Valuable Lessons

Engaging with the social context of science in schools

Recommendations and summary of research findings

Full report available at www.wellcome.ac.uk

The Wellcome Trust

The Wellcome Trust, the independent medical research charity, has sponsored this research in order to explore the value assigned to the teaching of socio-scientific issues, specifically those arising from biomedicine, in secondary and post-16 education. Today's young people will be the first to benefit from developments arising from, for example, the Human Genome Project and stem cell technology, but they will also be the first to face the challenging social and ethical questions these technologies raise.

The Wellcome Trust is committed through its core objective of Public Engagement to stimulating informed dialogue about biomedical science, its achievements, applications and implications. In turn, it believes the public has a role to play in the development of policy on important issues. We hope that the recommendations from this report will lead to improved scientific literacy among young people, and an educational experience that will enable tomorrow's citizens to engage critically with science, free from fear and anxiety.

Acknowledgements

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Tribute
Dr Sheila Turner, project co-director and Reader in Education at the Institute of Education, died on 4 November 2000 at the Princess Alice Hospice, Esher, Surrey. Sheila initiated this project at the Institute and was responsible for its early development. She was particularly influential in the area of health education, where her work has left a lasting impression. Although diagnosed with cancer shortly after the project began, Sheila remained energetic and committed throughout. Her courage and openness about her illness are truly inspiring.

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The ability to engage in discussion about the impact of science on society is increasingly seen as an essential part of young people's education. Some examples of good work currently exist in schools and further education colleges, but these examples are comparatively few.

An interdisciplinary team from the Institute of Education, University of London, carried out research for the Wellcome Trust in which they sought to uncover how, and in which curriculum subjects, controversies arising from bioscience are tackled in schools and colleges in England and Wales. The aims of the research were to highlight good practice, identify institutional obstacles, and find ways of enhancing young people's experience of science education, preparing them to engage confidently with the issues that they are likely to face in the future.

The study showed that 60 per cent of teachers from all types of institutions and all subjects think that there is too little coverage of the issues related to biomedical science. The majority of all teachers interviewed felt strongly that students should have an opportunity to explore such issues. Teachers view this kind of exploration as vital in building self confidence, developing lines of critical thinking and enabling students to deal with socio-scientific issues in a balanced way. They also consider that it engenders sensitivity towards the rights and needs of others.

Currently, the majority of science teachers consider it their role to present the 'facts' of their subject and not to deal with associated social or ethical issues. In general, science teachers feel that they lack the skills, confidence and the time to initiate and manage classroom discussion. Much could be learned from their humanities colleagues who demonstrably promote student discussions of ethical and social issues.

Science teachers highlight the existence of formal assessment as a major factor in determining the level of coverage of socio-scientific issues. Most science examinations reward knowledge and understanding rather than well-reasoned argument. Innovative mechanisms for assessing students' ability to present reasoned arguments are identified as essential for young people to engage with these issues.

Teachers of science should be supported to engage their students in discussion about these issues, through high-quality professional development, through the production of appropriate educational materials, clearer guidance from awarding bodies and with greater flexibility in their teaching.

Humanities teachers appear most confident when covering general ethical and social issues; they feel significantly less confident though about addressing socio-scientific issues. Many consider the scientific facts incidental to their teaching of issues-based topics – a source of concern for science educators who feel that disregarding the science and its accuracy reinforces student misconceptions.

The research identifies successful components of existing courses and strategies for sharing skills and knowledge among science and humanities teachers. Teachers of humanities and Personal, Social and Health Education (PSHE) should have access to educational resources that clearly set out the science and the issues it raises.

A lack of collaboration between different subject departments currently exists in schools. Science is perceived as value free and humanities as value laden. This results in the teaching of facts and the development of opinion and moral reasoning being kept separate. However, one promising model of cross-curricular collaboration identified is the 'collapsed day' – during which teachers work together to take students off-timetable to explore a theme. The introduction in England of Citizenship Education in 2002 could act as a catalyst to facilitate greater coordination among science, humanities and other teachers and develop closer working ties.

If future generations are to engage with the issues raised by science in a considered and responsible way, the education community must confront a range of challenges. These include establishing a clear philosophy about what science education should be, and how to resolve the demands of a conventional science education with a curriculum that examines science in society. The science curriculum in particular needs to provide the flexibility for teachers to explore the power and limitations of science within an ethical framework.

Recommendations

- Social, moral and ethical issues should be more clearly set out in examination specifications and syllabuses than they are at present. This would provide clearer opportunities for addressing issues arising from biomedicine.

- The Qualifications and Curriculum Authority and the Qualifications, Curriculum and Assessment Authority for Wales should identify where socio-scientific issues could be covered in the curriculum and make this explicit to the awarding bodies.

- Social, ethical and legal implications of the science should be integrated into the curriculum where possible and formal assessment criteria should be devised to give recognition both to discursive argument and knowledge of science.

- Research should be carried out looking at effective ethics teaching in science. Training opportunities should be made available to teachers of science and other subjects so that they can use the principles of moral philosophy when addressing socio-scientific issues.

- Educational materials should be developed that invite analysis of socio-scientific issues from a range of perspectives but which also provide sufficient, accurate and accessible technical scientific information for non-specialists.

- The DfES, professional subject bodies, teacher-training colleges and those involved in relevant education initiatives – such as Citizenship Education – should explore the potential for cross-curricular initiatives such as 'collapsed days'. Teachers should have access to continuing professional development to ensure that they can implement such schemes.

- The Citizenship curriculum to be introduced into schools in England in 2002 should encourage consideration of socio-scientific issues. It should foster interdepartmental cooperation and guide schools on relevant topics and issues.

- The science of the brain needs to be incorporated into mainstream science and post-16 biology, providing opportunity for greater consideration of the issues related to neuroscience and mental health.

- The school curriculum should encourage students to examine the biological, psychological, environmental and social factors associated with mental health problems. Research should be carried out among teachers, students and parents to identify attitudes towards learning about mental illness and its treatments.

- Post-16 students could be encouraged to take a course such as the new GCE Advanced Subsidiary Science for Public Understanding. Scientific issues could then be explored at a greater depth than they are in the very broad General Studies syllabus.

- Research should be carried out into how the philosophy courses currently run in some primary and secondary schools affect the moral development and ethical decision making by pupils.

- Quality training courses should be designed and piloted to update teachers on biomedical developments, such as stem cell technology, and their social, ethical and legal implications.

