The Student Voice and School Science Education

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> The pupil testimony is not privileged as 'more true' than the accounts of teachers and advisers, but it provides a crucial element still too often overlooked. (Nixon *et al.* 1996: 270)
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> Increasingly a new kind of work with and writing on children is being done. There is much literature which explores how children and young people see the world, their values and priorities and the ways in which they feel themselves marginalised… (Roche 1999: 477)
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> There is something fundamentally amiss about building an entire [education] system without consulting at any point those it is ostensibly designed to serve. (Cook-Sather 2005: 1)
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> School science education can only succeed when pupils believe that the science they are being taught is of personal worth to themselves. (Reiss 2000: 156)

One of the noteworthy features of the educational research literature in recent years has been the attention given to the 'student voice' (Branscombe, Goswami and Schwartz 1992; Lloyd-Smith and Tarr 2000; Schultz and Cook-Sather 2001; Burke and Grosvenor 2003; ESRC 2004; Fielding 2004a). Different researchers, however, have often used the term in different ways and directed their findings towards different ends. For some, the student voice refers to identifying, encouraging and expressing the unique self in an act of creative writing. For others, the focus of attention has been students' views about the form, content and aims of their schooling with a view to promoting dialogue and participation. The ultimate purpose of such dialogue and participation has ranged from, on the one hand, radical reform of the school, the curriculum and/or pedagogy to more efficient school management and governance, improved standards, increased student motivation, enhanced school effectiveness and the renewal of civic society on the other (Lensmire 1998; Fielding 2004b; Rudduck and Flutter 2004; Mirta 2004). More specifically, Polman and Pea have represented the student voice as an element of 'transformative communication' upon which to base classroom scientific inquiry that is not teacher driven and 'premised on known answers' (Polman and Pea 2001).

Among researchers in science education, there are several well-established strands of work that might legitimately be encompassed by the term student voice. There is, for example, an established corpus of research that has explored students' views about science and scientists, e.g., Mead and Métraux 1962; Chambers 1983. The work of Chambers, based on a 'Draw-a-Scientist-Test', has been subsequently developed and deployed by several other researchers, e.g., Mason, Kahle and Gardner 1991;

Symington and Spurling 1990), and more recent studies have revealed some shifts, including a greater degree of gender equity, in students' images of scientists over time (Matthews 1996). Inevitably, data generated by studies of this kind present problems of interpretation (Symington and Spurling 1990) and, perhaps at least partly for this reason, few of the findings seem to have been turned to significant pedagogical advantage.

There is also a substantial literature concerned with students' commonsense/everyday understandings of scientific concepts (Duit 2004), their views about the nature of science (Lederman1992; Kang *et al.* 2004; Ryder *et al.* 1999; Driver *et al.* 1996), their interests in science (e.g.,Tamir and Gardner 1989) and their attitudes towards science (Schibeci 1984; Simpson *et al.* 1994). Attitudes and interest seem likely to have a bearing on the teaching and learning of science (Bennett 2001; Häussler, 1987; Zembylas 2005) as well as being important among the outcomes of science education. Nonetheless, as with their views about science and scientists, research into students' interests and attitudes seems to have had little general impact on pedagogy, assessment or science curriculum reform, perhaps because the implications of the findings for the science curriculum and for the way in which science is taught, learned and assessed are by no means straightforward. Fensham has noted how no one had considered gathering data on students' sense of the relevance of the science topics included in the TIMSS achievement tests (Fensham 1998) and it is perhaps significant that the word student does not appear in the index of the two volume *International Handbook of Science Education*, published in 1998 (Fraser and Tobin 1998). It is also important to note that in investigating 'student interest', researchers have usually treated such interest as a personal attribute of the student rather than as an outcome of science education.[1]

More recent work has complemented these earlier studies of the 'student voice' in science education by redirecting research attention to focus more directly on what students think about the form, content and purpose of their school science education and exploring the curriculum and pedagogical implications of the findings. Researchers have also explored students' attitudes towards a variety of science-related issues and whether or not they wish to pursue a career in science or technology. This article asks why these aspects of the student voice in science education have received increased research attention in recent years and reviews some of the studies undertaken. It also comments upon the contribution that the findings might make to curricular and pedagogic reform, and explores their significance for policy makers, researchers, curriculum developers and teachers.

WHY NOW?

The present level of interest in the student voice in science education almost certainly owes much to the relative unpopularity of the physical sciences as subjects of advanced study in most industrialised countries and the associated gender differentials which have proved so resistant to significant change. Politicians, like educational researchers, want to know why these issues arise and want to do something about

[1] The science component of the PISA test to be conducted in 2006 is likely to investigate 'interest in science' as an outcome of school science education.

them. Within the European Union, for example, attention has recently been focused on the declining popularity of the physical sciences among young people as a result of a commitment by the Member States to increasing the number of science, mathematics and engineering graduates in accordance with the so-called Lisbon Declaration of 2000 and the subsequent call in 2002 by Heads of State to increase the proportion of European GDP invested in research from 1.9% to 3% (European Commission 2004). The untested assumption is that the more that is known about students' interests, enthusiasms, dislikes, beliefs and attitudes, the more feasible it will be to develop school science curricula that will engage their attention and help to reduce long-standing gender and other differentials.

At a more formal level, the wider context of education has been influenced by the European Convention on Human Rights and the UN Convention on Children's Rights. Article 12 of the latter asserts the right of a child to express an opinion and to have that opinion taken into account in any matter or procedure affecting that child, a right that also has implications for teachers and teacher educators (Osler 1994). Also, in recent years, many societies have accorded a heightened role to the views of young people about many of the activities in which they are required, or choose, to engage. Witness, for example, the 'Children's summit' (C8) held in advance of the G8 gathering of the world's richest nations in Gleneagles in Scotland in July 2005.

However, other factors can also be detected, especially in those education systems that have espoused a market philosophy. The consequences of this espousal are most evident in the language that has become commonplace in educational discussions in England and in some other countries that have adopted such a political philosophy in the last fifteen or so years. That language characterises a science curriculum as something to be 'delivered', defines education in terms of outcomes that can be measured and places students and their parents in the position of customers. Customers have rights in an educational market and one way of exercising those rights is to express views about what should be taught in school science courses and about how it should be 'delivered'. Although such views are likely to be far from homogeneous, differing both among parents and students and between them, they are increasingly seen as important elements of any curriculum debate. Traditionally, however, students have generally been regarded as consumers that are not worth consulting, a neglect that sits increasingly uncomfortably alongside the market philosophy referred to above (Rudduck and Flutter 2000).

From a historical, rather than a sociological perspective, seeking the views of students about their school science education can be seen as a reassertion of the student-centred curriculum initiatives of the 1960s, although these were much more marked in other, non-scientific, areas of schooling. They may, also, amount to something of a reaction to the narrow instrumentality that characterises much of the contemporary debate about school science education.

More pragmatic considerations may also be in play. Identifying and responding to the student voice may be seen as a means of reducing the alienation that some students feel from their schooling and thus of helping to overcome the associated problems. As with the earlier student centred movements within education, involving students in decisions about their education can be regarded as a means of introducing them to the complexities and limitations of the democratic process and thus as something of a preparation for their future role as citizens. From this perspective, accommodating the student voice becomes a means of transforming schooling (Kushman 1997; Fletcher 2003) and of making the curriculum more relevant to students' needs and interests.

> Science is in the curriculum because it *is* relevant and, it should be added, relevant to *people*. Relevance is the very reason for its existence, and it should be the very backbone of science teaching (Newton 1988: 7)

Translating relevance into curriculum terms is, of course, both contentious and problematic, although it should be noted that relevance has usually been defined with the interests of adults, rather than young people, in mind. In England, while 64% of a sample of science teachers felt that the science taught related to their students' everyday lives in half or more of their science lessons, only 35% of the students shared this opinion (NFER/DfES 2004). Accommodating the student voice thus also involves seeing students less as part of the problem of raising standards in school science and more as a key element in its solution.

The educational research community has not been slow to respond to this change of perspective. One internet search engine (scholar.google) lists over 60,000 entries under 'student voice', although most of these do not relate directly to school science education and the majority derive from work undertaken in the USA. In the United Kingdom, the Economic and Social Research Council (ESRC) has funded a major project entitled *Consulting Pupils about Teaching and Learning* (ESRC 2004). This initiative supports a range of more specific projects and has led to a large number of publications. Among much else, these offer teachers advice on how to consult pupils (MacBeath *et al.* 2003) and how to develop dialogue about teaching and learning (Arnot *et al.* 2003). Although science does not feature prominently in the overall programme of work, there is much likely to be of interest to science educators on the project website (http://www.consultingpupils.co.uk).

RESEARCHES AND STUDIES

In order to restrict the scope of this review, the literature discussed below is confined to research studies that seek to explore students' views about their school science education and matters related thereto, such as the way science is taught, its relevance to future employment or its implications for environmental education or activism. The scope is further restricted by referring only to research published in English and by excluding a field of work where a substantial research review or bibliography already exists, e.g., Schibeci 1984; Simpson *et al.* 1994; Duit 2004. In addition, studies more than ten years old have been excluded from the review, unless they are of particular methodological, conceptual or other interest. This is because there have been important changes in school science curricula in the last decade, so that the findings of earlier studies may be somewhat misleading. This may be especially the case for those studies that have explored students' views about practical work in school science, many of which have established that such views are historically sensitive and often significantly different from those of science teachers (e.g., Kerr 1963; Boud 1973; Boud *et al.* 1980; Hofstein *et al.* 1980; Lynch and Ndyetabura 1983; Denney and Chennell 1986; Boyer and Tiberghien 1989; see also Hodson 1993; Wellington 1998; Psillos and Nieddere 2002). Ten years have also brought seminal developments in science and technology. A decade ago, there was no Dolly the sheep, few students used mobile telephones, and issues such as cloning and genetically modified crops did not have the publicity and salience that have now become commonplace in many countries. As a result, students' opinions about their school science education are likely to have changed in this time, although some of their other views, such as their image of what a scientist looks like, may have remained relatively fixed.

One of the noteworthy features of the research that has been undertaken to establish what students think about their school science education is its methodological diversity. The research methods deployed include paper and web-based questionnaires, focus groups, and personal and telephone interviews. Beyond this, there are differences in sample size and bias, in the procedures employed for selecting the sample to be studied, in the purposes for which the research was undertaken and in the ways in which findings are analysed and reported. The research findings also relate to different age groups and embrace both national and international studies. There appear to be no large scale rigorous science-specific studies that have explored school students' views about how they would wish to be taught, although Leggett *et al.* (2004) have studied the importance that undergraduates and staff attach to the development of generic skills in science. Kinchin (2004) has used concept cartoons to investigate students' beliefs about their preferred role as learners, although without particular reference to the teaching and learning of science. Freestone, in a single school-based study undertaken as part of the ESRC project referred to above, showed that there were differences in the preferences of boys and girls with regard to ways of working in science. For example, most girls liked to work collaboratively whereas boys indicated that they would rather work alone or in friendship pairs (Flutter and Rudduck 2004: 35-6). Likewise, Zohar and Sela (2003), working with Advanced Placement classes in physics in Israel, have shown that girls react adversely to an excessively competitive atmosphere and to teaching that does not lead to understanding.

