mark scheme avoids the allocation of precise marking points. Notable too is the expectation that candidates should be able to engage in depth with the arguments of a major figure (Kant) – how

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BOX 2   Sample AS-level Science for Public Understanding examination question

2(b) The European Union (EU) has estimated that 1% of all disease in the EU is caused by chemicals in current use, including about 4500 deaths a year from cancer. In 2007 new EU regulations, called REACH, were introduced that require all chemicals to be tested for toxicity. Chemicals that have been in use for many years also have to undergo these tests. There are about 30 000 chemicals in use in the EU that have not yet been rigorously tested.

Large numbers of animals will be required for this testing programme. For example, to test a single substance for its risk of causing cancer needs 800 rats or mice.

Do you think the risk to humans justifies the use of large numbers of animals in this way? Explain your answer. (4 marks)

From AQA *General Certificate of Education – Advanced Subsidiary Examination Science for Public Understanding SPU1: Unit 1 Issues in the Life Sciences* examination paper (AQA, 2008a: 7).

Mark scheme

Any 4 for 1 mark each (total 4 marks)

- human health more important than rodent life
- animals bred specially
- animals must be well treated
- cost benefit in favour
- important to understand effects of chemicals/ causes of cancer
- many chemicals are not needed/more selective testing
- very large number of animals not justified if only 4500 human cases
- cost benefit argument over expense of testing many animals
- animals suffering/ethics
- animals not a good model
- use alternatives to rat and mice if possible
- only test chemicals that have shown some indication of harm

From AQA *General Certificate of Education – Science for Public Understanding 5401 SPU1: Unit 1 Issues in the Life Sciences* mark scheme (OCR, 2008b: 4).

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often do science papers require candidates to do this with the Darwins and the Newtons of science?

Recommendation 5

Those who are responsible for devising mark schemes to accompany question papers in science that assess knowledge and understanding of ethical issues should familiarise themselves with best practice in subjects, such as philosophy, with a well-established history of assessing ethics.

Future possibilities for the assessment of ethics in secondary school science

Assessment is important for many reasons, not least in that it shapes what is taught and valued as learning. The science educator Rick Duschl writes about some of the teaching his daughters received when learning to play the piano:

Performing, be it as a writer, a musician, a dancer, an engineer, a teacher, or a scientist, is a complex task made up of many sub-tasks. I was very

impressed, then, and pleased that my daughters' beginning piano teacher had a wonderful sense of the multiple skills and knowledge bases she would need to develop in order to achieve high levels of performance by her students. As I recall there were no less than 4 sets of goals: the development of strength and flexibility in the hands and fingers, the development of the ability to read musical notation, the development of the ability to learn musical phrasing and playing with feeling, and the nurturing of creative musicality. Students would receive feedback on each of these 4 domains of piano playing at each weekly lesson. (Duschl, 2003: 139)

Duschl's tale reminds us of two things. Firstly, that there is more to ethics than knowledge and understanding. There are, for example, attitudes, dispositions, skills and actions. Indeed, I can remember in the mid-1980s a UCLES Advanced Level Biology course that required teachers in teacher assessment of coursework to assess students' behaviour towards animals and the environment. It is worth noting that the Qualifications and Curriculum Development Agency now have '*Responsible citizens who make a positive contribution to society*' (QCDA, 2010: 1) as one of their three overarching aims of the curriculum. Secondly, Duschl's account illustrates the importance of regular formative assessment: his daughters received feedback on each of the four domains of piano playing in each of their lessons.

Recommendation 6

The way in which ethics is assessed should reward good teaching, and students should be provided with regular feedback on their learning.

In science teaching, while it is perfectly appropriate for ethical issues to feature more strongly in biology than in other parts of science, there is value in teaching about ethics across the science disciplines both in terms of the ethical issues faced by scientists undertaking their work and with reference to the applications to which science is put.

Recommendation 7

Teaching about ethics should be seen as important across the disciplines of science and not restricted to biology.

Progression in ethical thinking

Is there some natural progression in ethical thinking that might allow us to assess student achievement in this area? The Swiss educator Jean Piaget was perhaps the first person carefully to investigate the subject of moral development; that is, how individuals progress over time in their ethical thinking. In the 1920s, he studied the ways in which children viewed the rules of the games they were playing (Nucci, 2008). He concluded that morality was a developmental process. To a young child, morality is all about obeying rules. So telling lies is wrong because a child has been told not to tell lies. I can remember as a child being very upset that I had broken (unintentionally, I think as a result of excessive bending) one of the metal plates in my Meccano set. But what is intriguing is the sense of moral culpability I felt – perhaps because I had been told not to break objects just as I had probably been told not to tell lies. I am glad to say I can also remember being comforted by my somewhat bemused mother when she found me crying; thus do we learn what we have done that is morally wrong and what is not.

