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RESEARCH REPORT

Pupils' views of the role and value of the science curriculum: a focus-group study

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Pupils' perceptions of their experience of school science have rarely been investigated. The aim of the research reported in this paper, therefore, was to document the range of views that pupils held about the school science curriculum, the aspects they found either interesting and/or valuable, and their views about its future content. As such, the research aimed to articulate their views as a contribution to the debate about the future form and function of the school science curriculum. The method adopted to elicit their views was to use focus groups—a methodology that has not been extensively used in the science education research. Reported here are the findings from 20 focus groups conducted with 144 16-year-old pupils in London, Leeds and Birmingham, split both by gender and whether the pupils intended to continue, or not, with the study of science post-16. The findings of this research offer a window into pupils' perspective of school science revealing both their discontents and satisfaction with the existing curriculum. On the negative side, many pupils perceived school science to be a subject dominated by content with too much repetition and too little challenge. From a more positive perspective, pupils saw the study of science as important and were engaged by topics where they could perceive an immediate relevance, practical work, material that was challenging and high-quality teaching. The implications of these findings and the insights they provide for curriculum policy and school science curricula are discussed.

Introduction

In the post-war era, science education has been dominated by a desire to educate our future scientists (DeBoer 1991; Bryce 1996). However, the vocational preparation of a few trained scientists required for the future economic needs of the country can no longer sustain the justification for universal science education. Instead, the increasingly high profile of scientific issues within the media is leading to an increasing emphasis on the need to develop a scientifically literate populace (Millar 1996; Bybee 1997; DeHart Hurd 1997; Jenkins 1997b; Millar and Osborne 1998; Osborne and Young 1998) as it is thought that the dilemmas posed by science will form the major political, ethical and moral dilemmas of the future (*Independent* 1998; *Financial Times* 1999). Science education must, it is argued, seek to address a broader set of aims commensurate with the needs of an advanced industrial society where the ability to sort, sift and analyse information becomes as valuable as the knowledge itself (Coles 1998), and where it is suggested that:

> most of what non-scientists need to know in order to make informed public judgements about science fall under the rubric of history, philosophy, and sociology of science, rather than the technical content of scientific subjects. (Fuller 1997: 9)

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The growing disparity between science-as-it-is-experienced by the public at large, and science-as-it-is-taught has led to an expanding debate on the future of the science curriculum (Millar and Osborne 1998) in the UK and elsewhere (American Association for the Advancement of Science 1989, 1993).

Although there have been attempts to broaden the science curriculum to address the needs of the general populace—typified in the UK by examples such as Nuffield Secondary Science, Science at Work—and to introduce social and technological issues through such schemes as the Schools Council Integrated Science Project (SCISP) and Science and Technology in Society (SATIS), such initiatives have, by and large, had a limited impact, ultimately producing a curriculum that has served neither function well. Furthermore, recent evidence would suggest that the current emphasis on assessment as a measure of the performativity of the system have led to the elimination of any material that is seen as extraneous or ancillary to the core of examinable content (Watts and McGrath 1998). Science curricula are then dominated by factual knowledge—knowledge 'that' or knowledge 'how'—material, which is readily assessed rather than material that seeks to imbue a critical understanding of science reasoning or scientific practice (Apple 1992). The inevitable consequence is a curriculum with a foundationalist emphasis on basic concepts which fails to give pupils any overview of the major themes, processes and social practices of science (Millar 1996; Jenkins 1997a; Donnelly and Jenkins 1999). From this perspective, rarely, if ever, is each stage of education seen as an end in itself. Rather, science education has remained fundamentally an education for science rather than an education about science, dominated by the needs of the post-compulsory curriculum, and the needs of the scientific establishment who have a powerful constitutive voice in curriculum formulation through the agency of a wide range of professional bodies.