A study by Qualter, although now somewhat dated, is interesting in that students were invited to respond to two categories of statement, one set consisting of abstract scientific principles and the other such principles presented as applications (Qualter 1993). The list of statements was drawn from topics used in the Assessment of Performance project (APU) and Qualter found that the topics of particular interest to girls were predominantly biological. She concluded that girls lacked interest in 'abstract statements of physical science concepts' and that these were of 'very limited interest to boys' (Qualter 1993: 307)

A web-based questionnaire formed the basis of *The Student Review of the Curriculum* undertaken in England at the end of 2001 and the beginning of 2002. The questionnaire was designed by the students themselves and it was the students, with some professional academic support, who wrote the final report. The on-line questionnaire involved 55 questions, based upon a range of issues identified by young people at a series of nine regional meetings. These meetings varied in size from under a dozen to over 130, with an average of around 35 students. A selection of these students made up a national group that was given responsibility for the final design of the questionnaire and for analysing and reporting the findings. The on-line survey lasted six weeks and 1,493 questionnaires were received, although, as is common with research of this type, not all respondents answered every question. 77% of those responding were between 16 and 19 years of age, and a further 22% were 14-16 years old. Interestingly, given what is sometimes claimed about girls and computers, there were many more girls (66%) than boys (34%) among the respondents. Some care is needed, however, in reading the results of this survey since almost two thirds (64%) of the respondents were from independent, i.e., fee-paying schools. If the sample were representative, this figure would have been about 7% for 11-16 year olds and 20% for 16-18 year olds. The much higher percentage of independent school respondents probably reflects the greater level of computing resources available in some of these schools and the fact that some of the respondents were boarders at their schools. In this connection, it is interesting to note that 53% of the respondents were at co-educational schools, 41% at girls' schools and only 6% at boys' schools. About half (52%) of the 14-16 year olds in the sample were not expecting to go on to study science beyond 16, with the remaining 48% expecting to continue with their studies. This latter figure is almost certainly much higher than would be the case in the majority of maintained secondary schools in England (Planet Science *et al*. 2003).

The Planet Science study reported that 69% of the students in the sample (n = 1,471) thought that controversial issues should be included in school science courses, although a further 29% 'didn't mind'. 42% of the students (n = 1,432) thought that their science lessons up to the age of 16 had not made them 'curious about the world and interested in finding out more'. 57% (n = 1,467) indicated that 'discussions about philosophy and ethics (such as animal testing)' would make their school science education more interesting, although there were significant proportions who were opposed (15%) or 'didn't mind' (28%). Physics topics were judged most frequently by students to be the most boring aspects of their school science education, with biological topics the most popular, with chemical topics occupying an intermediate position.

> I don't really care how you worked out how fast a ball falls if it weighs 10kg and is falling 4 metres, it's not stimulating and I'm never going to use that information again.
>
> Physics, I have never, nor will I ever, see the point or understand physics. It always seemed pointless spending hours of experimental time proving what was already proven, or that black wasn't a colour, or whatever.
>
> Equations [and] bonding (chemistry) – for a person who KNOWS that she will not ever go into chemistry, that was pointless, difficult to grasp and boring. (Planet Science *et al.*: 17)

Gender differences in many of the responses to the Planet Science questionnaire were often particularly marked, with most girls expressing a preference for biological topics and many displaying a strong dislike of their school physics education (see also Angell *et al.* 2004). At some risk of oversimplifying the outcomes of this study, the broad messages seem clear. Many students wanted more discussion in their science lessons, they wanted school physics and chemistry to be more relevant to everyday life, especially the girls, and they wanted engagement with ethical and controversial issues to feature in their school science education.

When asked about their experience of school science teaching, 85% (n = 1,450) said that they felt it was 'exam.-led', with little difference (3%) evident in the responses from private and maintained schools. The students were also well able to discriminate between what was 'useful and effective' and what was 'enjoyable' to them as learners. For example, while only 15% of the sample described taking notes from a teacher as 'enjoyable', 45% categorised such an approach as 'useful and effective'. Likewise, 'looking at videos' was enjoyable for 75% of the sample but far fewer (27%) thought it a useful and effective way to learn science (Murray and Reiss 2005: 86).

The findings of the Planet Science study led Murray and Reiss to offer ten 'student recommendations' for the improvement of school science education. These ranged from reducing the curriculum content and offering pupils an opportunity to engage in dissection to more practical work and the inclusion of ethical and controversial issues. (*ibid.*: 91-2). A Select Committee of the House of Commons in the UK took evidence from some of the students who had participated in the research and the findings of the study had some influence on the Committee's report (House of Commons Select Committee 2002).

Several of the findings of the Planet Science study resonate with those of a focus-group based survey that sought the views of parents as well as of students, together with teachers' responses to the views expressed (Osborne and Collins 2000: 2001). The study involved 144 pupils aged 16, 117 parents and 26 teachers in 45 focus groups held in different parts of England and each consisting of about seven people. Of these 45 focus groups, 20 were with pupils, 20 with parents and 5 with teachers. The meetings took place between September 1998 and July 1999. Data were recorded on audio-tape and coded to give 430 codes grouped under 25 broad themes. Discussion in the focus groups was initiated by several prompts and/or questions that were different for the pupils, teachers and parents. As an example, the questions used in the focus group interviews with pupils concerned the value of school science, the application of science to everyday life, visions of science in the future and the appeal of science in everyday life. The main findings of the study were that pupils thought science important but valued their school science in terms of career aspirations rather than as a subject of intrinsic interest. They were also dissatisfied with many aspects of their school science education, with chemistry attracting the most antipathy.

> Pupils found too much of the later years of science education to be an experience that was rushed; dominated by content; repeated too much of material they had previously encountered; required too much 'copying'; lacked opportunities for discussion; and was fragmented leaving them without any overview of the subject. (Osborne and Collins 2000: 5)

Not all the messages about school science were negative. Biology was generally well-received, especially by girls, and science was interesting 'when it offered opportunities to engage in practical work, when it offered challenge and stimulation whilst not becoming too difficult or complex, and when it stimulated a sense of awe and wonder' (*ibid.*: 6). Osborne and Collins concluded that the dissatisfaction revealed by their study stemmed from a curriculum framework that was content-dominated, assessment driven and too homogeneous. However, their study also served to highlight the importance of good teaching in stimulating and sustaining interest in school science, an issue raised without prompting by all the pupils in the study. There was

> consensus among pupils that their interest was engaged and sustained by teachers who made lessons 'fun', either through their methods of presentation of the material or through the organisation of work which immersed pupils in practical activities. (*ibid.*: 40)

Pupils' views about science across Great Britain feature in a wide-ranging study undertaken in 2004 as part of the Nestlé Social Research Programme (Haste 2004). The sampling procedure and methodology of this study are more complex than most studies of the student voice in science education and the age range of those studied is also much wider. The sample consisted of 1,058 children and young adults between the ages of 11 and 21. 600 interviews were conducted with school and college pupils (11-18), 159 with university students (up to the age of 21) and 299 with others between the ages of 16 and 21 and no longer in full-time education. The questionnaire is described as 'versioned' with 704 young people answering the section on science. Interviews, paper and on-line techniques of data collection were used as appropriate.

Although the study focused attention on science rather than science education, the views of students about the former are of some significance for the latter, not least because the young people questioned science and technology in a number of ways. The study identified four 'distinct constellations of values, or value sets' among the students. The first set, labelled 'Green', 'linked ethical concerns, the environment, and scepticism about interfering with nature'. This set was particularly associated with girls under the age of sixteen and with those who would be interested in a job in science. The second set, 'Techno-Investor', linked 'enthusiasm for investing in technology (especially space-related) and in science research, with beliefs about the beneficial effect of science and trust in both scientists and government'. The strong association here was with boys under sixteen and young men over this age and in the workforce. The third, 'Science-Oriented', value set reflected an 'interest in science programmes on television, and science fiction, and a belief that a "scientific way of thinking" can be applied widely'. This set was widely associated with boys over sixteen both in full-time education and in the workforce. The remaining set ('Alienated from Science') reflected 'boredom with science, and scepticism about its limitations'. Such views were associated with younger girls and with older females in the workforce who were not interested in a job related to science. The author of the Nestlé report concluded that

> Girls are not so much less interested in science than boys: almost exactly the same proportion of girls as boys -about a third- would be interested in jobs related to science. But girls focus on different things. (Haste 2004: 3)

She also concluded that the 'strong link for girls between 'green' values and being interested in a job related to science indicates that 'green' values, as outlined above, 'are not inherently anti-science'. In the words of a press release for the Nestlé study, 'Girls like their science with a conscience' (Nestlé Social Research Programme 2004: 1). A different typology has been developed by Schreiner using data collected in Norway as part of the Relevance of Science Education Project (see below). She uses the data to identify 'five Norwegian student types': the 'unselective enthusiast', the unselective reluctant, the unselective undecided, the selective girl and the selective boy. The differences lie in such features as the degree of commitment to schooling and advanced education, and support for, and interest in, science and school science (Schreiner 2006).

In June 2005, an Examination Authority in England, OCR, reported the results of a survey carried out between November 2004 and February 2005 of students' perceptions of science and science education. The specific research objectives were to gather student feedback on science topics 'for use in the enhancement and development' of science courses for 14-16 year olds and in 'Science related PR' (OCR 2005). Data were gathered by means of an on-line questionnaire from students aged 14, 15 and 16 'across a range of schools and…abilities'. 950 pupils from 12 schools took part in the study. Invited to 'tick all that apply' to their school science education', 66% 'had something positive to say', e.g., school science is 'interesting' (54%), 'fun' (14%), 'easy' (13%), 'exciting' (12%), or 'creative' (12%). However, over half (51%) also referred to their school science as 'boring' (31%), 'difficult' (22%) or 'confusing' (27%). As with the findings of other studies, biology appealed to both boys and girls, and girls had a lower level of interest in chemistry and especially in physics. Perhaps unsurprisingly, the study revealed a strong correlation between the perceived ease of a subject and students' enjoyment of it: more than 80% of those who said that they found chemistry, physics or biology easy also said they enjoyed these subjects. Over a quarter of the sample said that they didn't really like studying science at school, with a further 7% saying they hated doing so. Older pupils were generally less positive than their younger counterparts about studying science at school and boys were generally more positive than girls (*ibid*.: 6-10).

In February 2006, the industrial company Siemens reported the results of a survey undertaken as part of its Generation21 initiative (Siemens plc.: 2006). The survey involved 245 male and 258 female students aged between 16 and 18 in the UK and was designed to reveal the reasons for their choice of subjects to study at A-level, the examination commonly used in England, Wales and Northern Ireland to select candidates for entrance to university. The choices that students make at the end of compulsory schooling thus have major implications for possible future careers. The survey suggested that 70% of the students believed that it was harder to get an A-grade at A-level in science-based subjects than in so-called 'softer 'subjects and that, for 65% of the students, this greater level of difficulty in obtaining a high grade was an important factor in deciding whether or not to study a science subject. Other factors relevant to the students' choice were enjoyment of the subject at the lower GCSE level and whether or not they liked their subject teachers. One of the noteworthy features of the survey is the analysis of responses on a regional basis, with Scotland and Northern Ireland, for example, differing markedly from the rest of the UK in having a majority of students who did not think it harder to get an A grade in science subjects than in non-science subjects (Scotland 52%, Northern Ireland 55%).

Students' views about their schooling in England, rather than their science education in particular, emerged from a competition organised by the *Guardian* newspaper in which schools and individuals were invited to describe the school that they would like. This competition mirrored one organised in 1967 by the *Observer* newspaper in which the focus was exclusively on the secondary school. The later competition in

2001 offered three categories of entry, covering primary, lower secondary and upper secondary schooling. The focus was the future of schooling itself and the competition generated entries from over 1,500 schools and many hundreds of pupils. The responses took a variety of forms that included essays, photographs, pictures, stories, plays, designs, plans, poems and film and photography. The outcome is a rich archive which remains to be quarried with school science education in mind. The following examples relating to school science are drawn from Burke and Grosvenor (2003).