- Support material should be developed and piloted to accommodate the range of religious and secular perspectives towards various socio-scientific issues.

Introduction

We live in an age of unprecedented technical advance that has hastened rapid social change and a transformation in the way we view ourselves. These developments pose challenges for the individual, the family, for wider society and the democratic process. Genetically modified crops and transgenic animals have all prompted 'new dialogical relationships in society'[1] where the public can no longer expect experts to solve problems for them.

Science education has undergone a number of changes over recent years, though for the most part these changes have focused on 'standards' and 'skills'. Towards the end of the twentieth century, the science education community became increasingly vocal in their concern that science education was geared towards 'the few' rather than 'the many', and is too technically focused. The publication by The Nuffield Foundation in 1998 of *Beyond 2000: Science Education for the Future*[2], produced clear recommendations that, were they to be enacted, would give students an experience of science education more in keeping with science in the real world. The report clearly sets out that the form of science education currently on offer is outmoded, and is fundamentally a preparation for future science careers rather than for broader scientific literacy.

The Institute of Education was commissioned by the Wellcome Trust to investigate current educational practice in teaching about socio-scientific issues broadly related to biomedical research. The research team set out to identify the following:

- the perceived importance of socio-scientific issues related to biology;
- strategies currently employed;
- successes and obstacles preventing successful education in this area;
- the experience of teaching the social, moral, ethical and legal impacts of genetics research;
- the types of support materials and training requested by teachers.

School science has always been heavily burdened with content, though the introduction of the national curriculum and increasing demands placed on teachers and students by school league tables may have resulted in an even greater dependence on concepts and content rather than discussion and exploration. In this setting, the research team identified how teachers perceive the importance of socio-scientific issues in young people's education in general. They sought to uncover attitudes towards the teaching of ethical issues among science teachers and the comparative levels of confidence among scientists and non-scientists when addressing controversy in class.

In this summary report:

- the term 'socio-scientific' is used to refer to the social and ethical issues raised by biological research;
- 'humanities' is used to cover history, geography, sociology, English and related subjects;
- 'teachers' includes those working in schools and further education colleges;
- 'student' includes both school-aged pupils and those in post-16 education.

[1] Giddens, A, *Tomorrow's Citizen*. Institute for Public Policy Research, 2000.

[2] Millar, R, and Osborne, J (Editors), *Beyond 2000: Science Education for the Future*. Nuffield Foundation, 1998.

Research methods

Two previously piloted data-gathering techniques were used comprising a survey and follow-up interviews. These were supplemented by a one-day seminar held at the Wellcome Trust in London.

Quantitative research

One thousand questionnaires were issued to schools across England and Wales. The study was based on a stratified random sample of secondary schools and further education institutions in England and Wales. The sample assured a balance of each of the various types of institution, including local education authority secondary schools (573), grant-maintained (162) and independent schools (151), as well as city technology colleges, sixth-form colleges and further education colleges (114 in total). Furthermore, the study included educational institutions from urban, suburban and rural settings.

One of four questionnaires was issued to each of the following members of staff for each educational institution:

Headteacher or Principal
Head of Biology/Science
Head of Humanities/Social Science
PSHE coordinator or equivalent

The questionnaire issued to each of the subject heads was identical. The form sent to headteachers also contained questions about the nature and ethos of the school.

The questionnaires sought information on:

- the school in general;
- how confident teachers felt about addressing issues-based topics;
- the topics related to biomedical science covered in their teaching;
- the resources used;
- teaching strategies;
- departmental or whole school/college policies.

Overall, 305 of those institutions sent a questionnaire responded (30.5 per cent); the percentages vary between school and college type with the highest response seen from grant-maintained schools at 37 per cent, and the lowest from further education colleges at 27 per cent. More questionnaires were returned from single-sex schools (all-girls at 59.4 per cent; all-boys at 46.8 per cent) compared with co-educational institutions (at 25.8 per cent).

Qualitative research

On the basis of the questionnaire responses, 20 institutions were selected for follow-up interview – ten local education authority schools, three grant-maintained, four independent and three further education institutions. Whereas the quantitative research sought perceptions more broadly, the interviews were designed to explore further the views of teachers and headteachers. Interviewees were asked whether they would be happy to have their interviews tape-recorded – virtually all agreed to this. As with the questionnaires, interview formats were tailored to the members of staff involved; some were one-to-one sessions while others involved small groups of between two and six teachers.

Research findings

What do teachers think science education is for?

A successful education strategy relies upon the support of the teachers who are responsible for its presentation. It is they who interpret directives and policies, and breathe life into them. In identifying how teachers feel about scientific controversy, as applied to the science curriculum, they present a broader philosophical view as to why they feel science is taught. Many science teachers consider it their role to convey facts, to interpret complex concepts and develop technical skills.

A large proportion of teachers across the curriculum perceive the teaching of science to be about the delivery of facts, and not about values, opinions or ethics. Almost half of all science teachers interviewed feel that their teaching of science should be 'value free' – that it does not yield issues that have social or ethical implications. Others inferred that considering the ethical and social concerns raised by science might undermine the integrity of the subject overall. One science teacher provided a revealing concern about the teaching of ethics within science classes:

Almost half of all science teachers interviewed feel that teaching science should be 'value free'.

"When we talk about the ethics of anything you're going to give an opinion rather than something that's fact based. Once you start giving an opinion then you express disagreement. Then they treat the whole of the subject in the same way that they treat your opinion in that they disagree with it personally. So they might end up treating your fact-based stuff in the same manner."

(Science teacher, school A)

Even though all science teachers covered biomedical topics, they touched upon social and ethical issues only if there was time or if students raised them. The constraints of an already full curriculum may be partly responsible, but interviews revealed that the teaching of 'value-free' concepts is a preferred style. After covering the core information, science teachers often feel it appropriate for students 'to reach the decision themselves'.

A key problem of using science to teach broad themes covering controversial issues lies in the rules that relate to the use of 'talk' within the classroom. Students are seen to draw a strong distinction between subject discourse and talk. For some teachers informal talk is a diversion from the subject and is therefore considered unsuitable. In science lessons, students may perceive such discussions as non-science and therefore not worthwhile. It may also be that the physical layout of science laboratories does little to promote dialogue and discussion.