Piaget (1932) observed that, as children age, and in interactions with others, they move to a more autonomous and less rule-bound view of morality. Piaget's conclusions were developed further by Lawrence Kohlberg, who, while also accepting that moral reasoning proceeded in stages, argued that it can continue throughout our lives and that very few of us ever reach its ultimate conclusion. Kohlberg (1958) viewed the moral reasoning and practice of individuals as falling into one of six stages. Stage 1, as for Piaget, is characterised by the acceptance of moral teaching because of a fear that one will be punished if one transgresses. At the other extreme, stage 6, rarely found in empirical studies, is characterised by abstract principles of moral reasoning in which the acceptability or otherwise of actions is judged against principles of ethical fairness that are established as such not merely because most people agree with them but because they result from universal, logical argument (as in Kant's *Groundwork of the Metaphysics of Morals* or Rawls' *A Theory of Justice*).

Kohlberg's work has been critiqued, refined and extended but the fundamental notion remains of moral development from an unreflective position of selfishness to one in which the needs and wants of others are also accepted and acted upon.

Progression in ethical thinking in science

The work of Piaget and Kohlberg and their successors in the field of moral development is valuable but difficult to apply directly to science education. In a New Zealand project on bioethics education (Jones *et al.*, 2007), a range of indicators were developed to indicate how a science teacher might want students' ethical thinking to progress (Figure 1).

Figure 1 should not be read rigidly (Reiss, 2010). It is not the case that individuals progress uniformly from left to right, nor would it be altogether surprising to find individuals who are situated at the left of the figure in some respects and at the right in others. Furthermore, any individual's position on Figure 1 will be affected by the individuals around them, the particular scientific issue being considered, their motivation and a range of other factors. Nevertheless, it may be that good teaching in this area should help individuals move from the left to the right of Figure 1.

Such movement, indicating progression in ethical thinking, would entail the following:

● moving from viewing an ethical issue (for example, eating meat from intensively farmed animals) in terms of its effects for oneself (for example, the meat tastes delicious) to one's peers (for example, how the rest of one's family feels about this) to others in one's country (for example, consequences for national employment) to people globally (for example, effect on world trade);

● moving from seeing oneself as the moral universe (egocentrism) to following social rules (for example, one should not buy pets in pubs) to holding reasoned principles (for example, one should not buy pets where there is a significant chance of an animal suffering as a result of congenital disorders, even when such purchase is legal);

● moving from only being able to use one ethical framework (for example, consequentialism) to using two to using three or four to evaluating the usefulness of the frameworks for different situations (for example, considering the frameworks of consequentialism, rights and virtues when considering whether or not a woman who is pregnant with a fetus that has a severe genetic disorder should be allowed to choose whether or not to have an abortion);

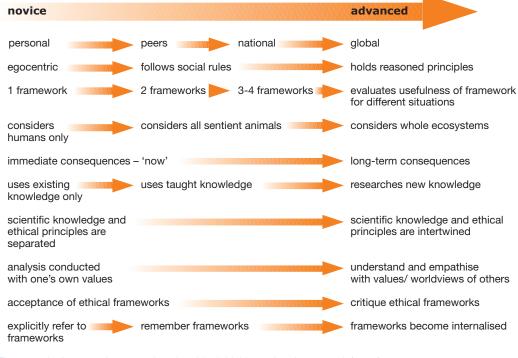● moving from considering humans only (for example, when devising a plan for how to manage

Figure 1 Indicators of progressions in ethical thinking; after Jones *et al*. (2007)

a national park) to considering all sentient animals to considering whole ecosystems;

● moving from considering ethical issues (for example, mining for gold) solely in terms of the 'now' to the long term (for example, pollution resulting from use of mercury);

● moving from relying solely on one's existing knowledge (for example, when discussing how to reduce one's carbon emissions) to using taught knowledge to researching new knowledge;

● moving from a situation where scientific knowledge and ethical principles (for example, about whether time and money should be spent conserving endangered species) are considered in isolation to one where they are drawn together;

● moving from considering socio-ethical issues only within one's own set of values (for example, about the relative merits of meat eating, vegetarianism and veganism) to considering them within others' too;

● moving from simply accepting standard ethical frameworks (for example, about the acceptability of nuclear power) to being able to critique them;

● moving from needing to consult frameworks before using them to remembering them to internalising them so that one finds oneself using them automatically.

Conclusion

There are good reasons for striving to improve the quality with which ethics in science is taught and assessed. Such teaching and assessment is often not easy. However, science education often strives to value aspects that are not easy to assess (for example, practical work and how scientific knowledge is arrived at). Ethics is only likely to play a small part in science curricula but it is important that, when it is included, it is taught to a high standard and assessed appropriately.

Recommendation 8

Professional science organisations and other bodies involved in improving the quality of school science education should examine what they can do to enhance the teaching and assessment of ethics in science.

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