> The school I'd like would be situated in my own bedroom. Here there would be a telephone, a computer (or laptop) and a television where you could interact with your teacher…You would get your work from each of your subject teachers either weekly or monthly by email. For lessons such as Design technology and the Sciences, you would book a place by computer or telephone for the course you wanted to take. Then you would go to the local education research centre (a local laboratory)…Each week you would have to go on at least two courses to improve your science and Design technology skills…the lab. caters for physics, chemistry, biology and Design technology…you can do experiments…instead of just doing written work. (Boy, aged 16)
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> The school would be integrated into the wider community. The notion of writing prize-winning essays on tropical rain forests without taking some action would be seen as strange. (Boy, aged 17)
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> I think our school should look at plants and wildlife and nature…(Girl, primary age)

Research into what students might wish to be taught in their school science lessons has, for the most part, been confined to one or more 'snapshot' studies. Research, especially qualitative research, into how the student voice might change over time is much less common. A study undertaken by Dawson examined how the interests of 203 Year 7 (upper primary) students (92 boys, 111 girls) in 12 schools in South Australia had changed between 1980 and 1997 (Dawson 2000; see also Dawson 1981; Dawson and Bennett 1981). Using a 5-point Likert scale, Dawson invited students to express their opinions about each of 77 topics and 17 types of activities. The topics were chosen to represent various areas of science and to reflect those commonly taught internationally at the upper primary level. The list of activities were those likely to be found during the course of school science teaching and ranged from watching television programmes or videos about science to teacher talk. Dawson concluded that, although there had been some changes in the views of the students studied and boys continued to show a greater general level of interest in science topics than girls, there had been an overall decrease in interest on the part of both boys and girls. More specifically, boys' interest in topics drawn from the physical sciences had strengthened in the seventeen years that followed 1980, whereas that of the girls had remained constant.

The views of Australian students formed an element of a wide-ranging national study undertaken in November 1999 by Rennie and her colleagues on behalf of the Department of Employment, Training and Youth Affairs of the Australian Commonwealth Government (Goodrum *et al.* 2000; Rennie *et al.* 2001).The study involved both upper primary and secondary schools. In the former, 40% of students (n = 1,221) reported that they were 'often' or 'always' bored in their science lessons, a percentage that needs to be set alongside the 43% who were 'often' or 'always' excited. (Rennie *et al.* 2001: 475). At the lower secondary level (n = 2,802), the authors concluded that

> the science they are taught lacks relevance to their needs and interests and fails to develop key aspects of scientific literacy. Only about one fifth of lower secondary students report that science lessons are relevant or useful for them, very often or almost always. About one third of these students indicated that science never deals with things they are concerned about or helps them make decisions about their health (*ibid.*: 473).

The views of Australian students also formed an important element of the Science Class of Tomorrow (SCOT) project. The survey of student opinion of this electronically-based course illustrated the range of learning styles to be found within a class and raised a number of issues about the role of the teacher and the readiness of students to learn (Rennie and Edwards 2005).

In India, a study carried out by the National Council of Applied Economic Research on behalf of the Indian National Science Academy drew upon a sample of 345,000 respondents from rural and urban areas of the country. Despite some criticisms of the methodology, the main findings have not been disputed (IOSTE 2005). As in many other parts of the world, students' degree of satisfaction with their school science education declined with increasing age (from nearly two thirds of 11-14 year olds to 40% in the case of 16-18 year olds) but it should be noted that this is in a country with exceptionally high levels of unemployment among graduates and postgraduates in science.

One of the prominent features of research and policy in science education in recent years has been the emergence of large-scale international comparisons of the outcomes of schools science teaching. The best known examples are the Third[2] International Mathematics and Science Study (TIMSS) and the OECD Programme for International Student Assessment (PISA). The results of these international comparisons have been widely used by policy-makers, despite the methodological and other difficulties associated with international comparative research and the criticism to which such work is vulnerable (Shorrocks-Taylor and Jenkins 2000). The focus of these two studies is different. TIMSS has focussed attention on the curriculum as a broad explanatory factor underlying student achievement (Martin and Mullis 2000) whereas the emphasis in PISA is on the extent to which the education systems in the participating countries prepare students to become life long learners able to play constructive roles as citizens in society (Schleicher 2000)[3]. Science is the major domain[4] to be investigated in the PISA project in 2006 but it is interesting to note that the 2003 survey found no systematic differences between the performance of males and females on the science component of the test. The volume of data generated by

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[2] TIMSS is now known as the Trends in International Mathematics and Science Study. TIMSS surveys have been carried out in 1995, 1999 and 2003.

[3] For an attempt to compare the outcomes of TIMSS, PISA and the US National Assessment of Educational Progress, see http://nces.ed.gov/timss/

[4] The principal focus of the PISA study in 2000 was reading literacy. In 2003 it was mathematics.

these projects is immense and each prompts interesting, if sometimes difficult, questions about students' views of school science. In the case of the USA, for example, there were considerable discrepancies between, on the one hand, the beliefs of eighth grade students about how well they did in science and their generally positive attitudes towards school science and, on the other, their level of performance in TIMSS tests (Schmidt *et al.* 1999: 106). About 40% of these same students described their school science as 'boring', a figure that the researchers suggest may not be very different from that applicable to other countries involved in the TIMSS study (*ibid.*: 110). It is, of course, possible that a broadly similar response might be forthcoming when students are asked for their views about other subjects in the school curriculum such as mathematics, history, modern languages or geography. The 2003 PISA study reported, for example, that less than one third of the sample of 15 year old students in OECD countries looked forward to their mathematics lessons (PISA 2004: Table 3.1). What seems certain is that students' liking for a given subject in the school curriculum depends on many factors, including the age of the students' themselves. In Japan, for example, Ogura has found that the proportion of students who 'like the study of science' decreases from Grade 5 to Grade 7 and then remains at the same level until Grade 9 (Ogura 2003). From a study involving approximately 1,000 eight to eleven year-old students from 44 schools across Northern Ireland, Murphy and Beggs concluded that 'age is a more significant determinant than gender of primary children's attitudes to science and that these attitudes become less positive as the children reach the more senior primary classes (Murphy and Beggs 2003:115; see also, NFER/DfES 2004).

The international *Science and Scientists* (SAS) project, based at the University of Oslo, published its results in May 2000. Unlike TIMSS and PISA, the emphasis here was not on evaluating the outcomes of formal schooling but on the 'interests, experiences and perceptions of children in many countries that might be of relevance for the learning of science'. The study was an attempt to 'open up for critical discussion …how one might approach teaching and learning in science in a way that takes into consideration cultural diversity within one country as well as differences between countries and cultures' (Sjøberg 2000: 4). A further objective was described as 'networking and capacity building with a special focus on engaging female researchers from developing countries in joint research' (*ibid.*: 7). Some 30 researchers from 21 countries and over 9,000 children aged 13 were involved in a questionnaire-based study constructed around seven broad themes: The scientist as person, Out of school experiences/What I have done, Things to learn about, Importance for a future job, Science in action, Scientists at work and Me as a Scientist. Some elements of the questionnaire drew upon and developed earlier work, e.g., the 'Draw-a-Scientist' test (Chambers 1983; Matthews 1996) and an inventory of Out of School Experiences (Lie and Sjøberg 1984; Whyte 1986; Whyte *et al.* 1987). The results presented a number of paradoxes and surprises. For example, those from pupils in the Nordic countries often revealed greater gender differences (in enrolment, in attitudes and in achievement) than those from pupils elsewhere, despite the long-standing public commitment to gender equity in countries like Norway and Sweden (*ibid.*: 66). Likewise, Japanese pupils, despite scoring well on international tests of achievement such as TIMSS, judged school science to be more difficult than children in any other country participating in the SAS study (*ibid.*: 64). The SAS research instrument was used by Jones *et al.* in a survey of sixth grade students (n = 437) in five schools in the southeast of the USA. Significant gender differences were found with respect to each of the elements of the survey.

> Males reported more extracurricular experiences with a variety of tools…such as batteries, electric toys, fuses… Females reported more experiences with bread-making, knitting, sewing, and planting seeds. More male than female students indicated they were interested in atomic bombs, atoms, cars…whereas more females reported interest in animal communication, rainbows, healthy eating, weather and AIDS. [When asked about future jobs], males saw variables such as controlling other people, becoming famous, earning lots of money, and having a simple and easy job as important. Females, more than males, wanted to 'help other people'…..Significantly more females than males reported that science was difficult to understand, whereas more males reported that science was destructive and dangerous, as well as more 'suitable for boys' (Jones *et al.* 2000: 180).

Other studies that have explored the interaction of culture, gender and science include those by Backman (1997), Myrland (1997), Vazquez and Manassero (1997), Chunawala and Ladage (1998), Hjartardottir and Arnadottir (1998) and Gunnarsson *et al.* (2003), relating to Sweden, Norway, Spain, India and Iceland respectively.

The SAS study was an important precursor of the Relevance of Science Education Project (ROSE), also based at the University of Oslo. This later project rejects the notion of a school science and technology curriculum for all pupils that is 'universal and culture- free (or culture-neutral)' and seeks to 'provide empirical evidence and to stimulate theoretical discussions about priorities and alternatives in science and technology education' (Schreiner and Sjøberg 2004: 5). Data were obtained using a lengthy paper-based questionnaire, divided into sections with the following titles: What I want to learn about (3 sections 108 items), My future job (26 items), Me and the environmental challenges (18 items), My science classes (16 items), My opinions about science and technology (16 items), My out-of-school experiences (61 items) and Myself as a scientist (a free response item). The ROSE project is a large-scale international study, involving over 40,000 students aged about 15 and, at the time of writing, analysis of the data is ongoing. However, a number of country-specific (Alonso and Mas 2004: Ogawa and Shimode 2004); Teppo and Rannikmäe 2004; Jenkins and Nelson 2005; Trumper 2004; Lavonen *et al.*: 2005; Ogawa and Shimode 2004) and comparative reports (Schreiner and Sjøberg 2003; Busch 2005) and working papers have been published). These, together with a number of conference presentations, are available on or via the project website which is updated on a regular basis (http://www.ils.uio.no/forskning/rose/). The data published thus far show strong gender differences in the responses to many of the items in the ROSE questionnaire. Interestingly, many of the ROSE findings resonate with those of Jones *et al.* (*op.cit*) in the USA, despite the fact that the students in the latter study were about three years younger than those surveyed in the ROSE project.

The findings of the ROSE project also reveal that students in the developing world have markedly different views about many aspects of science and technology and the role that they can play in economic development. In many industrialized countries, students do not regard school science as opening their eyes to exciting jobs whereas the reverse is the case in developing countries. In the former, this may be a factor influencing students' choices of career, although it is clear that such choices are governed by many variables (Munro and Elsom 2000; Lyons 2003 and in press; Cleaves 2005).[5] Likewise, students in many industrialized countries judge school science to be less popular than other subjects, their counterparts in the developing world again expressing a contrary view. In both contexts, however, girls seem to dislike school science rather more than boys, although the gender differences vary considerably from one country to another (Sjøberg and Schreiner 2005). The clustering of differences in the responses to many of the ROSE items around the concepts of developed and developing countries, together with the generally more positive responses from students in the latter, is noteworthy. Since the school science curricula and teaching methods within the developed/industrialized countries are often markedly different, any explanation of students' reluctance to study the physical sciences, especially physics, beyond compulsory schooling in such countries may lie as much outside the school system as within it (Jenkins and Nelson 2005).