Most humanities teachers think that scientific concepts are incidental to the main focus of their teaching. A sociologist for example is interested in genes and insurance, in the context of control, power relations and decision making. This is exemplified by a Head of Humanities:

"I think the scientific side of this is fine but it is dealt with in science. Humanities is looking at the moral issues behind it. Now, I am not saying we shouldn't have the facts there, but if we start doing the facts...then it is easy to get away from what we are doing and end up sort of teaching the science... What I perceive my job to be is to, say, look at the moral issues behind the holocaust (and the gas chambers). The chemical composition of Zyklon B makes no difference whatsoever..."

Those non-science teachers who did attempt to deal with the science raise other concerns for their science colleagues, particularly when it comes to answering students' questions and correcting inaccurate statements from them. Many science teachers express concerns that inaccurate coverage reinforces misconceptions.

...there is currently too little coverage of socio-scientific issues.

"One does worry as a science teacher that when issues like cloning are being dealt with that people dealing with it are clear about the science of it and are not...presenting the view which we sometimes get through the media. Cloning is a brilliant example because it seems to me that at least half the population think a clone is a fully formed adult...people are trying to deal with ethical issues concerned with this but they're not necessarily getting the science right."

(Physics teacher, school D)

A number of humanities teachers acknowledge the problem of not knowing enough of the science and would welcome resources to support them when managing class discussion on scientific issues. These should cover the basic science underpinning a particular topic, pitched at a non-expert audience.

The perception of science as 'value free' and humanities as 'value laden' sustains a curricular divide between science and humanities. Students' knowledge underpins the ability to engage in informed discussion but this is not the most important factor. Teachers expressed the view that students also need to be guided in debate and discussion of controversial issues and so opinion-forming activities depend on both the confidence and the knowledge base of the teacher.

Some courses successfully marry ethical issues with the source of scientific facts. A good example is the General National Vocational Qualification (GNVQ) Health and Social Care, in which real-life science issues are viewed from an ethical perspective. The ethical issues provide the context for factual knowledge, which is fed in as students need it. In the GNVQ course the science knowledge is dependent on the ethical dilemmas, so teachers can judge what science their students need to know to understand the ethical dimensions of a particular scenario. Though GNVQ is a promising model, current assessment criteria mean that students do not explore issues in any great depth.

How important for teachers are the issues raised by biomedical science?

An apparent contradiction emerges between the high value ascribed to socio-scientific issues by respondents and the comparatively few occasions when they are broached. Where they are not mentioned in the syllabus or specification, they tend to be omitted. Teachers of all subjects, it appears, prioritize topics according to whether they are explicitly identified and formally assessed.

Nearly all teacher interviewees feel that it is important for students to explore the topics underpinning the social and ethical aspects arising from biomedical research and how these might influence their lives. There is a growing awareness about how advances in genetics techniques are applicable to a range of subject areas. Geography teachers for example, might discuss human migration, sociologists might look at genetic fingerprinting, whereas Religious Education (RE) teachers would bring out the moral aspects of reproductive technologies in terms of the sanctity of life.

Almost 60 per cent of the survey respondents thought that there is currently too little coverage of socio-scientific issues related to biomedical science. Despite this, only three of a list of topics presented – AIDS/HIV, genetic engineering and eating disorders – are covered by more than half of the teachers, AIDS/HIV coming top of the list. Given the topicality of the Human Genome Project at the time of the survey, it is surprising that only 25 per cent of teachers had covered this topic in their teaching, nearly all of them science specialists. Indeed, only four humanities teachers had included any reference to the Human Genome Project and a significant number had not even heard of it.

When teachers were asked to indicate which topics they cover in their teaching, a clear pattern emerges. Other than eating disorders, teachers deal with issues related to mental health less often than other topics, with brain science topics the least frequently taught (Figure 1). The interviews accentuated this, revealing that many teachers are anxious about dealing with mental health issues in the classroom.

Why is the teaching of socio-scientific concepts important?

Biomedical research is having a growing impact on society; students need to be able to handle issues arising from this science so they can make their own decisions. Teachers also think that a sound knowledge of the basic scientific facts would help to counterbalance any sensationalist reporting in the media. Covering the social and ethical aspects of issues in the classroom encourages students to debate contemporary events.

"It helps them deal with developments such as newspaper screaming headlines so that we can respond...with a balanced approach rather than just leave them at the mercy of the mass media."

(Headteacher, school C)

A teacher expanded on the importance of improving skills to comprehend risk:

"Nowhere in teaching do we help them assess risk and what it means to them."

(Science teacher, school I)

Figure 1: The number and percentage of teachers covering each of the topics listed (total no. of respondents = 390)

Topics	Number	Percentage
AIDS/HIV	286	73.3
Genetic engineering	214	54.9
Eating disorders	212	54.4
In vitro fertilization	189	48.5
Reproductive technologies	183	46.9
Animal experiments	175	44.9
Nature–nurture	169	43.3
Dolly the sheep	162	41.5
Genetic testing, for example for sickle cell anaemia	148	37.9
Consumption of genetically modified (GM) foods	141	36.2
Prenatal screening	131	33.6
Over-prescription of antibiotics	129	33.1
Genetic fingerprinting	125	32.1
Animal to human transplantation (xenotransplantation)	113	29.0
Human Genome Project	99	25.4
Depression	96	24.6
Behavioural genetics	58	14.9
Other topics dealing with social and ethical issues in science	47	12.1
Dementia	44	11.3
Brain tissue transplants	19	4.9

The understanding of risk is critical if young people are to be able to evaluate some of the complex ethical questions raised by biomedical science. However, the educational value goes beyond this since once acquired, it could be applied in assessing risks more widely.

Some teachers stress the importance of building self confidence – giving students enough information for them to be able to express their opinions from their own viewpoints. Others feel that such topics encourage students to develop lines of critical thinking and analysis that would also stand them in good stead in other subject areas.

Using techniques in class to examine social and ethical perspectives can also help students to learn to detect bias. English teachers in particular and humanities teachers in general tend to use the media as a learning resource to help identify underlying messages and thereby promote independent thinking. Science teachers, by contrast, largely perceive the media as a source of bias leading to student misconceptions, coverage of GM foods being quoted most often.

In some cases, teachers highlight the ethical dimension of encouraging students to face the unknown:

"...equipping them with the tools to engage in the world that is not even yet...the principles of the values of life."

(RE teacher, school I)

Teaching students about the sanctity of life, for example, should include consideration of issues such as cloning, xenotransplantation and animal experiments. By discussing these issues in class, students can develop their sense of values.