Totally absent from this debate are the voices of pupils and parents—an absence that may reflect an implicit assumption that the only views of import are those of scientists and science educators. If 'Science for All' is to foster an appreciation and understanding of science, there is a need to determine those aspects of science that pupils and parents value, and use in their everyday lives. Lay people engage with science and technology in a range of contexts (health, nutrition, waste disposal, pollution), and research suggests that within these situations they are able to articulate their perceived needs for scientific knowledge (Layton *et al*. 1993; Irwin and Wynne 1996). Whilst pupils' and parents' views cannot be the sole determinant of science curricula, it is essential to at least articulate and recognize their contribution to the debate. To what extent is school science responding to pupils' and parents' needs enabling them to engage with a major influence on their society and culture? What are their expectations of school science and do they think it has failed or succeeded in meeting those aspirations? This research reported here sought to document those needs and expectations through the use of focus group interviews with pupils and parents, and then to seek teachers' responses to those views. In this paper, we report some of the data and the finding from the interviews with pupils.[1]

In addition, there is a longstanding vein of research that has sought to examine pupils' attitudes to school science, reviews of which can be found in Gardner (1975), Osborne *et al*. (1996), Schibeci (1984), Weinburgh (1995). Much of this research has been reliant on questionnaires that have attracted numerous criticisms, principally for attempting to reduce a multi-faceted, and interdependent construct to a few easily measurable quantitative dimensions (Gardner 1975). Gardner illustrates his point effectively by use of a 'dining room table analogy' arguing that though the weight, length and height of a table can all be measured meaningfully, adding these three variables together to form some kind of 'Dining Table index' simply produces a meaningless, uninterpretable variable.

From a social psychological perspective, Potter and Wetherall (1987) argue that questionnaires, the basis of much of this research, merely reveal the 'tip of the iceberg', that is the most-evident attributes of any attitude and fail to expose any underlying complexity of feelings or view. Attitudes are not, they argue, a stable construct and should be evaluated in the context of the object of inquiry. Relatively few studies of pupils' attitudes to science have adopted a qualitative approach seeking to explore in some depth pupils' views and their rationale. Thus, in adopting a qualitative, interview-based approach to exploring pupils' views of their experience of school science, this research offers fresh insights into its nature and quality. Such findings are important—for not only do they record what experiences engage and interest pupils in school science and what are the 'points of disengagement' but also, unlike quantitative studies, they offer an explanation of the root causes. At a time when science education—at least in the developed world—is suffering from a lack of positive interest (Beaton *et al.* 1996) and, at least in the UK, static or falling numbers choosing voluntarily to continue the study of science post-16—it is important to begin to comprehend the source of any lack of interest. For, if, as the protagonists for science would claim, science is one of the major cultural achievement of western societies, and a body of epistemically privileged knowledge, any failure to engage the interest of societies' youth represents a threat not only to the culture but also to science itself.

Aims and Methodology

Consequently, the aims of this research reported here were to determine the views of pupils on:

1. the kind of scientific knowledge, skills or understanding that they need for dealing with everyday life;
2. the aspects of science that they find interesting;
3. the value of the content of the school science education that they received; and
4. the future content of the science curriculum for all.

Since the purpose of this research was to seek insight into the experiences, views and beliefs of pupils, the data required were essentially qualitative. One approach to gathering such data would have been to use individual interviews. Whilst this method provides extensive data, it is extremely time-consuming to collect a representative sample of views, values and opinions. The focus group in contrast, offers a means of exploring the principal issues of interest in a dynamic manner which utilizes the group interaction to challenge, and probe, the views and positions espoused by individual members in a non-threatening, relatively naturalized social context. The group context also offers a degree of support and security and the option not to respond, which is not available in one-to-one interviews. The data, therefore, may offer a more accurate reflection of individual views as there is no compulsion to tell a 'story' to please the interviewer. Strother (1984), for instance, provides evidence that focus group interviews yield more accurate information about what participants actually think than do other research methods. Nevertheless, it should be noted that there is always the possibility that there exists a gulf between attitudes, actions and beliefs (Ajzen and Fishbein 1980), and, as a methodology, they suffer from using a less natural setting than that of participant observation or ethnographic studies in the field where participants' actions may be more indicative of views and values than any expression of views at interview.