As noted above, the ROSE questionnaire includes a section entitled 'Me and the environmental challenges'. This consists of 18 statements about the environment with which the respondents are invited to agree or disagree using a 4-point Likert-type scale. The results suggest that, in all countries, boys are less concerned about the environment than girls, although all agree that it is important to 'care more' about environmental protection (Sjøberg and Schreiner 2005). Any country-specific or international findings from this section of the questionnaire (e.g.,Jenkins and Pell 2006) need to be considered alongside the outcomes of other research in environmental education. Such research, which includes much that can be categorised as the 'student voice', has burgeoned in the last twenty or so years and, perhaps unsurprisingly, is characterised by conceptual and methodological diversity. The field has been usefully and critically reviewed by Hart and Nolan (1999). The research that relates to students' views about the environment covers attitudes, beliefs, values and perceptions and much of the published work is quantitative and strongly positivist in nature. Researchers working within this tradition have typically focussed their attention on students' answers to questions about the environment or on students' environmental behaviour. The periodic Eurobarometer and National Science Board surveys are substantial sources of international data of this kind (National Science Board 2004: European Commisssion 2005a; 2005b; 2005c). More recent work has tended to be much more exploratory and less normative in nature, probing students' ideas, values and beliefs about a range of environmental issues. This has generated substantial insights into students' understanding of a range of environmental concepts, such as 'nature', the greenhouse effect, the ozone layer, radon, and endangered species. Significant insights are also available into the personal and cultural determinants of students' views about a range of environmental issues. Although the nature of the interaction of these determinants often remains elusive, the evidence suggests strongly that childhood experience is important in determining life-long attitudes, values and patterns of behaviour towards the environment (Hart and Nolan *op.cit.*; Chawla 1998; Palmer 1998 but see also EER 1999 for a critique).

Schreiner and Sjøberg (in press) have used the results of the responses from Norwegian students to a section of the ROSE questionnaire to explore how the

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[5] For a study of the influence of pupil perceptions on subject choice at 14+ in history and geography, see Adey and Biddulph 2001.

students think of their role, and that of others, when confronted with environmental issues. Do they agree, for example, that ‘Environmental problems make the future of the world look bleak and hopeless’ or that ‘Environmental problems are exaggerated’? Are they willing to make personal material sacrifices in order to help overcome environmental problems or do they believe that environmental problems should be left to the experts? In thus attempting, among much else, to characterise and conceptualise the hopes and vision of young people in Norway for the future with respect to the environment, they have drawn upon ideas relating to post-modern/youth culture in industrialized/ Western societies and tapped into an extensive literature that has not hitherto had much attention from science educators. If, as a number of sociologists have argued (e.g., Bauman 1995; 1998; Habermas 1981), such societies are characterised by, among much else, a prioritising of consumption over production and a colonisation of the cognitive and moral spheres of human life by the aesthetic realm, such features are unlikely to be without impact on the way in which young people perceive, and respond to, science and technology. As Lash (2001) has noted, any shift from cognition to perception heightens the importance of personal and social experience and diminishes the value to be attached to knowledge gained through the abstraction of judgement. Schreiner’s doctoral study (2006) is a notable exception to this general neglect of the sociological literature which, together with that relating to futures education (Lloyd and Wallace 2004), also features in a study by Schreiner, Henriksen and Hansen (2005) of how young people might be empowered to meet the challenges presented by climate change.

In almost all of the studies discussed above, data have been obtained by asking students to respond to questions prepared, piloted, finalised and presented in various forms by the researchers. A different methodological approach has been followed by Baram-Tsabari and Yarden who have sought to identify children’s ‘spontaneous interests’ by analysing the questions submitted by children to an Israeli cable television programme, broadcast 11 times weekly (Baram-Tsabari and Yarden 2005). The programme was first broadcast in August 2003 and, by early January 2004, over 3,100 questions had been collected in an e-mail database. Of these, 1,535 related to science and technology, falling into categories such as Animals, Health and Medicine, Earth and Space, Inventors and Inventions and ‘How stuff works’. Since some of the children’s queries embodied more than one question, the final sample consisted of 1,676 science and technology-related items, with most of the questions coming from children in the later years of elementary school and in the early years of the Junior High School (ages 9-12). The questions were categorised by field of interest and type of information requested, and whether or not they related to a specific motivation on the part of the child, e.g., How can I build my own Internet site?. The field of interest was dominated by biology (49.6% of the questions), followed by technology (25.0%), astrophysics (12.1%) and earth sciences (6.1%), with physics and chemistry accounting for 4.2% and 2.4 % respectively. Of the biological questions asked by the children, most (72%) were zoological and one quarter addressed issues in human biology. The field of interest was age-dependent, with older children showing less interest in zoology than in human biology and an increased interest in technology at the expense of biology. Physics proved surprisingly popular with the younger children in the study. Most of the questions asked by the children sought factual knowledge, with a little more than a quarter seeking explanations. Only 4% of the questions could be categorised as methodological, evidential or open-ended. In a later study, Baram-Tsabari *et al.* (2005) examined the 1,555 questions submitted by 1,167 grade 4-12 students (56.4% girls, 43.6% boys) to the MAD scientists network, operated by the Washington University in St.Louis (http://www.madsci.org). The authors report significant differences between spontaneous (n = 920) and school-related (n = 635) interests, with astrophysics featuring prominently among the former. Biology again proved more popular than other sciences (44% of the questions), followed by chemistry (21.9%) and physics (12.9%).The questions submitted to another internet site, *Scienzaonline* in Rome, have been studied by Falchetti, Caravita and Sperduti (2003). Those asking questions of the site were aged between 7 and 74, although the largest single group fell into the age range 20-30. Most of the questions were biological in nature and most were seeking information of a practical nature. Requests for opinions about controversial science-related issues are described by the authors as unexpectedly few in number. The authors concluded that 'relevance for everyday life seems to be the main motivation' of those contacting the Internet site.

DISCUSSION

How should science educators, policy makers or teachers respond to the various expressions of the student voice in science education? Any response to this question requires attention to a number of matters. Of fundamental importance are methodological issues, notably the general limitations of the different research methods that have been used to gather data, such as questionnaires, focus groups or interviews, and/or the techniques used to analyse and present the data obtained. These are discussed thoroughly in the relevant literature (e.g., Ary *et al.* 1996; Cohen *et al.* 2000; Robson 2002) and are not, therefore, rehearsed here, although particular attention is drawn to the debate in the literature that relates to the construction of Likert scales (e.g, Ray 1980; Weng 2004) and the manipulation of numerical data derived therefrom. The influence of research methodology and the rigour with which it is pursued on the confidence that can be placed in the data generated cannot be overlooked. Particular caution is needed when drawing inferences from quantitative data when the assumptions underlying the statistical techniques employed to generate that data may not be fully met.

It is also important to acknowledge that students do not 'speak' with a single voice. The diversity among students' views is well illustrated by the different 'value sets' referred to above (Haste 2004, although it is important to recognise that any components identified by a factor analysis of data obtained from questionnaires or other sources reflect clusters of opinions/beliefs/ values, not types of student. It is also illustrated by several findings from the ROSE project. For example, when students completing the ROSE questionnaire were asked for their views about a range of environmental issues and challenges, factor analysis of their responses revealed differences in their perception of the seriousness of the problems facing the environment, the extent to which they, rather than the experts, had responsibility for addressing them, and their willingness to make personal sacrifices to this end (Schreiner and Sjøberg 2003). There is some resonance here with what Christensen has distinguished as egocentric, anthropocentric and ecocentric attitudes towards the environment (Christensen 1991).

The student voice also changes throughout compulsory schooling. Too few explorations of the student voice in science education have had a genuinely longitudinal dimension, the work of Lindahl (2001; 2005) being a notable exception, together perhaps with that of Cleaves (2005) and the very different narrative provided by Reiss (2000). Many studies such as the Eurobarometer and National Science Board surveys simply report results obtained at different points in time. In what the authors described as a feasibility study, Stark and Gray invited pupils at different stages of schooling in Scotland (primary 4, primary 7 and secondary 2) to identify their preferences in a list of topics presented to them. The topics were drawn from three broad categories: Living things and the processes of life, Energy and forces, and Earth and Space. They reported that most girls preferred biological topics and that such topics became less popular with boys with increasing age (Stark and Gray 1999). If changes in the student voice throughout schooling are to more fully understood, research methodologies that are more complex, sensitive, qualitative and differently focused than those used thus far are required, and these will need to allow the salient issues to be identified and tracked over time. Until some of the outcomes of research of this kind are known, attempts to encourage more students to choose the physical sciences as subjects of advanced study seem likely to be at best hit and miss, and at worst, counterproductive.

It is clear that there is much that is positive in the data relating to the student voice in science education. For example, science is acknowledged as important by young people in both the developing and the developed world, and as bringing more benefits than disadvantages. That judgement, however, is inevitably coloured by what the students regard as science. This is by no means obvious and it calls into question the extent to which students can be said to be expressing an informed opinion or choice. Science now embraces many disciplines, from astrophysics to molecular biology, as well as others whose status, *qua* science, is more open to debate, e.g., medicine, psychology. Moreover, the word science has different connotations in different countries and, in some cases, the academic discipline is known by a different name from the school subject (Schreiner and Sjøberg 2004: 40). The judgement is also equally likely to be coloured by allying science with technology, with many students not being required to make a distinction between them, or failing to do so (Toussaint *et al.* 2001), and thereby highlighting the instrumental value of science and, by implication, of science education.

> I think science is really important because, for example, now in present days, we wouldn't be using washing machines because they were constructed by the scientists weren't they? I mean because when you use computers and well, it's a bit like technology – everything, everything with cars and trains, actually I think is related to science.
>
> It's [science has] led to a lot of discoveries that wouldn't have been discovered without science…technology and stuff like that…
> (Osborne and Collins 2000: 17)

In the case of both science and technology, students' perceptions are also likely to be strongly coloured by their experience of the school versions of these enterprises and these experiences are themselves likely to differ to different degrees. Such perceptions are also almost certainly gender-related.

The generally positive view of the role of science and technology in society stands in some contrast to the reluctance of sufficient numbers of young people in the developed world to pursue the study of science beyond the point where they are required to do so. Much more needs to be known about why this is so, especially in the case of those students who are particularly sympathetic to science but do not anticipate a science-related career (Ogawa and Shimode 2004; see also Häussler *et al.* 1998). To what extent, if at all, can such reluctance be attributed to school-based factors, such as the content of the science curriculum, the way science is taught and/or assessed and/or the alleged difficulty of the physical sciences as subjects of study? How are students' attitudes towards science related to success at school and what influences that success? How important are other factors such as the influence exerted by parents, students' peer groups within and outside school, or careers' advisers, and what is the nature and extent of their interaction? For an interview-based study of the interplay of factors such as self-perception with respect to science, students' occupational images of working scientists, their relationships with significant adults and their perceptions of school science in the formation of science choices during secondary schooling, see Cleaves (2005).

In addressing these and other questions related to student choice, it will be important to distinguish between the basic scientific disciplines. Most of the research that has been undertaken to identify students' views about aspects of their school science education has been done in terms of 'science' rather than of individual scientific disciplines, notably, physics, chemistry and biology. However, students have very different attitudes towards these disciplines and the differences are significant. Biology is always better liked, by both boys and girls, than chemistry or physics, the last of these being especially unpopular among girls. As Reiss's five year observation of more than 500 science lessons over a five year period in a secondary school reveals, students differentiate readily between the basic scientific disciplines and are clear about what they like and what they do not (Reiss 2000). They may also be more perceptive than is usually acknowledged about what their teachers think about teaching outside their area of professional subject expertise.

> Biology with you is O.K. Chemistry is fun. But you like physics don't you?
>
> The pupils soon judge which science you like. A colleague teaches physics but the pupils are very clear he doesn't like the subject, even though he teaches it pretty well. (Donnelly and Jenkins 1999: 16)

Boys and girls also have different views of the topics that they would like to learn about (Dawson 2000; Jenkins and Nelson 2005; OCR 2005; Sjøberg and Schreiner 2005; Jones *et al.* 2000). Although the views expressed in a range of studies fall well short of uniformity, there is a degree of commonality, differentiated by gender. In broad terms, biological, personal and health related issues are more popular with girls than with boys whose views tend to reflect a stronger interest in the technical and the violent/destructive.