Which teaching strategies are employed?

The 'new biology' may raise new ethical issues or it may simply have raised the profile of some existing ones. Either way, the subject matter of bioethics is comparatively new to schools and colleges, though the techniques required for teaching already exist. Teachers use a wealth of approaches and methods to cover controversy and issues. They frequently commented on how much students enjoy debating issues in class.

Understanding risk is critical if young people are to be able to evaluate complex ethical questions.

"A lot of these issues have come up in...formal debates where they have to take on a point of view that's different to their own. So they then have to look up information, find information...in order to persuade their audience...and they find that quite enlightening, and they also find information that they dismissed before...and find that they perhaps haven't taken in all the information that they should have done before, and I often point out to them, sometimes it's easier to take on a point of view that you don't particularly believe in because...the information is new to you, you can actually go and get fresh research to help your argument."

(Head of English, school K)

The most often cited methods for addressing socio-scientific issues are discussion and debate, most commonly after watching videos or after reading newspaper articles; occasionally discussion may have been prompted by a breaking story on the radio news. Formal class debates are also commonly used, though science practitioners tend to employ both these and informal class discussions far less frequently than their humanities colleagues. Science teachers express concerns about discussions getting out of control and advocate this along with curriculum constraints for not having such discussions in their lessons:

"I remember that there was something about genetics that came up, looking at animal testing. At the end of the video a couple of kids picked up on it and there was a debate and I wasn't really involved. One child spoke vehemently against testing for cosmetics. And these sorts of issues are raised in an uncontrolled way and that's part of the problem and can catch people unawares."

(Science teacher, school A)

Ethics cannot be taught without an understanding of the values underpinning these issues.

The reasons for the difference between these experiences of impromptu discussion are varied but are likely to include an already overburdened science curriculum, time constraints and lack of teacher confidence. Science teachers may appear less confident because their awareness of the complexity of the subject matter makes it difficult for them to feel that they can do justice to it and to their students' understanding. By contrast, English teachers appear to relish the challenge of prompting and managing class debates – both formal and spontaneous:

"...those lessons are often the best lessons you have. Because the kids are absolutely electric, they're alive, and this really gets them going. And you have to manage the debate, which in a class of 20–30 takes some doing, but that's what the job is. You then need to steer it because you get the breadth of understanding of the whole issue."

(English teacher, school J)

When asked about how confident they felt when teaching social and ethical issues in general, half of all humanities and PSHE teachers said they felt confident compared with only a third of science teachers. When this question was put again but in the context of socio-scientific issues, less than 20 per cent of humanities and PSHE teachers expressed confidence this time whereas almost 50 per cent of scientists felt confident in their teaching of such issues.

Teachers use role-play for generating empathy and to explore balanced arguments. The science textbook series *Salter's Science* was mentioned by several teachers as offering good opportunities for role-play, and is used in the sixth form to explore issues such as animal experimentation, though science teachers remark on the lack of time to use role-play methods more fully.

Lessons that involved inviting external speakers, true–false statement agreement exercises, general 'chalk and talk', and dramatic productions were mentioned, but on far fewer occasions by teachers. Science issues theatre has been shown to be effective but is not widely available.

What stance should the teacher take when addressing controversial topics?

Teachers often find themselves in a difficult position when teaching controversial issues because students probe them for their own viewpoint. In some circumstances, teachers may play devil's advocate to stimulate debate, in others they may take a neutral stance or attempt to balance arguments:

"Occasionally to stimulate an argument I'll go in and take an extreme point of view. And I'll make it as soundly and logically as I can and I hope they'll tear me to pieces."

(Head of Sixth Form, school P)

Whether teachers should adopt a particular position depends on the context and the issue. Some teachers say they would take a particular position, say devil's advocate, in one context, and remain neutral in another.

Some teachers feel that it is important they put across personal viewpoints so that:

"...students know you have opinions."

(Geography teacher, school D)

Although teachers did volunteer their own opinions, they always did so with the qualification that it was only one possible opinion among many:

"You give your opinion but make clear it's yours."

(Group of teachers, school C)

Many survey respondents expressed concern about indoctrination or forcing students to adopt one position. Some teachers are adamant that they should not tell students what to think or use their authority to influence students' opinion. A number felt that when considering controversy, there was a need to be detached from their personal viewpoint.

Teachers draw upon their own experience and that of those around them to personalize these controversial issues. Science teachers are enthusiastic advocates of this approach, possibly because they then feel more confident about the context in which they cover these issues. Teachers feel that using personal experiences in this way helps students to relate the topic to real life and so examine the impact it may have. Issues surrounding mental health can have personal implications for teachers and may have substantial influence on how confident they feel when dealing with the topic.

Teachers raised a number of their own ethical concerns related to broaching sensitive topics. These included the age and emotional maturity of the students, their faith and culture, and any particularly delicate issues pertinent to a student group.

"After a video on sickle cell anaemia during a topic on blood one student said 'I got that, does it mean my children are going to have it?' and we got into a discussion about what it means to have it and the chances of children having it."

(Science teacher, school A)

Arguably the most sensitive biomedical topic is the use of animals in scientific research, though attitudes in general do appear to shift over time. There is widespread unease about animal experiments among younger secondary age students, though attitudes tend to change as students grow older.

"Children of 11, 12, 13 are very, very opinionated about [animal experiments], usually anti-, whereas in years 10 and 11 they've got a more distanced view of it and they understand the difference between animal experiments for medical use and for cosmetic use."

(Head of English, school E)

Some teachers feel that students would be better served if certain issues were introduced earlier. Eating disorders, in particular, are mentioned as needing to be addressed early on in the curriculum so that young girls in particular could be aware of the cultural factors that influence their developing self image.

Some biomedical issues raise dilemmas among religious sections of the community, including pro-life attitudes to *in vitro* fertilization or attitudes among the Muslim community to the use of pig organs for xenotransplantation. While RE teachers thought there was a reasonable amount of literature from Christian, Jewish and Muslim groups on these issues, it was felt that there is a need for more information on perspectives from other faiths such as Sikhism and Hinduism.

A balancing act

Teachers are sensitive to accusations of indoctrination and take care not to impose their own values on their students – especially in the areas of politics and religion. Parents and teachers are thought to share this sentiment, possibly as an acknowledgement that the UK is heterogeneous and a pluralist society.