The fundamental aim of this methodology is to gather data on the topic and participants' perceptions and understanding. Such research seeks to develop a deeper understanding of its central focus exploring not only what participants think but why they think it (Kitsinger 1994). As such the goal is not necessarily to produce data that can be generalized to larger populations, but rather, to explore the range of attitudes, values and beliefs that are commonly held within the populace, the strength of feeling and the reasons for those beliefs. Whilst previous research suggests that data saturation is achieved after three to four focus groups (Vaughan *et al.* 1996) with any one sub-group, generalizing to a wider population must always be undertaken with caution (Bers 1989; Vaughan *et al.*, 1996).

Essentially, focus groups seek to expose what Schutz and Luckman (1973) have termed the 'intersubjectivity'—the collective description of everyday reality and its interpretation. Critics of the focus group have argued that there is a tendency for the discussion to degenerate into a negative critique (Powney and Watts 1987), or that participants are subject to a group dynamic that subtly imposes consensus (Morgan and Kruegar 1993). Our experience would suggest that there is some truth in the first of these points, particularly with pupils. Given that most pupils were simply astonished to be asked to express their views, there was inevitably a tendency to express long-harboured dissatisfactions. The preliminary phase of the research provided us with an opportunity to develop our questions and technique so that participants were specifically asked to recall their positive experiences and explain what was valued about the event. As for the second critique, the emergence of any group dynamic was inhibited by always asking individuals to record on paper, out of sight of the others, their views about any statement presented to them. Participants were then asked to reveal what they had put and justify their choice which nearly always exposed a divergence of opinion and led to extended discussion and challenge. One of the primary functions of the moderator, too, was to attempt to sustain an open, inclusive and permissive atmosphere in which all felt free to express their views. On the rare occasions when there was a tendency to group consensus, it was always with boys' groups where one individual was significantly more articulate than the others.

Group size determines the number of lines of communication and the time for any one individual to contribute. With n participants the number of lines of communication is simply $n(n-1)/2$. Hence with 10 people, there are 45 possible channels with a danger of curtailing the group dynamics. For this reason, a group size of six to eight is often considered optimal (Folch-Lyon and Trost 1981) though groups can function with as few as four and as many as 12. In this research the average group size was seven.

Our aim was to report on the views of pupils participating in normal state education. Our sampling technique was therefore based upon avoidance of the exceptional and 20 state schools were recruited from Leeds, Birmingham and

London whose GCSE scores lay with ±15% of the national average. The study focused upon age 16 science pupils capturing their views at the end of compulsory schooling—a time when their memories are fresh and recent. The groups were comprised of participants deemed 'similar' along key dimensions:

1. Male versus female: there is a significant body of research that demonstrates the differential responses of males and females to science and science education (Harding 1983; Weinburgh 1995). More practically, the dynamics of male-female discourse in groups is often at the expense of the female voice (Holloway 1984; Tannen 1989). Both of these factors provide reason to run focus groups for male and females separately.
2. Scientific versus non-scientific orientation: participants will differ in terms of their general orientation to science, that is, their understanding and appreciation of science. For the pupils, the notion of 'scientific orientation' was operationalized in terms of whether they intended to work, or to undertake further study, in such a field.