One frequent complaint voiced by students in those countries where the research has been done is that the school science curriculum is overloaded with content, a complaint sometimes echoed by those who teach them (Millar and Osborne 1998; Osborne and Collins 2000). It is also a complaint that seems to have been commonly and uncritically accepted as valid. As Donnelly as remarked, it is easy to forget, when reading references to an overemphasis on scientific content, that ‘one is dealing here with probably the greatest intellectual and material development of humankind’ and one that presents significant intellectual challenges (Donnelly 2005: 304). Given this, it is interesting to note the finding that difficulty may not necessarily be a barrier to enjoyment of science at school: 42% of students in a survey in England admitted enjoying biology even though they found it difficult: the corresponding percentages for physics and chemistry are 28% and 32% respectively (OCR 2005: 13).Equally easy to overlook is the fact that complaining about an overloaded school science curriculum has a long history. It has proved remarkably resilient in the face of profound changes in curriculum content (most often involving a reduction) and in assessment techniques, coupled, in some countries, with major reorganisations of the pattern of schooling that have led to more students studying more science than at any time in the past.[6]

Students’ complaints about overloading of the school science curriculum are frequently allied with significant levels of dissatisfaction about the relevance of much of that content. When Jarman and McAleese (1996) asked 15 year old pupils in Northern Ireland when they used their school science in their everyday lives, the question seemed to puzzle them and led many to answer in terms of wiring an electrical plug. Claims of this kind can be placed in a wider context by contrasting them with Haste’s finding that 35% of her sample of young people aged 11-21 expressed disagreement (disagreed or disagreed strongly) with the statement that ‘science is largely irrelevant to my everyday life’: interestingly, a further 31% neither agreed or disagreed with the same statement (Haste *op.cit.*: 6). One underlying difficulty here is the perspective from which relevance is to be judged. Reiss has suggested that some science educators simply misunderstand what is required. Citing a study undertaken in a pseudonymous rural ‘Owens County’ in the USA, he notes how the teachers tried to relate science to the everyday life of their students.

> For example, during one lesson the fifth-grade teacher illustrated principles of motion through a kickball demonstration. A third-grade instructor had students conjecture about how simple acts like obtaining water would be different if performed on the moon rather than in Owens County. (Reiss 2000: 145, quoting Charron 1991: 683)

Reiss acknowledges that the argument for such teaching is that, when it is done well, ‘it stretches the mind, fascinates, intrigues and provides new insights into the workings of the physical universe’. However, as he drily observes, ‘ I am confident that even a richly developed understanding of how to obtain water on the Moon will be of little practical relevance to most of the future citizens of Owens County’ (*idem*). For some with an interest in the educational function of science, stretching the mind, fascination, intrigue and new insights into the physical world might be thought to be the central purpose of school science education. However, reconciling such a purpose with presenting science in a way that at least a majority of students is likely to see as of practical significance in their everyday lives is by no means a straightforward undertaking. One response to the challenge would be to construct a science

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[6] In the case of England, such a complaint also needs to be reconciled with the steadily increasing pass rates in the sciences in public examinations, itself a matter of a rather different complaint.

curriculum based upon students' expressed interests and thereby build a community of learners from which scientific ideas emerge for discussion and learning (Gallas 1995: see also Häussler and Hoffmann 2000). Another might be to devise a suite of science courses that accommodates diversity and choice, as in the*21st Century Science* project in the UK (Hunt 2003), a curriculum innovation that advertises 'genuine choice for the diversity of students' interests and aspirations' (http://www.21stcenturyscience.org/home). A third possibility, reflected in the variety of curriculum initiatives embraced by the very diverse Science-Technology-Society (STS) movement and often directed at 'citizenship' or 'social responsibility', prioritises the social relations of science among the educational functions of school science (Cross and Price 1992; Solomon and Aikenhead 1994). Yet another way forward might be to develop better links between science in the context of formal schooling and the so-called 'free-choice science education' offered by science centres, museums, the print and broadcast media and the Internet (Falk 2001). For some feminist scholars, however, responding satisfactorily to the student voice requires the transformation not only of school science but of science itself, since the latter is categorised as a 'masculine' construct in need of fundamental reform (Harding 1991; Rose 1994)

Perhaps surprisingly, some attempts to make science school curricula more appealing to students by making them more 'relevant' seem to have given little or no attention to the findings of the substantial body of research that sheds light on how adults actually relate to science and use scientific knowledge (Irwin 1995; Irwin and Wynne 1996; Layton *et al.* 1993; Jenkins 1997), although Aikenhead's study with respect to nurses should be noted (Aikenhead 2005). Such research reveals that the interaction of adult citizens with science is rarely, if ever, narrowly cognitive. In addition, such citizens regard scientific knowledge as much as a resource for the construction and maintenance of personal identity as an external instrumentality for understanding and manipulating the material world. Also ignored has been research that explores the relationship between scientific knowledge and praxis (Layton 1991; 1993; Barton 2002; Roth and Désautels 2002) and more generally between knowledge and action (Aitken 1985; Vincenti 1993).The implications for school science education of findings in both these fields need much more attention than they have so far received

Attention might also be directed usefully at the implications of findings about the student voice in science education for the rapidly expanding[7] programme of research into 'informal science education', i.e., the learning of science that takes places outside the context provided by schools, colleges and universities. One of the distinguishing features of such learning is the emphasis on self-motivation derived from learners' needs and interests (Dierking *et al.* 2003).

Evidence that many students also dislike the way much of the content is presented at school is available from several of the studies reported above. The broad messages seem to be that students dislike such activities as the repeated presentation of scientific topics and the dictating or copying of notes. They want their school science courses to be more relevant to everyday life, to include more practical/hand-on

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[7] The American Educational Research Association has an Informal Learning Environments Research Special Interest Group and *Science Education* devotes a section of each issue to this field. The National Association of Research in Science Teaching (NARST) issued a policy statement on 'Informal Science Education' in 2003.

activities, to give more attention to contemporary science-related issues, and to provide greater opportunity for discussion and participation. However, there is ample room for ambiguity in these student responses (Kinchin 2005) and the broad messages need to be treated with a degree of caution. They are sensitive to age, to gender, to student ability and to the cultural and linguistic diversity found in multi-cultural communities (Levy *et al.* 1997). Campbell, using data derived from questionnaires and semi-structured interviews, has reported that 'the most mentioned negative factor in learning science' by a small sample (n = 26) of primary and secondary school students in England was writing.

> We hate writing.
> Writing things up: that's what we do not like.
> That's definitely what we don't like (Campbell 2001: 127)

However, there is also evidence that older (Year 11) students are more likely than their younger counterparts to acknowledge that 'taking notes from the teacher can be effective' (OCR 2005: 7). Similarly, girls express less enthusiasm than boys for autonomous learning styles such as taking notes from books, reading textbooks or researching using the Internet (*ibid.*: 23). Pell and Jarvis in a study of primary school pupils' attitudes towards learning science in England reported that while the pupils were 'clear about the tasks, activities and teaching styles that they preferred in science', there were 'some striking differences in the choices expressed by pupils in higher and lower ability groups' (Pell and Jarvis quoted in Flutter and Rudduck 2004: 35). Flutter and Rudduck, drawing upon a study of secondary school pupils undertaken as part of the ESRC *Consulting Pupils Project*, noted that:

> higher attaining pupils expressed strong preferences for things like practical work and discussion in science lessons whereas it was only the lower attaining pupils (both boys and girls) who mentioned the use of textbooks in science as being enjoyable. It was also noted that lower attaining pupils liked to carry out their own projects in science (Flutter and Rudduck: 36).

The broad messages may also disguise other preferences. For example, the OCR study referred to above suggested that the popularity among students of doing a science experiment in class (defined, unprompted, as the 'best thing' about learning science at school) may have owed rather less to its intrinsic merit as a means of promoting learning than to its potential as a 'fun factor' (*idem*). As for the expressed wish for more discussion in science lessons, good science teachers have always invited pupils to discuss such matters as the possible design of an experiment or the apparatus with which to conduct it, or the best way to obtain, present or interpret results. Such teachers have also gone frequently beyond the science itself to discuss with their students the applications or implications of some of the scientific concepts or data under consideration and to relate these to everyday life. Moreover, the use of language to explore scientific ideas is a key element of the so-called constructivist approach to science teaching (e.g., Driver *et al.* 1994) and there is now a substantial body of research that illustrates the important role that language plays in the development of understanding (e.g., Lemke 1990; Duschl and Osborne 2002; Mortimer and Scott 2003). However, it cannot be assumed that those students who urge more discussion in their science lessons are also willing to make the intellectual effort necessary to ensure that any such discussion is well-informed and grounded in the relevant science. In addition, the manner in which some students articulate their wish for more discussion in science lessons may hint at something more fundamental than a reformed approach to teaching science, namely a challenge to the authority and standing of science itself. From this perspective, some elements of the student voice can be seen as a particular manifestation of broader intellectual changes captured by such terms as post-modernism and constructivism and the associated rejection of a number of traditional Enlightenment values and assumptions. If there is no universal scientific truth, only a variety of truths from which one should be free to pick and choose, why should science teachers' opinions carry any more weight than those of parents, students or organisations seeking to press a particular political and/or religious agenda? If the dangers of such an intellectual position seem obvious or far removed from the pressing everyday concerns of most science teachers, they remain the source of vigorous controversy (e.g., Gross and Levitt 1994; Sokal and Bricmont 1999) and are not without serious consequences in some countries (Matthews 1998; Dembski 1999; Nanda 2003; Shanks 2004; Hongladarom 2005). As Donnelly (2005: 305) has remarked, there is an important debate to be had about the issues implicit in the view that pupils in their science lessons 'should be asked to put forward [their] own theories instead of being told what is right' (Planet Science *et al.*: 9).[8]

Every science teacher is likely to be aware that students have views about how their work is assessed. Fensham has explored the opinions of a small sample of Australian students in their final year of schooling about the tests used in TIMSS. He has reported that 'almost all students expressed a 'clear preference for multiple choice items' in tests and examination in science, although the reasons given for the preferences varied considerably (Fensham 1998: 486). In general, however, students' views about assessment have received much less attention than other aspects of their school science education.

One of the most consistent messages to emerge from research concerned with the student voice in science education relates to gender. Whether in terms of what they would like to learn, of how they prefer to be taught or assessed, of their attitudes towards science and technology, of what they regard as important in their future employment or how they perceive teachers deal with them, there are significant differences in the views of most boys and girls. While it is important not to overlook the diversity to be found within either group (Brickhouse *et al.* 2000), these differences prompt the question of whether a common science curriculum and/or pedagogy can best meet the needs of both boys and girls. While the dangers of a science curriculum differentiated by gender are obvious, the data suggest that it is

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[8] It would be a step too far to argue that the student voice has been a major determinant of recent curriculum initiatives such as *ChemCom* in the USA, *21st Century Science* in the UK or the various reforms encompassed by the *STS* movement. The principal impulses have been the need to promote scientific literacy, to devise curricula that give attention to the role that science and technology have come to play in society and to respond to the needs of the majority of students who will not pursue the study of science beyond compulsory schooling (Fensham 2000; Hargittai 2000; van Berkel 2005) Nonetheless, all initiatives of this kind require students to engage in discussion of a range of important socio-political issues that may be local, regional, national or international.

perhaps time to examine whether a commitment to gender equity might be better met by such an approach.