A recurring theme from the interviews was that teachers believe a balanced approach is the best approach. Almost one-third of headteachers mentioned 'balance' or 'impartiality', 'lack of bias' or 'objectivity'. It is interesting to note how strongly held these views about balance are.

Several teachers acknowledged that presenting a balanced view is not always easy. There are problems of disentangling an unbiased view from one's own world view.

"You can't avoid your own personal prejudices and life experience affecting the way that you deliver certain topics."

(Head of Psychology, school H)

The need to be seen to be balanced appears instrumental in allaying fears of indoctrination – a theme echoed in both questionnaire and interview responses. Some of the issues in biomedical sciences are deeply complex, the technologies are rapidly changing, and the legal and ethical perspectives are far from immutable. Even with a substantial amount of information at the disposal of the teacher, it can sometimes be difficult to put forward a balanced point of view because there are so many aspects to every point of view.

One strategy adopted by teachers is simply to present all sides of the argument. Some of the teachers interviewed advocated exposing students to a range of the 'quality' newspapers to 'find the balance point on an issue'. The assumptions that finding a balance point is the ultimate purpose of an ethical debate and that the quality newspapers represent the full range of political and social views on bioethical issues may need to be challenged. Ethics cannot be taught without an understanding of the values underpinning these issues. It might be argued that presenting a range of options to young people and then encouraging them to decide which they favour simply reinforces existing views and offers little opportunity for developing critical awareness.

Teachers cited respect for differing perspectives as an important component of balanced classroom discussion, although they acknowledged the problems of maintaining a balance between promoting an atmosphere of tolerance and open-mindedness, and dealing with unacceptable viewpoints.

Science interviewees reported that teaching the factual information in an impartial way is the predominant teaching style in science classes. With two exceptions, the science teachers interviewed did not feel it to be within their professional scope to discuss the ethical aspects of an issue, with one remarking:

"I'm very much...'well here's the information...you choose what to do with it.'"

(Head of Science, school F)

Others feel uncomfortable with this view, believing that it is in their remit to help students form opinions.

Few teachers make ethical concepts explicit in their teaching. Teachers offered little appreciation of the use of ethics as enquiry to help students to make judgements on a rational and reflective basis. Introducing a component of moral philosophy into education could provide the platform for teachers and students to argue through controversial topics – and so lead students to form their own opinions based upon an ethical framework.

What is the role in assessment in determining the status of socio-scientific issues?

Assessment is crucial to the seriousness and depth of teaching a topic and is a consistent theme throughout the interviews. Although previous science syllabuses contain statements that social, ethical, legal and economic factors were to be considered when covering, for example genetic engineering, the fact that this aspect of the work is seldom, if ever, examined means that teachers pay little heed to it.

Science teachers have been reluctant to adopt assessment techniques used by arts and humanities teachers – since they are both time consuming and seemingly less objective. Innovative methods will need to be developed if knowledge and understanding of socio-scientific issues are to be embedded within the science curriculum.

Assessment is crucial to the seriousness and depth of teaching of a topic.

Socio-scientific issues could be covered in other subject areas, but these too pose related problems. For example, PSHE currently lacks any formal assessment, a fact that contributes to its low status.

If it is accepted that many science teachers have limited experience of discursive argument in the course of their work, then it is understandable why they feel insecure about adopting new forms of assessment. While this approach may be new for scientists, it is not new for their colleagues in English and humanities, social science and the arts, for whom assessing students' views and opinions is

their stock-in-trade. The necessary expertise and techniques are therefore close at hand. Science teachers would need to feel confident about dealing with more opinion-based responses to questions whether they be for an exam or for homework. Once the awarding bodies provide more appropriate means of probing students' grasp of the bioethical concepts, training would need to be provided to ensure that teachers would feel confident to assess students' understanding.

How could scientific controversy be addressed in Citizenship Education?

Citizenship, which is due for introduction in English secondary schools in 2002, has been identified as an appropriate place for tackling socio-scientific issues. Science teachers view Citizenship as an opportunity to develop thinking about social and ethical aspects of scientific developments, whereas humanities practitioners are more sceptical about the initiative, suggesting that it is intended to focus on civics education rather than say, developing critical debating skills.

Citizenship Education will account for 5 per cent of the whole secondary curriculum. It is not proposed that Citizenship takes place within a designated lesson – consequently some or most of its teaching will take place within standard school subjects. Though science teachers are more optimistic about Citizenship than their humanities counterparts, they feel that there is not enough scope at Key Stage 4 to include socio-scientific issues in the framework of the Citizenship curriculum.

How do teachers use the media to address socio-scientific issues?

The research shows, not unexpectedly, that much of the knowledge about issues raised by science is gleaned from newspapers and news programmes on television and radio. Teachers use these sources of reporting about contemporary science issues to stimulate interest and discussion among students.

Interviewees react very differently when asked about the role of the media in teaching socio-scientific issues, but broadly they split along subject boundaries. Once again, the scientists and humanities practitioners have markedly different approaches. Science teachers, for example, tend to view the tabloid press as a source of misinformation, bias and propaganda. 'Brainwashing students', 'scandalous', 'emotive', 'sensationalizing' and 'Frankenstein-food nonsense' are typical terms used by science teachers when referring to specifically the tabloid press. However, they feel that the broadsheets depict scientific controversy in a fair and balanced way. By contrast, although humanities teachers are sceptical of the media, most welcome tabloid headlines and articles as ways of generating debate:

"Stuff comes out in the newspapers the whole time...[and] provokes people into discussion, and in a way the more outrageous the better."

(Head of English, school K)

Interviews with English teachers suggest that the focal points of discussion are the underlying values expressed within the article rather than the accuracy of the content.

While teachers are concerned with students' lack of interest in topical events and the news in general, they also signal their worries that students have very strong views about issues like animal rights and cloning, with little evidence to substantiate them.

From the interviewees' responses there is a clear indication that students need to be taught how to interpret the language in newspaper reports, identify the appropriate clues and relate that knowledge to their own developing understanding of a topic.

Collapsed days may be an effective model of collaboration.

Science teachers utilize television programmes – such as *Equinox* and *Horizon* – in their coverage of certain topics and these are considered to be good resources for the teaching of socio-scientific issues, in the post-16 courses in particular.

Is PSHE an appropriate location for addressing socio-scientific issues?