Consequently, there were four (2 × 2) distinct categories of participants and for each 'dimension' five focus groups were held to ensure data saturation. Thus, in all, 20 focus groups were run with 144 pupils. The preliminary phase of the work, undertaken from January-June 1998, was used to trial questions and strategies to be used. The final set of statements and accompanying questions (Appendix) were designed to 'provoke' an individual response and address the main themes of the research questions. Each individual was then asked to commit themselves to their position by recording it on a table. Discussion then moved to exploring what individuals had recorded and, in particular, the justifications for the position they held. Inevitably, there was rarely a consensus and the differing positions held by individuals provided a vital stimulus for mutual exchange of views and elaboration of the participants' positions. The focus group finished by asking each participant to reflect on what they considered to be the most important issue that had emerged, providing an important means of summarizing and closing the discussion (Vaughan *et al.* 1996). Such an opportunity is also important in a situation where the issues may have generated some controversy as it allows participants an opportunity to make one final, unchallenged statement that they may have withheld until that point (Morgan and Krueger 1997).

All the focus groups, undertaken between September 1998-July 1999, were taped and then transcribed. Data were then coded reflexively to identify emergent themes and issues using a 'grounded theory' approach (Strauss and Corbin 1994). Codes were then tested iteratively against the data to produce a final set of 430 codes, 20 of which were major codes and the rest sub-codes, many of which were iterated under each major heading. A reliability check was conducted by independently coding the same transcript which gave a 79 per cent initial level of agreement which rose to 90 per cent after the differences in coding were discussed. This was considered sufficiently acceptable to proceed with coding the full data set. Codes were then recorded with the NUD·IST qualitative data analysis package for systematic analysis and interrogation. Such software enables preliminary analysis of the frequency of the certain codes; the differences between the sub-groups; and the rapid testing of tentative hypotheses as it can rapidly retrieve any data that lies at the point of intersection of two or more codes—for instance, if the data support the hypothesis that girls' comments about physics are more negative than boys'.

Hence, the software supports not only the quality of the analysis but also the extent of what is feasible within a given time.

Whilst the primary intention of focus groups is to document and report the insights revealed by the data, the best evidence that a topic is of significance comes from a combination of three factors: how many people mention a topic; how many groups mentioned a topic; and the energy and enthusiasm the topic generated amongst the participants (Morgan and Krueger 1997).

Results and Findings

The findings from the focus groups with pupils can be summarized under seven major headings which are:

1. Pupils' views of the importance of school science.
2. Aspects of school science found uninteresting.
3. Aspects of school science found interesting.
4. Aspects of science found interesting in everyday life.
5. Ways in which science is useful in everyday life.
6. Aspects of science which are not useful in everyday life.
7. Changes to the school science curriculum.

Within this paper, the data reported are drawn predominantly from the first three sections. It is these data that provide the most insight into pupils' contents and discontents with their current experience of school science education. Whilst this subset do not embrace all the data, they do manage to capture the major elements of what the pupils had to say, and hence, are used as the framework for this paper.

Pupils' views of the importance of school science

Pupils saw scientific knowledge as being an important component of their education. Reasons given were that science is 'all around us'; that it helps 'you to understand the world', providing you with a knowledge of 'how your body works', 'how to fix a car' or 'how to wire a plug'. Science is also useful for explaining things to other people. Such rationales were, however, more clearly articulated by the girls than the boys. Although arguments for the importance of science, typified by the comment below, were not extensive, they were offered by the majority of the groups with the exception of the boys' non-science groups.

> Colin:[2] It's [science] led to a lot of discoveries that wouldn't have been discovered without science, ... technology and stuff like that, and ... if it wasn't for science we wouldn't be where we are today. Really, we'd be still living in caves ... so I think it's really important. (BS2/379)[3]

In the majority of the comments, the emphasis was on the general value of science in society, often illustrated with examples of its instrumental value.

> Helen: 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. (GN2/525)

Such arguments reflect a lack of any distinction between science and technology and a modernist faith in science as a source of solutions. The controversial nature of scientific research was less prominent in pupils' comments, and there was little recognition that one value of scientific knowledge was the facility to engage critically with contemporary scientific issues. Rather what was emphasized was that scientific knowledge offered a point of entry into the discussion.