Another consistent message emerges from those studies that have given some attention to students' views about their future careers. As long ago as 1969, Musgrove and Batcock showed that one third of a sample of 338 undergraduate science/engineering students had made up their minds about their choice of career by the age of 12 and had remained committed to their decision (Musgrove and Batcock 1969). Some of the responses to the ROSE questionnaire in England show that most students aged 15 had firm views about whether or not they wished to pursue a science- or –technology-related career, although, once again, the findings are strongly gender–related. The evidence that the later years of primary schooling are important in helping to form children's interest in, and attitudes towards, possible careers in science and technology is now strong (Ormerod and Duckworth 1975; Blatchford 1992; Pell and Jarvis 2001, Reid 2003). The policy implications of such evidence, however, may not be quite as straightforward as they may appear, since at least one study shows that both boys' and girls' enthusiasm declines progressively with age throughout primary schooling alongside a similar decline in their perception that science is difficult (Pell and Jarvis 2001). In addition, as noted above, students' choices of subject for advanced study are governed by a set of factors that interact in ways that are complex and, for the most part, ill-understood.

Finally, what might research into the student voice have specifically to say to those teaching science in schools? There is evidence to suggest that consulting students about their perceptions of science and their school science education can enhance their motivation and contribute to the development of a wider range of teaching strategies and, thereby, to raising the levels of student attainment in science (Flutter and Rudduck 2004, especially pp.34-7; CUREE 2006)

> If he asked more questions then we'd become more alert instead of just sitting there like, just listening to him all the time (McIntyre *et al.* 2005: 153)
>
> The opportunity to get some insights into pupils' thoughts about lessons has been fascinating…you become aware that some of them have more positive attitudes towards learning than is necessarily apparent…it's made me aware that I've got into a kind of routine way of working and it isn't necessarily the routine that they would want (*ibid.*: 163)

The same evidence suggests that such consultation requires clear objectives and a willingness to engage students as genuine partners in the teaching-learning process. For Fielding, this partnership involves working with students as co-researchers and using the findings to promote a 'dialogic learning community' (Fielding 2001: 137). While he describes his approach as transformative and radical, there seems little room for doubt that both students and teachers have much to learn from exploring jointly and constructively the task in which they are mutually engaged. As McIntyre *et al.* have shown, teachers tend to respond positively and to be reassured by the insightfulness of pupils' views about teaching and learning, even when they find some of these views uncomfortable (McIntyre *et al. op.cit.*).

REFERENCES

ADEY, K. and BIDDULPH, M. 2001. The influence of pupil perceptions on subject choices at 14+ in geography and history, *Educational Studies,* 27 (4), 439-450.

AITKEN, H.G. 1985. *Syntony and Spark. The origins of radio*, Princeton, NJ, Princeton University Press.

AIKENHEAD, G.S. 2005. Science-based occupations and the science curriculum: concepts of evidence, *Science Education*, 89 (2), 242-75.

ALONSO, A.V. and MAS, M.A.M. 2004. *Young pupil's views on the environmental challenges from the Spanish ROSE data.* Paper presented to the IOSTE XI Conference, Lublin, July 2004 (available at http://www.ils.uio.no/forskning/rose)

ANGELL,C., GUTTERSRUD, Ø., HENRIKSEN, E.K. and ANDERS, I. 2004. Physics: Frightful but fun. Pupils' and teachers' view of physics and physics teaching, *Science Education*, 88 (5), 683-706.

ARNOT, M., McINTYRE, D., PEDDER, D. and REAY, D. (2003). *Consultation in the Classroom; Developing Dialogue about Teaching and Learning*. Cambridge, Pearson publishing.

ARY, D, JACOBS, L.C. and RAZAVIEH, A. 1996. *Introduction to Research in Education*, Fort Worth, Harcourt Brace.

BACKMAN, P. 1997. *Flickor, pojkar och naturvetenskap.* Unpublished dissertation, Midthogskolan, Harnonsand, Sweden.

BARAM-TSABARI, A. and YARDEN, A. 2005. Characterizing children's spontaneous interests in science and technology, *International Journal of Science Education*, 27 (7), 803-26.

BARAM-TSABARI, A., SETHI, R.J., BRY, L. and YARDEN, A. 2005. *Students' spontaneous and school-related interests in science and technology*. Paper presented at the ESERA conference, Barcelona, August 2005.

BARMAN, C.R. 1996. How do students really view science and scientists? *Science and Children*, September, 30-33.

BARTON, A.C. 2002. Urban Science Education Studies: A Commitment to Equity, Social Justice and a Sense of Place, *Studies in Science Education*, 38, 1-38.

BAUMAN, Z. 1995. *Life in Fragments. Essays in Postmodern Morality*, Oxford, Blackwell.

BAUMAN. Z. 1998. *Work, Consumerism and the New Poor*, Buckingham, Open University Press.

BENNETT, J. 2001. Science with attitude: the perennial issues of pupils' responses to science, *School Science Review,* 82 (300), 59-67.

BLATCHFORD, P. 1992. Children's attitudes to work at 11 years, *Educational Studies,* 18, 107-18.

BOUD, D.J. 1973. The laboratory aims questionnaire – a new method for course improvement? *Higher Education,* 2, 81-94.

BOUD, D.J., DUNN, J., KENNEDY, T. and THORLEY, R. 1980. The aims of science laboratory courses: a survey of students, graduates and practising scientists, *European Journal of Science Education*, 2, 415-28.

BOYER, R. and TIBERGHIEN, A. 1989. The aims of science laboratory courses: a survey of students, graduates and practising scientists, *European Journal of Science Education*, 11, 297-308.

BRANSCOMBE, A., GOSWAMI, J. and SCHWARTZ, J. 1992. *Students Teaching, Teachers Learning*, Portsmouth NH, Boynton/Cook.

BRICKHOUSE, N.W., LOWERY, P. and SCHULTZ, K. 2000. What kind of girl does science? The construction of school science identities, *Journal of Research in Science Teaching,* 37 (5), 444-58.

BURKE, C. and GROSVENOR, I. 2003.*The School I'd Like*, London, Routledge-Falmer.

BUSCH, H. 2005. Is science education relevant? *Europhysics News,* 5, September/October, 192-7.

CAMPBELL, R. 2001. Pupils' perceptions of science education at primary and secondary school. In: H. Berendt, Dahncke, H., Duit, R., W.Gräber, M. Komorek and A. Kross (Eds.), *Research in Science Education- Past, Present and Future,* Dordrecht, Kluwer, 125-30.

CHAMBERS, D.W. 1983. Stereotypic images of scientists: the Draw-a-Scientist-Test. *Science Education*, 67, 255-65.

CHARRON, E.H. 1991. Classroom and community influences on youths' perceptions of science in a rural county school system, *Journal of Research in Science Teaching*, 28, 671-87.

CHAWLA, L. 1998. Significant life experiences revisited. A review of research on sources of environmental sensitivity, *Journal of environmental* education 29 (3) 11-21.

CHRISTENSEN, C. 1991. Views of nature in environmental education, *ENSI-NEWS,* 2, Paris, OECD/CERI, 10-15.

CHUNAWALA, S. and LADAGE, S. 1998. *Students' ideas about science and scientists*, Mumbai, India, Homi Bhabha Centre for Science Education.

CLEAVES, A. 2005. The formation of science choices in secondary school, *International Journal of Science Education*, 27 (4), 471-86.

COHEN, L., MANION, L. and MORRISON,K. 2000. *Research Methods in Education.* London, Routledge Falmer.

COOK-SATHER, A. 2005. Authorizing Students' Perspectives: Toward Trust, Dialogue, and Change in Education, available at http://www.aera.net/pubs/er/pdf/vol31AERA310402.pdf. or via googlescholar.

CROSS, R. T. and PRICE, R.F. 1992. *Teaching Science for Social Responsibility*, Sydney, St.Louis Press.

CUREE (Centre for the Use of Research and Evidence in Education) 2006. *Pupil Voice: what might we learn from our students?* Bulletin No. 5, http://www.nerf-uk.org/bulletin (accessed January 2006).

DAWSON, C. 1981. What science would Year 7 students like to study? Some questions, answers and differences, *South Australian Science Teachers' Journal,* December, 13-17.

DAWSON, C. 2000. Upper primary boys' and girls' interests in science: Have they changed since 1980? *International Journal of Science Education*, 22 (6), 557-70.

DAWSON, C. and BENNETT, N. 1981. What do they say they want? Year 7 students' preferences in science, *Research in Science Education*, 11, 193-201.

DEMBSKI, W.A. 1999. *Intelligent Design: The bridge between science and theology*, Downers Grove, ILL., Intervarsity Press.

DENNY, M. and CHENNELL, F. 1986. Science practicals: what do pupils think? *European Journal of Science Education,*8, 325-36.

DIERKING, L.D., FALK, J.D., RENNIE, L., ANDERSON, D. and ELLENBOGEN, K. 2003. Policy statement of the "Informal Science Education" Ad Hoc Committee, *Journal of Research in Science Teaching*, 40 92), 108-11.

DONNELLY, J. F. 2005. Reforming science in the school curriculum: a critical analysis, *Oxford Review of Education*, 31 (2), 293-309.

DONNELLY, J.F. and JENKINS, E.W. 1999. *The Expertise and Deployment of Science Teachers at Key stage 4*, Leeds, Centre for Studies in Science and Mathematics Education, University of Leeds.

DRIVER, R., ASOKO, H., LEACH, J., MORTIMER, E. and SCOTT, P. 1994. Constructing scientific knowledge in the classroom, *Educational Researcher,* 23 (4), 5-12.

DRIVER, R., LEACH, J., MILLAR, R, and SCOTT, P. 1996. *Young People's Images of Science*, Buckingham, Open University Press.

DUIT, R. 2004. *Students' and Teachers' Conceptions and Science Education: A bibliography*. Available at http://www.ipn.uni-kiel.de/aktuell/stcse/stcse.html

DUSCHL, R.A. and OSBORNE, J. 2002. Supporting and Promoting Argumentation Discourse in Science Education, *Studies in Science Education*, 38, 39-72.

EER 1999. Critical Commentaries on Significant Life experience, *Environmental Education Research*, *Special Issue*, 5 (4) *passim.*

ESRC 2004 *Consulting pupils about teaching and learning: an ESRC network project* (http://consultingpupils.co.uk)

EUROPEAN COMMISSION 2004. *Europe Needs More Scientists: Report by the High Level Group on Increasing Human Resources for Science and Technology in Europe*, Brussels, European Commission, Directorate C.

EUROPEAN COMMISSION 2005a. *The attitude of European Citizens towards the Environment,* Brussels, Directorate for General Research, Special Eurobarometer, 217.

EUROPEAN COMMISSION 2005b. *Europeans, Science and Technology*, Brussels, Directorate for General Research, Special Eurobarometer no. 224.

EUROPEAN COMMISSION 2005c. *Social Values, Science and Technology*, Brussels, Directorate for General Research, Special Eurobarometer no. 225.

FALCHETTI, E., CARAVITA, S. and SPERDUTI, A. 2003. *What lay people want to know from scientists: An analysis of the data base of 'Scienzaonline'*. Paper presented at the 4th ESERA Conference, Noordwijkerhout, The Netherlands, 19-23rd August.

FALK, J.H. (Ed.) 2001. *Free-Choice Science education. How we learn Science Outside of School*, New York, Teachers College Press.

FENSHAM, P.J. 1998. Students' response to the TIMSS tests, *Research in Science Education*, 28 (4), 481-9.

FENSHAM, P.J. 2000. Providing suitable content in the 'science for all' curriculum. In R.Millar *et al.* (Eds.) *Improving Science Education; The contribution of research*, Buckingham, Open University press, 147-65.