All schools and most further education colleges devote some curricular time to PSHE. It forms part of the non-statutory component of the national curriculum in England where students are asked to consider social and moral dilemmas, including young parenthood, genetic engineering, and attitudes to the law. It may therefore seem like an appropriate location to consider the controversies raised by scientific research.

Initial survey responses by teachers suggest that PSHE is an appropriate curriculum site to teach issues-based topics because it brings together personal and social issues. But few teachers interviewed felt this to be so. This mainly stems from the fact that the subject content is neither compulsory nor examined, so is not regarded highly by students or teachers. In addition, limited time is allocated to the teaching of PSHE and though the potential list of relevant topics is vast, its main purpose is seen to be delivering drugs and sex education.

What is the potential for cross-curricular collaboration and coordination?

Bioethics is an interdisciplinary subject. Academic bioethics comprises many specialist backgrounds including science, social science and philosophy. It would therefore be appropriate to approach the subject in a cross-curricular context. The research sought to identify whether structures exist for formal cross-curricular collaboration within educational institutions or whether different departments are aware of common themes.

The survey revealed a fundamental lack of collaboration between different subject departments. The organization of national curriculum subjects in state schools appears to work against both teacher and interdepartmental collaboration.

"In a school like ours with very rigid departments, independent departments with their own subject areas, it is sometimes difficult to find a place for things which are not on the syllabus, and a lot of these [socio-scientific] issues lend themselves to cross-curricular approaches, don't they?"

(Deputy headteacher, school E)

Where collaboration does occur, mostly it is informal. Teachers might discuss matters on an *ad hoc* basis in the staff room, for example a science teacher may approach the Head of RE to anticipate religious sensitivities when teaching about xenotransplantation. Other teachers may opt to share resources, such as newspaper clippings, in a fairly informal manner.

Teachers believe that more time should be devoted to controversy, but also feel the existing curriculum is overcrowded.

Interviews confirmed that there is very little cross-curricular coordination between science and humanities departments. Only three of the twenty schools visited had any significant level of cross-curricular collaboration with only one such collaboration at whole-school level. Although great opportunities lie in the fact that science teachers and humanities teachers are looking at different aspects of the same topic, when it comes to bringing the many facets together there is no current integrated framework for the teachers to follow. In RE, for example,

"...we'd be looking at the moral and ethical issues [of GM foods] whereas they [science department] would be primarily interested in the make-up of it."

(Head of Humanities, school J)

An interesting model of cross-curricular planning run by one school is the 'collapsed day' where the timetable is suspended and students take part in a thematic programme. For example, a year-group is taken off-curriculum to look at religion and secular society, pursuing themes such as science and religion or religion and medical ethics. The assessment is through RE but science teachers become involved and make a contribution.

"Brain tissue transplants and animal-to-human transplantation we cover specifically as an RE topic. We had a moral and ethics day. We deliver our RE curriculum instead of one period a week, we have collapsed days, and I help to put together some of the material we used to get people to confront these major moral issues. If we believe someone has an important input they could bring to a particular topic then we'd use them and we'd always try to put them in the context of the other studies they're doing."

(Psychology teacher, school J)

Collapsed days may be an effective model of collaboration provided there is sufficient opportunity, time and resources for advance planning between teachers of different subject areas. Other requirements include an agreed format between subject areas – especially concerning through which subject any assessment is to be made, and a structure for ensuring equal participation in decision making by all teaching partners.

This model of cross-curricular collaboration should be investigated further to evaluate its effectiveness in discussing socio-scientific issues.

What are the challenges for the curriculum?

Teachers believe that more time should be devoted to controversy but also feel that the existing curriculum is overcrowded. In particular, science teachers feel that creativity and innovation are limited by an overly rigid and narrow science curriculum, the demands of which are thought to inhibit the flexibility to respond to topical events or issues.

"We are so blinkered in terms of the national curriculum, we monitor it, we check it, we do our analysis of data to improve our targets, we are very skilled at doing that. But are we actually providing children with the desire to take science further? And if we could somehow bring in modern issues into our science teaching and say, look this is alive, this is what it's about, you could be part of that in three or four years' time."

(Head of Science, school A)

The double-award GCSE Science specifications are considered to be too overcrowded with concepts and content preventing discussion of social and ethical issues. The English Language GCSE syllabus is seen to be the least prescriptive, although not unsurprisingly there are different perceptions of its relationship to biomedical issues. There is no constraint on teachers' freedom to develop any topic they want in English, the limitations being based on prescribed authors and themes such as 'nineteenth century' or 'poetry'.

English is a promising site for the discussion of issues such as the 'new genetics'. As one Head of English explains:

"We deal with controversial issues all the time...the only texts worth doing are those with controversial issues in them or else there's nothing to talk about."

(Head of English, school E)

Most of the English teachers interviewed made similar comments about the popularity of issues related to biology in the English syllabus. *The Tempest* and *King Lear* proved to be popular texts for stimulating discussion on nature–nurture, for instance. The English curriculum allows students to pick out emotive language and look at persuasive techniques.

RE teachers addressed biomedical issues through an ethics or religious context. Students like talking about ethical issues and anything concerned with expressing an opinion, thus ethics is a popular option in these courses. Girls in particular appear to enjoy discussing ethical issues concerned with the new genetics. Biomedical topics can also enable discussion about the comparative perspectives of different religions, as for example in the scenario of a dying person whose only hope of survival is being given a heart from a genetically modified pig but whose religion forbids it.

The history of medicine modules in GCSE History provide a context for approaching scientific issues from a historical perspective. For example, the Assessment and Qualification Alliance (AQA) specification for GCSE History includes the following statement in its rationale:

'Key features in the development of medicine are linked with changes in society through time. Social, cultural, religious and ethnic diversity is addressed across the Development Study by looking at the medical traditions of different countries.'

(AQA GCSE History, Schools History Project, Specification 2000)

Geography encourages students to look at the international dimension and is an appropriate location for consideration of topics such as biodiversity and sustainable development.

General Studies is popular in the sixth form and could be an appropriate location for teaching about socio-scientific issues, though because the course is so broad, topics are covered only superficially. Students may be able to form some sort of argument about scientific issues, but teachers indicated that few really grasp the relevant facts. Students pursuing humanities courses post-16 find any science-based questions difficult, owing to their lack of scientific knowledge.

"I've just marked 300 scripts with a question on animal experiments and what comes across very strongly...and the board will tell you this...it's just an emotional argument on one sort of level and trying to get them beyond that is so difficult. Everybody over the years has known it's quite a complex issue but it doesn't get across to the students."