> Lucy: It's really important for me to learn science to keep in line with everything else, because, if you switch on the TV, they're always talking about things that they've discovered and new ways they can do things. To understand what they're talking about you've got to know about science. (GS5/615)

Hence what was articulated clearly, in all of these comments, was a recognition that learning science was important—and that science and scientific knowledge was an important aspect of contemporary life. For science educators, this is an important finding, which is supported by earlier work (Assessment of Performance Unit 1988; Breakwell and Beardsell 1992) as it suggests that their subject has achieved such a level of significance in contemporary society, that its place on the curriculum is unquestioned.

On a personal level, one of the reasons advanced for the importance of science was that the subject was prestigious. Those who could do science were seen to be intellectually able and enjoyed higher academic status. However, the most common argument for the importance of science was its instrumental value for future careers. Predominantly, these were careers traditionally associated with science, e.g. medicine, veterinary work, airline pilots. Nevertheless, most groups felt that the value of science for future employment was less apparent than English and mathematics, and many of the pupils felt that there were a large number of posts for which science was unnecessary. Many suggested, in contrast, that for career purposes IT skills were more relevant. It was argued, for instance, that you did not need science to become a hairdresser, a banker, a rock star, an artist or a lawyer. However, in some instances there was a creeping recognition that science might have import for a wider set of careers than those traditionally associated with science, although this argument was only ever articulated in general terms rather than by reference to specific examples.

What these findings suggest is that science has a marketing problem. If the main value that pupils are placing on science is its instrumental value rather than its intrinsic interest, then science teachers should endeavour to make clear the wide range of occupations which scientific knowledge supports, how it might be used, and why it is useful. Whilst there would appear to be a growing awareness amongst some pupils of the general career value of science, the lack of specific examples raised implies that little has been done to emphasize the value of science qualifications in a wide range of occupations—or alternatively that science has as much value as a cultural resource for any 'educated' individual as does a knowledge of literature. At the moment, the attitude of too many pupils would appear to be summarized by the view that—yes, studying science post-16 is important, but not for me.

A closer examination of the many reasons given for the importance of science shows a marked difference between boys and girls in the number of statements offered. Girls had little difficulty in elaborating reasons for the importance of science to themselves and their own everyday lives (67 text units as opposed to

10). A good example, found in the following comment, illustrates the point that everyday life is the context where the salience, or not, of learning in school is realized:

> Julie: Like a little electric heater ... I remember I was plugging it in and I felt the plug was warm, and I remember learning that warm was faulty. I told my mum and she was so impressed. And if I hadn't learned that if it was warm it was faulty I would have plugged it in and found out ... (GS1/520)

Boys, in contrast, had little to say about the importance of science either to themselves or to their everyday lives. What they did say was very similar to the comments made by girls, although one or two of the examples they offered had a more traditional gender bias such as its value for 'fixing plugs' and 'fixing cars'. This would suggest that they held similar sentiments but simply failed to articulate them to the same extent. Another distinction between the groups was that it was the girls' science groups who, surprisingly, offered the least number of qualifying statements about the value of science. In contrast, the boys' science groups offered as many as the non-science groups suggesting that they still held residual doubts about the value of science, either for themselves personally or more generally. However, despite pupils' generally positive view of the value of science, there were many aspects of school science that they found uninteresting.

Aspects of science pupils found uninteresting

In conducting this research, we had anticipated that the science subject for which there would be most antipathy would be physics. The subject has a long history of being regarded as mathematical, abstruse and difficult. In addition, historically the take-up by girls has been low. The surprise that emerged from much of the data (figure 1) was that, for many, the subject that attracted the most vehement