FIELDING, M. 2001. Students as radical agents of change, *Journal of educational change*, 2, (2) 123-41.

FIELDING, M. 2004a. Transformative approaches to student voice: theoretical underpinnings, recalcitrant realities, *British Educational Research Journal,* 30 (2), 295-311.

FIELDING, M. 2004b. 'New Wave' student voice and the renewal of civic society, *London Review of Education,* 2 (3), 197-217.

FLETCHER, A. 2003. *Meaningful Student Involvement: Resource Guide,* (www.soundout.org)

FLUTTER, J. and RUDDUCK, J. (2004). *Consulting pupils: What's in it for schools?* London, RoutledgeFalmer.

FRASER, .J. and TOBIN, K.G. (Eds.) 1998. *International Handbook of Science Education*, Dordrecht, Kluwer.

GALLAS, K. 1995. *Talking their way into science: hearing children's questions and theories, responding with curricula*, New York, Teachers College Press.

GOODRUM, D., HACKLING, M. and RENNIE, L. 2000. *The Status and Quality of the Teaching and Learning of Science in Australian schools: A Research Report,* Canberra, Department of Education, Training and Youth Affairs.

GROSS, P.R. and LEVITT, N. 1994. *Higher Superstition. The academic left and its quarrels with science*, Baltimore, Johns Hopkins University Press.

GUNNARSON, G.H., HARALDSSON, H. and STEFÁNSSON, K.K. 2003. *The Relevance of Science Education in Iceland*, accessible at http://www.ils.uio.no/forskning/rose/

HABERMAS, J. 1981. Modernity versus Postmodernity¸ *New German Critique,* 26, 13-30.

HARDING, S. 1991. *Whose science? Whose knowledge? Thinking from women's lives*, Ithaca, NY, Cornell University Press.

HARGITTAI, I. 2000. *Conversations with Famous Chemists*, London, Imperial College Press.

HART, P. and NOLAN, K. 1999. A critical analysis of research in environmental education, *Studies in Science Education*, 34, 1-69.

HASTE, H. 2004. *Science in my Future: A study of values and beliefs in relation to science and technology among 11-21 year olds*, London, Nestlé Social Research programme.

HÄUSSLER, P. 1987. Measuring students' interest in physics – design and results of a cross-sectional study in the Federal Republic of Germany, *International Journal of Science Education*, 9 (1) 79-92.

HÄUSSLER, P., HOFFMANN, L., LANGEHEINE, R., ROST, J., SIEVERS, K. 1998. A typology of students' interest in physics and the distribution of gender and age within each type, *International Journal of Science Education,* 20 (2), 223-38.

HÄUSSLER, P. and HOFFMANN, L. 2000. A curricular frame for physics education: development, comparison with students' interests, and impact on students' achievement and self-concept, *Science Education*, 84 (6), 689-705.

HJARTARDOTTIR, G. and ARNADOTTIR, M. 1998. *Visindi og visindinmenn - kynin og visindin.* Unpublished dissertation, University of Akueyri, Akueyri, Iceland.

HODSON, D. 1993. Rethinking old ways: Towards a more critical approach to practical work in school science, *Studies in Science Education*,22, 85-142.

HOFSTEIN, A., MANDLER, V., BEN-ZVI, R. and SAMUEL, D. 1980. Teaching objectives in chemistry: a comparison of teachers' and students' priorities, *European Journal of Science Education*, 2, 61-66.

HONGLADAROM, S. 2005. The Science War in Thailand: Clashes between traditional and modernized belief systems in the Thai Media, *Pantaneto Forum* 21 (http://www. Pantaneto.co.uk).

HOUSE OF COMMONS SELECT COMMITTEE ON SCIENCE AND TECHNOLOGY 2002. *Science Education from 14-19: third report of session 2001-02. Volume 1: Report and Proceedings of the Committee*, London, The Stationery Office.

HUNT, A. 2003. 21st century science: a new flexible model for GCSE science, *School Science Review,* 85 (310), 27-34.

IOSTE 2005. *Newsletter*, 8 (2), December 2005, 9-10.

IRWIN, A. 1995. *Citizen science. A study of people, expertise and sustainable development*, London, Routledge.

IRWIN.A. and WYNNE, B. (Eds.) 1996. *Misunderstanding science? The public reconstruction of science and technology*, Cambridge, Cambridge University Press.

JARMAN, R. and McALEESE, L. 1996. A survey of children's reported use of school science in their everyday lives, *Research in Education*, 55, 1-16.

JENKINS, E.W. 1997. Scientific and Technological Literacy for Citizenship: What can we learn from research and other evidence? In: S.Sjøberg and E.Kallerud (Eds.), *Science, Technology and Citizenship. The Public Understanding of Science and Technology in Science Education and Research Policy,* Oslo, Norsk Institut for studier av forskning og utdanning, 29-50.

JENKINS, E.W. and NELSON, N.W. 2005. Important but not for me: students' attitudes towards secondary school science in England, *Research in Science and Technological Education*, 23 (1) 41-57.

JENKINS, E.W. and PELL, R.G. 2006. Me and the environmental challenges: a survey of English secondary school students' attitudes towards the environment, *International Journal of Science Education* (forthcoming)

JONES, M.G., HOWE, A. and RUA, M.J. 2000. Gender differences in students' experiences, interests and attitudes towards science and scientists, *Science Education*, 84 (2) 180-192.

KANG, S., SCHARMANN, L.C. and NOH, T. 2004. Examining students' views on the nature of science: Results from Korean 6th, 8th and 10th graders, *Science Education,* 89, 314-44.

KERR, J.F. 1963. *Practical Work in School Science: An account of an inquiry sponsored by the Gulbenkian Foundation into the nature and purpose of practical work in school science in England and Wales*, Leicester, Leicester University Press.

KINCHIN, I. 2004. Investigating students' beliefs about their preferred role as learners, *Educational Research,* 46 (3), 301-12.

KINCHIN, I. 2005. Personal opinion: Let's agree on some basic definitions, *School Science Review*, 87 (318), 6-8.

KUSHMAN, J. (Ed.) 1997. *Look Who's Talking Now: Student Views of Learning in Restructuring Schools*, Portland OR, North West Regional Laboratory.

LASH, S. 2001. Technological forms of life, *Theory, Culture and Society,* 18 (1), 105-20.

LAVONEN, J., JUUTI, K., UITTO, A., MEISALO, V. and BYMAN, R. 2005. *Attractiveness of Science Education in the Finnish Comprehensive School,* Helsinki, Department of Applied Sciences of Education, University of Helsinki.

LAYTON, D. 1991. Science Education and Praxis: the relationship of school science to practical action, *Studies in Science Education*, 19, 43-79.

LAYTON, D. 1993. Science Education and Praxis: the relationship of school science to practical action. In E.W.Jenkins (Ed.)*, School Science and Technology: Some issues and perspectives*, Leeds, Centre for Studies in Science and Mathematics Education, University of Leeds, 118-159.

LAYTON, D., JENKINS, E.W., MacGILL, S. and DAVEY, A. 1993. *Inarticulate Science? Perspectives on the public understanding of science and some implications for science education*, Driffield, Studies in Education.

LEDERMAN, N.G. 1992. Students' and teachers' conceptions of the nature of science: a review of research, *Journal of Research in Science Teaching,* 29 (4) 331-59.

LEGGETT, M., KINNEAR, A., BOYCE, M. and BENNETT, I. 2004. Student and staff perceptions of the importance of generic skills in science, *Higher Education Research and Development*, 23 (3),295-312.

LEMKE, J. 1990. *Talking science: Language, learning and values*, Norwood, NJ, Ablex.

LENSMIRE, T.J. 1998. Rewriting student voice, *Journal of Curriculum Studies*, 30 (3), 261-91.

LEVY, J., WUBBELS, T., BREKELMAN, M. and MORGANFIELD, B. 1997. Language and cultural factors in students' perceptions of teacher communication style, *Journal of Intercultural Relations,* 21 (1), 29-55.

LIE, S. and SJǾBERG, S. 1984. I "Myke" jenter i "harde" fag? (Soft girls in hard science?), Oslo, Universitetsforlaget.

LINDAHL, B. 2001. Feeling for science? About pupils' attitudes to science. In D. Psillos, P. Kariotoglou, V. Tselfes, G. Bisdikian, G. Fassoulopoulos, E. Hatzikraniotis & M. Kallery (Eds.), *Science Education Research in the Knowledge Based Society: Proceedings of the Third ESERA Conference, 2 vols.* (Thessaloniki, ESERA/University of Thessaloniki), 733-5.

LINDAHL, B. 2005. *A longitudinal study about students' attitudes to science.* Paper presented to the ESERA Conference, Barcelona, August-September 2005.

LLOYD, D. and WALLACE, J. 2004. Imaging the future of science education: the case for making futures studies explicit in student learning, *Studies in Science Education*, 40, 139-78.

LLOYD-SMITH and TARR, J. 2000. Researching children's perspectives: A sociological dimension. In A. Lewis and G. Lindsay (Eds.), *Researching Children's Perspectives*, Buckingham, Open University Press 59-70.

LYNCH, P.P. and NDYETABURA, V.L. 1983. Practical work in schools: an examination of teachers' stated aims and the influence of practical work according to students, *Journal of Research in science Teaching*, 20, 663-71.

LYONS, T. 2003. *Decisions by science proficient Year 10 students about post-compulsory high school science enrolment. A socio-cultural exploration.* Ph.D. thesis, University of New England, Australia.

LYONS, T. (in press). The puzzle of falling enrolment in physics and chemistry courses: Putting some pieces together, *Research in Education*.

MacBEATH, J., DEMETRIOU, H., RUDDUCK, J. and MYERS, K. (2003).*Consulting Pupils: A Toolkit for Teachers*, Cambridge, Pearson publishing.

McINTYRE, D., PEDDER, D. and RUDDUCK, J. 2005. Pupil Voice: comfortable and uncomfortable learnings for teachers, *Research Papers in Education,* 20 (2), 149-68.

MARTIN, M.O. and MULLIS, I.V.S. 2000. Perspectives from the TIMSS International Study Center. In D.Shorrocks-Taylor and E.W.Jenkins (Eds.) *op.cit.*, 29-47.

MASON, C.L., KAHLE, J.B. and GARDNER, A.L. 1991. Draw a Scientist Test: Future Implications, *School Science and Mathematics*, 91, 193-8.

MATTHEWS, B. 1996. Drawing Scientists. *Gender and Education,* 8, 231-43.

MATTHEWS, M. R. 1998. *Constructivism in Science Education: A philosophical examination*, Dordrecht, Kluwer.

MEAD, M. and MÉTRAUX, R. 1962. The Image of the Scientists among High-School Students: A Pilot Study. In B.Barber and W.Hirsch (Eds.), *The Sociology of Science*, New York, Free Press, 230-46.

MILLAR, R. and OSBORNE, J. (eds.) 1998. *Beyond 2000: science education for the future*, London, King's College London.

MIRTA, D.L. 2004. The significance of students: Can increasing 'Student Voice' in schools lead to gains in youth development? *Teachers College Record*, 106 (4) 651-88.

MORTIMER, E. and SCOTT, P. 2003. *Making meaning in secondary science classrooms*, Buckingham, Open University Press.

MUNRO, M. and ELSOM, D. 2000. *Choosing Science at 16: The influence of science teachers and careers advisers on students' decisions about science subjects and science and technological careers*, Cambridge, National Institute for Careers Education and Counselling/ Careers Research and Advisory Centre.

MURPHY, C. and BEGGS, J. 2003. Children's perceptions of school science, *School Science Review*, 84 (308), 109-15.