(Head of Politics and General Studies, school B)

What training is required?

The House of Lords Select Committee on Science and Technology has identified the need for an upgrading in the quality of Continuing Professional Development (CPD) among science teachers, citing that:

'A healthy democracy needs a public with a broad understanding of major scientific ideas, one that can engage critically with issues and arguments – which involve both scientific knowledge and the limitations of science.'

(*Science in Schools*, Select Committee on Science and Technology, House of Lords, 2001)

In its introduction, the report states why CPD is important:

'Good teachers matter more than good courses in inspiring children and stimulating their enthusiasm.'

The research highlights the need for training – both initial and in-service – so that teachers feel confident in broaching relevant ethical principles. Such training would include increasing familiarity with the nature of ethical enquiry as well as developing the classroom teaching strategies that support discussion of moral and ethical issues. Since teaching about socio-scientific issues relies heavily on confidence, teachers need to be able to rehearse arguments for themselves before they can feel secure about ethical debate in the classroom. A possible model may involve a case-by-case approach of exploring ethical concepts. A training programme therefore might look at a specific issue such as stem cells – covering the underpinning science, the moral and religious values that could be brought to bear on the topic, and the complexity of the argument. It could also explore how to apply ethical positions from one case to another.

Initial teacher training courses should provide prospective science teachers with more opportunities in the areas of initiating and managing classroom discussions. Practising teachers could improve and update such skills through CPD. Approximately one-quarter of the teacher respondents emphasized the importance of knowledge and information for in-service training, and about half of these specifically referred to up-to-date information. It is worth noting that the controversial issues raised are allied to recently developed technology and research findings, often unfamiliar to teachers in the middle of their careers.

What educational support materials do teachers want?

Almost all teachers interviewed think there is a lack of support materials relating to socio-scientific issues. Ninety per cent of respondents believe there is an urgent need for new high-quality resources. Currently, teachers use a range of materials, but by far the most commonly cited was video. Multimedia resources, high-quality worksheets, visual stimulus materials (such as slides and posters) and articles from newspapers were also mentioned relatively frequently.
However, many teachers feel sceptical about videos and websites, suggesting that they are 'propaganda' for a range of commercial companies and single-issue groups. They stress that they are very careful when selecting and using these materials. Teachers requested a regularly updated, independent and reliable source of advice on resources of this kind, as well as guidance on the appropriate use of such resources.

Teachers need to have confidence in any support materials they use. Interviewees were particularly concerned that they had access to high-quality stimulus material when dealing with subject matter beyond their expertise. For example, science teachers expressed a need for quality support materials depicting various standpoints whereas non-scientists preferred materials that offered short, quick-to-read summaries clearly depicting the science.
Again, teachers felt support materials should offer a balanced approach with up-to-date and accurate information.

In addition to the general issues of quality, accuracy and immediacy of resources, science teachers usually mentioned specific information they would welcome, such as updates from researchers on issues in animal experimentation or in legislation about, for example, embryo testing. According to one science teacher:

"[The] law appears to be lagging behind the technology...we've the science to be able to do certain things like reverse the menopause, and we haven't got any legislation for those kinds of things."
(Science teacher, school I)

Humanities teachers rely heavily on the use of newspaper articles and issues raised in media news programmes because of a lack of contemporary educational materials that convey the immediacy of the topics under consideration. They do not want to feel:

"Like someone who had just read the newspaper."
(Head of Humanities, school J)

...and so request materials that have technical information about current developments in the biomedical sciences but at a level appropriate to non-scientists.

The rapidly changing issues in the biomedical sciences were noted as problematic by all teachers, particularly PSHE coordinators who feel they do not have access to contemporary materials to address topical issues. There is a demand, therefore, for accessible information that can be easily updated for non-specialists.

The way forward

Social, moral and ethical issues should be more clearly set out in examination specifications and syllabuses than they are at present. This would provide clearer opportunities for addressing issues arising from biomedicine.

School and college students have an entitlement to engage with the controversial topics that will affect their lives in the future. Efforts should therefore be made to create such opportunities both within the science curriculum and elsewhere. Awarding bodies should highlight topics that raise socio-scientific issues and be explicit in what these issues are. For instance, the Human Genome Project would be identified as an area of potential controversy and examples of issues it raises (e.g. ownership of genetic information) should be stated.

The Qualifications and Curriculum Authority and the Qualifications, Curriculum and Assessment Authority for Wales should identify where socio-scientific issues could be covered in the curriculum and make this explicit to the awarding bodies.

Guidance to awarding bodies for specifications and syllabuses in science and other subjects originates from the bodies responsible for determining the curriculum in these parts of the UK. An independent group could be established who would offer guidance to each of the agencies responsible for the curriculum, on a range of socio-scientific controversies and where in the science and broader curricula these could be addressed.

Social, ethical and legal implications of the science should be integrated into the curriculum where possible, and formal assessment criteria should be devised to give recognition both to discursive argument and knowledge of science.

Consideration of the social, ethical and legal implications of scientific topics should be of equivalent status to the technical science and not simply an appendage. School league tables – one element of an increasingly competitive educational climate – foster a culture where only that which is formally accredited is valued. Consequently, students must be tested on their understanding and opinions related to these topics. The various

bodies responsible for the curriculum should ensure that the value assigned to socio-scientific aspects is maintained through researching and implementing new methods of assessing discursive examination responses.

Research should be carried out looking at effective ethics teaching in science. Training opportunities should be made available to teachers of science and other subjects so that they can use the principles of moral philosophy when addressing socio-scientific issues.

Teachers expressed concerns that learning about socio-scientific topics relies on the expression of unstructured opinion. It is unlikely in the foreseeable future that moral philosophy will be introduced into the mainstream school curriculum. However, opportunities could be made available for teachers and accordingly their students, to develop greater understanding of ethical reasoning, thus helping students to weigh arguments on the basis of values and principles rather than on opinion alone. Short philosophy courses could be developed targeting specific sets of say, bioethical concerns. These courses could be developed through collaborations between philosophers and humanities and science educators.

Educational materials should be developed that invite analysis of socio-scientific issues from a range of perspectives, but which also provide sufficient, accurate and accessible technical scientific information for non-specialists.