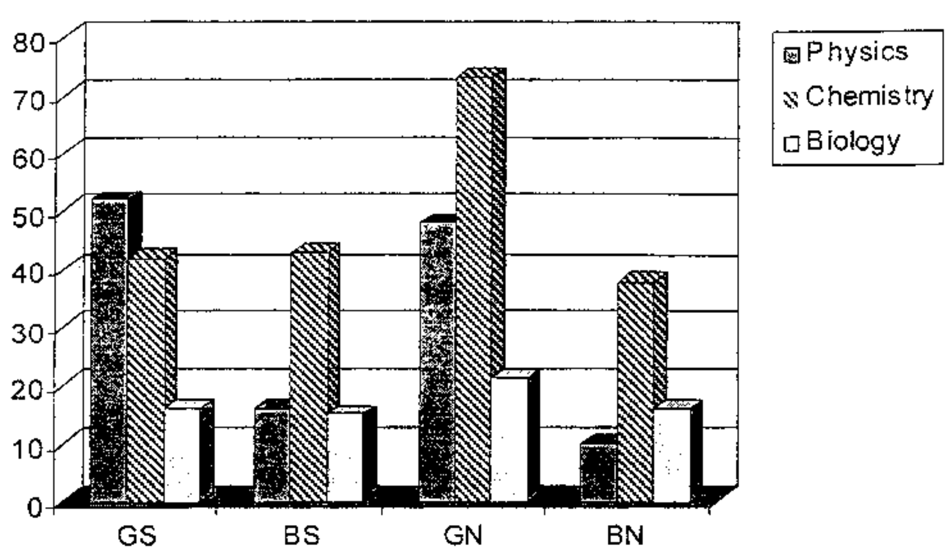

Figure 1. Chart showing number of comments coded 'uninteresting' for each science subject.

expression for its lack of relevance and appeal was chemistry. Boys' 'continuing science' groups, and girls' 'not continuing with science', in particular, made more negative comments about chemistry, whilst girls' continuing science groups commented more on aspects of physics. The other major feature of this data set is that girls in both groups made many more negative comments about physics than boys which would suggest that school physics still lacks appeal for girls.

One aspect of chemistry that attracted universal antipathy among non-science pupils was the periodic table. Not only did they experience difficulty in memorizing the constituents of the table, but they also failed to perceive its relevance to their everyday lives at present or in the future:

> Edward: It doesn't mean anything to me. I'm never going to use that. It's never going to come into anything, it's just boring. (BN2/272)

Similarly, continuing science groups were unable to see the purpose of the inclusion of the blast furnace in school science:

> Roshni: The blast furnace, so when are you going to use a blast furnace? I mean, why do you need to know about it? You're not going to come across it ever. I mean look at the technology today, we've gone onto cloning, I mean it's a bit away off from the blast furnace now, so why do you need to know it? (GS5/513)

The lack of perceived relevance to pupils' lives of such topics was a recurring theme throughout these discussions in all groups, either for continuing education in science and/or career aspirations. For instance, it was argued, 'I won't need to know all the equations or the chemicals' (BN1/388). Without this essential ingredient, sustaining interest was difficult, if not impossible. In the past two decades, chemistry education has reduced the number of activities that involve the manipulation of chemicals, chemical combination and analysis. Many of the more 'spectacular' demonstrations have also been excized due to the exigencies of more stringent safety regulations. In its place, there has been a concentration on more fundamental aspects such as atomic and molecular bonding, which are essential for explaining chemical combination. However, the theoretical emphasis on intangible and microscopic entities introduces an element that appears to too many pupils to be abstruse and far removed from their daily concerns. Pupils' complaints about the study of industrial processes which are no longer a mainstay of the British economy, and not readily on-hand for organized school visits, would therefore seem to have some substance.

Hard or difficult subject. Amongst all pupils there was general agreement that many aspects of science were 'hard' or 'difficult to understand', which in turn made them uninteresting for some. Points of difficulty mentioned were: the language with its unfamiliar words; the nature of complex concepts such as bonding; and the fragmented nature of the subject. Although challenging work was welcomed, principally by continuing science groups, pupils found sustained difficulty demoralizing:

> Julie: I think sometimes when we don't understand something that's what makes it boring. But at the same time, if you see something and you want to know what—that's what makes it interesting. If it's something that you want to understand and you can't, it just gets boring after a while. (GS1/492)

Science itself was seen as being a very logical subject, which in one sense was akin to common sense, and therefore, at the introductory level, relatively undemanding. However, there was recognition that beyond this point science became more difficult. The transition point, where science became notably more difficult was in Year 9 at age 14.