MURRAY, I. and REISS, M. 2005. The student review of the science curriculum, *School Science Review*, 87 (318), 83-93.

MUSGROVE, F. and BATCOCK, A.1969. Aspects of the swing from science, *British Journal of Educational Psychology*, 39, 320-25.

MYRLAND, K. 1997. *Vitenskap og forskere Norske 13-aringers oppfatninger om naturfag og forskere innen naturfagi.* Master's thesis, Oslo,University of Oslo.

NANDA, M. 2003. *Prophets Facing Backward: post-modern critiques of science and Hindu nationalism*, Piscataway, NJ, Rutgers University Press.

NATIONAL SCIENCE BOARD 2004. *Science and Engineering Indicators*, *2 vols.*, Arlington, VA, National Science Foundation.

NESTLÉ SOCIAL RESEARCH PROGRAMME 2004. *Press Release*, 14 July 2004.

NEWTON, D.P. 1988. *Making Science Education Relevant*. London, Kogan Page.

NFER/DfES 2004. *Where England Stands in the Trends in the International Mathematics and Science Study (TIMSS), National Report for England*, Slough/London, National Foundation for Educational Research/ Department for Education and Skills.

NIXON, J., MARTIN, J., McKEOWN, P. and RANSON, S. 1996. *Encouraging Learning: Towards a theory of the Learning School*. Buckingham, Open University Press.

OCR 2005. *Pupils' Perceptions of Science. Report from research carried out on behalf of OCR.* Leeds, RBA research Ltd.

OGAWA, M. and SHIMODE, S. 2004. Three distinctive groups among Japanese students in terms of their school science preference: from preliminary analysis of Japanese data of an international survey, 'The Relevance of Science Education Project' (ROSE), *Journal of Science Education in Japan*, 28 (4) 279-91.

OGURA, Y. 2003. *Informal Science education for promoting children's science learning in Japan.* Paper presented to the International Seminar on Improvement of Students' Science Achievement and attitude through Informal Science Education, Korea, December 5-6, 2003.

ORMEROD, M. and DUCKWORTH, D. 1975. *Pupils' attitudes to science*, Slough, National Foundation for Educational Research.

OSBORNE, J. and COLLINS, S. 2000. *Pupils' and Parents' Views of the School Science Curriculum*, London, King's College London.

OSBORNE, J. and COLLINS, S. 2001. Pupils' views of the role and value of the science curriculum, *International Journal of Science Education*¸ 23, 441-67.

OSLER, A. 1994.The UN Convention on the Rights of the Child: some implications for teacher education, *Educational Review*, 46 (2), 141-50.

PALMER, J. 1998. *Environmental Education in the 21st Century: Theory, Practice, Progress and Promise*, London, Routledge.

PELL, A. and JARVIS, T. 2001. Developing attitude to science scales for use with children of ages from five to eleven years, *International Journal of Science Education*, 23 (8), 847-62.

PISA 2004/ *Learning for Tomorrow's World: First results from PISA 2003*, Paris, OECD (summary available at http://www.pisa.oecd.org)

PLANET SCIENCE, INSTITUTE OF EDUCATION AND SCIENCE MUSEUM 2003. *Student Review of the Science Curriculum: Major Findings*, London, Planet Science.

POLMAN, J.L. and PEA, R.D. (2001). Transformative Communication as a cultural tool for guiding inquiry science, *Science Education*, 85, 223-38.

PSILLOS, D. and NIEDDERER, H. (Eds.) 2002. *Teaching and learning in the science laboratory*, Dordrecht, Kluwer.

QUALTER, A. 1993. I would like to know more about that. A study of the interest shown by girls and boys in scientific topics, *International Journal of Science Education,* 15 (3) 307-17.

RAY, J.J. 1980. How many answer categories should attitude and personality scales use? *South African Journal of Psychology,* 10, 53-4.

REID, N. 2003. Gender and physics, *International Journal of Science Education*, 25 (4), 509-36.

REISS, M. 2000. *Understanding Science Lessons: Five Years of Science Teaching*, Buckingham Open University Press.

RENNIE, L.J., GOODRUM, D. and HACKLING, M. 2001. Science Teaching and Learning in Australian Schools: Results of a National Study, *Research in Science Education*, 31 (4), 455-98.

RENNIE, R. and EDWARDS, K. 2005. The science classroom of tomorrow? In S. Alsop, L. Bencze and E.Pedretti (Eds.), *Analysing Exemplary Science Teaching,* Maidenhead, Open University Press, 32-8.

ROBSON, C. 2002. *Real world Research: A Resource for Social Scientists and Practitioner-researchers*, Oxford, Blackwell.

ROCHE, J. 1999. Children: rights, participation and citizenship, *Childhood*, 6 (4), 475-93.

ROSE, H. 1994. The two-way street: reforming science education and transforming masculine science. In: J. Solomon and G. Aikenhead (Eds.), *STS Education: International perspectives on reform*, New York, Teachers College Press, chapter 16.

ROTH W-M. and DESAUTELS. J. (Eds.) 2002. *Science Education as/for Socio-political Action*, New York, Peter Lang.

RUDDUCK, J. and FLUTTER, J. 2004. *How to Improve Your School: Giving Pupils a Voice*, London, Continuum.

RYDER, J., LEACH, J. and DRIVER, R. 1999. Undergraduate science students' images of science, *Journal of Research in Science Teaching*, 36 (2) 201-19, SCHIBECI, R.A. 1984. Attitudes to Science: An Update. *Studies in Science Education*, 11, 25-69.

SCHLEICHER, A. 2000. The OECD Programme for International Student Assessment. In D. Shorrocks-Taylor and E.W.Jenkins (Eds.) *op.cit.* 63-77.

SCHMIDT, W.H., McKNIGHT, C.C., COGAN, L.S., JAKWERTH, P.M., and HOUANG, R.T. 1999. *Facing the Consequences: Using TIMSS for a Closer Look at U.S. Mathematics and Science Education*, Dordrecht, Kluwer.

SCHREINER, C. 2005. *Exploring a ROSE-garden: Norwegian youths' orientations towards science - seen as signs of late modern identities,* Doctor Scientiarum thesis, University of Oslo.

SCHREINER, C. and SJØBERG, S. 2003. *Optimists or pessimists? How do young people relate to environmental challenges?* Paper presented to the European Science Education Research association (ESERA), Netherlands, August 2003.

SCHREINER, C. and SJǾBERG, S. 2004. *ROSE: The Relevance of Science Education. Sowing the seeds of ROSE. Background, rationale, questionnaire development and data collection for ROSE – a comparative study of students' views of science and science education*, Oslo, Department of Teacher Education and School Development, University of Oslo. Also available at http://www.ils.uio.no/forskning/rose

SCHREINER, C. and SJǾBERG, S. (in press) Empowered for action? How do young people relate to environmental challenges? In S.Alsop (Ed.), *Beyond Cartesian Dualism: Encountering affect in the teaching and learning of science*, Dordrecht, Springer.

SCHREINER, C., HENRIKSEN, E.K. and HANSEN P.J.K. 2005. Climate Education: Empowering Today's Youth to Meet Tomorrow's Challenges, *Studies in Science Education* 41, 3-50.

SCHULTZ, J. and COOK-SATHER, A. (Eds.) 2001.*In our Own Words: Student perspectives on School*, Lanham MD, Rowman and Littlefield.

SHANKS, N. 2004. *God, the Devil and Darwin: A critique of intelligent design theory*, Oxford, Oxford University Press.

SIEMENS plc. 2006. http://www.siemens.co.uk/index.jsp

SHORROCKS-TAYLOR, D. and JENKINS, E.W. (Eds.) 2000. *Learning from Others: International Comparisons in Education*, Dordrecht, Kluwer.

SIEMENS plc 2006. *Siemens shows pupils shun sciences for easier A-level*
SIMPSON, R.D., KOBALLA, T.R., OLIVER, J.S. and CRAWLEY, F.E. 1994.Research on the affective dimension of science learning. In D.Gabel (Ed.),

Handbook of Research on Science Teaching and Learning, New York, Macmillan,chapter 6.

SJØBERG, S. 2000. *Science and Scientists: The SAS study. Cross-cultural evidence and perspectives on pupils' interests, experiences and perceptions. Background, Development and Selected Results.* Oslo, Department of Teacher Education and School Development.

SJØBERG, S. and SCHREINER, C. 2005. *Young people and science: attitudes, values and priorities: evidence from the ROSE project.* Keynote presentation at the European Union Science and Society Forum, Brussels, March 2005. Also available at http://www.ils.uio.no/forskning/rose

SOKAL, A. and BRICMONT, J. 1999. *Fashionable nonsense: Postmodern intellectuals' abuse of science*, New York, Picador.

SOLOMON, J. and AIKENHEAD, G. (Eds.) 1994. *STS Education: International perspectives on reform*, New York, Teachers College Press.

STARK, R. and GRAY, D. 1999. Gender preferences in learning science, *International Journal of Science Education*, 21 (6), 633-43.

SYMINGTON, D. and SPURLING, H. 1990. The Draw-a-Scientist Test: Interpreting the data. *Research in Science and Technology Education*, 8, 75-7.

TAMIR, P. and GARDNER, P.L. 1989. The Structure of Interest in High School Biology, *Research in Science and Technology Education,* 1, 113-79.

TEPPO, M. and RANNIKMÄE, M. 2004. *Relevant Science Education in the Eyes of Grade Nine Students*. Paper presented at the IOSTE XI Conference, Lublin, July 2004 (available at http://www.ils.uio.no/forskning/rose)

TOUSSAINT, R.M.J., BOUCHER F., MARCHILDON, L., ARBOUR, C. & CUILLERE, J-C. 2001. Students' perception of science and technology in the Mauricie_Centre-du_Québec region, in: D.Psillos, P.Kariotoglou, V. Tselfes, G. Bisdikian, G. Fassoulopoulos, E. Hatzikraniotis & M. Kallery (Eds.), *Science Education Research in the Knowledge Based Society: Proceedings of the Third ESERA Conference, 2 vols.* (Thessaloniki, ESERA/University of Thessaloniki), 664-67.

TRUMPER, R. 2004 *Israeli students' interest in physics and its relation to their attitudes towards science and technology and to their own science classes*. Paper presented to the IOSTE XI conference, Lublin, July 2004.

Van BERKEL, B. 2005. *The Structure of Current school Chemistry: A quest for conditions for escape*, Utrecht, CD-β Press.

VASQUEZ, A. and MANASSERO, M. 1997. Escribir sobre ciencia: La imagen de la ciencia y de los cietintificos entre adolescentes, *Cultura y Education*, 6/7, cited in Jones *et al.* 2000, *op.cit.,* 192.

VINCENTI, W.G. 1993. *What engineers know and how hey know it: analytical studies form aeronautical history*, Baltimore, Johns Hopkins University Press.

WELLINGTON, J.J. (Ed.) 1998. *Practical Work in School Science: Which way now?* London, Routledge.

WENG L-J. 2004. Impact of the number of response categories on coefficient alpha and test-retest reliability, *Educational and Psychological Measurement*, 64 (6), 956-72.

WHYTE, J. 1986. *Girls into Science and Technology: The Story of a Project*, London, Routledge and Kegan Paul.

WHYTE, J., KELLY, A. and SMAIL, B. 1987. *Girls into Science and Technology: Final report of Science for Girls*, Milton Keynes, Open University Press.

ZEMBYLAS, M. 2005. Three perspectives on linking the cognitive and the emotional in science learning: conceptual change, socio-constructivism and poststructuralism, *Studies in Science Education*, 41, 91-116.

ZOHAR, A. and SELA, D. 2003. Her physics, his physics: gender issues in Israeli Advanced Placement physics classes, *International Journal of Science Education*, 25, (2), 245-68.