Educational resources should highlight the main socio-scientific controversies related to developments in biomedical science. These should lead with the social and ethical issues – addressing sufficient science to enable the user to develop an informed perspective, without being distracted by technical detail. The emphasis would shift according to whether the primary audience for a particular resource is science, humanities or other. The types of educational material that need to be developed include:

- up-to-date information, possibly on dedicated websites;
- provision of basic science, in accessible language for non-specialists;
- individual scenarios explored through various ethical approaches;
- themes, ideas and resources for school assemblies, aimed at a range of ages;

- resources to help students detect and challenge bias in various types of literature and media;

- exemplar material on the key biomedical research initiatives such as the Human Genome Project, on risk and on relevant human rights issues;

- exemplars of materials and approaches to teaching controversial aspects of biomedical topics;

- materials for students with low levels of literacy or English as an additional language;

The DfES, professional subject bodies, teacher-training colleges and those involved in relevant education initiatives – such as Citizenship Education – should explore the potential for cross-curricular initiatives such as 'collapsed days'. Teachers should have access to continuing professional development to ensure that they can implement such schemes.

Conventional cross-curricular initiatives have had only limited success. The reasons for this are complex – though unequal status of subject areas and lack of time for proper coordination, are likely obstacles to success. The 'collapsed day' model, where all students in a year group go off-timetable to explore a theme, has been used to some success in other areas. Research is needed into whether this approach would allow science and non-science teachers to work with students, free of the expectations and limitations of the conventional curriculum. It would also be valuable to ascertain how the intensive but singular experience compares with a more conventional approach, in terms of developing critical understanding that is sustained over time.

The Citizenship curriculum to be introduced into schools in England in 2002 should encourage consideration of socio-scientific issues. It should foster interdepartmental cooperation and guide schools on relevant topics and issues.

The research findings indicate that there is no obvious location for socio-scientific issues to be covered in the existing subject-focused curriculum. As part of the implementation of the Citizenship initiative, guidance could be given to schools on how to ensure that duplication does not occur between subjects.

The science of the brain needs to be incorporated into mainstream science and post-16 biology, providing opportunity for greater consideration of the issues related to neuroscience and mental health.

Our understanding of the brain has increased greatly over the past fifteen years, though this is not reflected in the school curriculum. Applications of some of the research findings in neuroscience look set to equal the impact of genetics. The school science curriculum should prepare young people for this likelihood so that they can understand the underlying processes taking place within the brain and the implications of advances in neuroscience for society. The wider curriculum should provide opportunities for discussion about the social and ethical issues raised by an increased understanding of brain physiology, the relationship between genetics, brain chemistry and mental health, and the association between genes, environment and behaviour. Curricular agencies should include 'brain science' as part of the science and biology curriculum. They should ensure that socio-scientific concerns are embedded within this section of work.

The school curriculum should encourage students to examine the biological, psychological, environmental and social factors associated with mental health problems. Research should be carried out among teachers, students and parents to identify attitudes towards learning about mental illness and its treatments.

According to the World Health Organization, the level of mental illness has increased rapidly in recent years, with depression alone set to become the second highest cause of debilitating ill health worldwide. Mental health education in schools and colleges has been approached in an *ad hoc* manner and there is significant variability in young people's educational experience in this area. School managers and teachers are wary of teaching about mental health. The Government and mental health professionals should encourage research into what underlies the reluctance of schools to address the topic.

Post-16 students could be encouraged to take a course such as the new GCE Advanced Subsidiary Science for Public Understanding. Scientific issues could then be explored at a greater depth than they are in the very broad General Studies syllabus.

Consideration should be given to ensuring that most post-16 students study an accredited course enabling them to develop the critical skills and background knowledge to engage with discussions about contemporary socio-scientific issues.

Research should be carried out into how the philosophy courses currently run in some primary and secondary schools affect the moral development and ethical decision making by pupils.

Some pupils in primary and the lower years of secondary schools participate in courses on basic philosophy. It would be of value to appraise how the ethical reasoning of these students compares with that of other pupils in similar schools who are not exposed to these courses.

Quality training courses should be designed and piloted to update teachers on biomedical developments, such as stem cell technology and their social, ethical and legal implications.

Continuing professional development courses should be developed targeting science teachers and those engaged in teaching about socio-scientific issues. These sessions should be thematic and comprise information about developments in research, current issues on legislation and regulation, and address the social and ethical issues raised. They could be designed to take up a single in-service training day.

Support material should be developed and piloted to accommodate the range of religious and secular perspectives towards various socio-scientific issues.

Socio-scientific topics raise issues for the range of religions and cultures represented in UK schools. Educational support materials and guidelines could be developed that would assist teachers of RE to be aware of the full range of attitudes to these issues. The resources would also help teachers across the curriculum to recognize the sensitivities of each religious group to particular issues.

Conclusion

Though teachers believe that young people should engage in discussion about how science in general and biology in particular will affect their lives, curriculum overload and other educational initiatives leave limited opportunities for this. Science teachers feel that it is their responsibility to cover the concepts and content of science and maintain that school science is largely value-free, while claiming that those issues that do arise are best dealt with elsewhere in the school curriculum.

Some teachers of humanities subjects, though skilled in managing controversy, feel constrained in discussing socio-scientific topics with students by the availability of accessible support materials. Others feel that focus should be the controversy itself, not the science. If more widespread scientific literacy is to be achieved, policy makers and others responsible for developing the curriculum will need to explore ways of bringing humanities and science teachers together.

Research shows that young people also want to engage in discussion about science and society and are motivated by the relevance of contemporary issues – but wish to be credited for having done so. If teachers and their students are to accord greater status to this curricular component, new forms of assessment and education practice will need to be developed. Continuing Professional Development opportunities should ensure that science teachers feel confident about incorporating socio-scientific issues into their lessons and that this is achieved without imposing upon them an additional burden.

As developing citizens young people should develop the analytic skills that will enable them to use ethical reasoning when considering scientific and other controversies. They should be empowered to discuss the issues of the day using their scientific knowledge within an ethical context.

The future of science in the UK depends on the continual supply of highly trained and competent researchers, but also demands an environment in which innovative research can flourish. Science is an intrinsic part of our culture and is linked to many of the wider issues and controversies arising from the modern world. Young people's formative experience of science takes place in the classroom and their attitudes towards science are largely dependent on the quality of this experience. Accordingly, the scientific and wider communities will both benefit if today's young people develop into tomorrow's scientifically literate citizens.

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