> Jane: I think the point when it changes is about Year 9, because you've had two years of it and years nine's like ...
>
> Megan: Just after Year 9.
>
> Jane: ... when you're picking you're options and ...
>
> Jessica: Everything's more difficult ... (GN1/310-313)

Somewhat in contrast, pupils in continuing science groups described science as an 'academic' subject where, 'you can't just memorize it, you have to understand it' (GS3/305) which was part of its appeal for them.

All groups commented on the mathematical aspects of physics and chemistry, through the use of formulae and equations. Amongst girls and boys in continuing science groups, there was a feeling that a comprehension of aspects of maths was a prerequisite of understanding physics and chemistry. For the small number of girls who experienced difficulty with mathematics, their difficulties with physics were then compounded. There were also a significant number of pupils across all groups who, because of their sustained difficulty, in one form or another with some aspects of science—predominantly chemistry and physics—no longer had an appetite for the challenges it offered. Rather they were resigned to the fact that their attainment in tests and examinations would be low.

Rushed curriculum. One of the most strongly articulated features, in approximately half of the groups, was the sense that pupils were being frog-marched across the scientific landscape, from one feature to another, with no time to stand and stare, or absorb what it was that they had just learnt.

> Keiran: It's all crammed in, and you either take it all in or it goes in one ear and out the other. You catch bits of it, then it gets confusing, then you put the wrong bits together and, if you don't understand it, the teachers can't really understand why you haven't grasped it. (BS1/232)

The basis for these comments was predominantly the pupils' experience of examination courses in science from age 14-16. Their points suggest that a broad syllabus covering physics, chemistry, biology, earth sciences and basic astronomy, coupled with the exigencies of limited time, left little space for reflection. The final year, in particular, was a year in which considerable pressure was applied as a number of topics were covered superficially and in haste, despite the substantial amount of curriculum time (approximately 18-20%) devoted to science teaching in the UK.

The result often was practices that were seen as of little educational benefit such as copying—and which had a negative affective outcome on interest in the subject.

> Vishal: Yeah, you're writing things down from the overhead projector, you haven't had time to read it while you're copying it down, it's only when you come back to revision that you think 'I didn't understand that and I wished I'd asked him'. But then you remember that you didn't have a chance to ask because you were that busy trying to copy it down you weren't reading it. (BS1/426-427)

> Roshni: But still like this morning we were talking about genetic engineering ... She didn't want to know our options and I don't reckon that the curriculum let's them, lets us discuss it further. I mean science, okay you can accept the facts, but is it right, are we allowed to do this to human beings? (GS5/88)

As an activity, there is now considerable research that shows that copying or undemanding writing activities are of little educational value. Predominantly, they are associated with transmissive modes of teaching, which research has shown to be the least effective in helping pupils to attain knowledge and understanding of the subject (Eggleston *et al*. 1976). 'Copying', which in this case may be a euphemism for 'boring writing', is an activity in which little active processing or participation is required by the learner. The explanation for their lack of stimulation perhaps lies in the words of the famous saying that 'lectures are a device where the notes of the lecturer are transferred to the notes of the student, without going through the mind of either'. Such work offers pupils little control over their own learning, and ultimately leads to boredom, disenchantment and alienation (Wallace 1996).

In part, teachers are being driven into this practice by the use of examination scores both to measure the quality of their work and the achievements of the school. If the examination system emphasizes low-level skills and the recall of factual information, teachers respond with a transmissive pedagogy, which traditionally has been perceived to maximize pupil achievement in such limited assessments. This finding simply reinforces other findings based on systematic classroom observation (Hacker and Rowe 1997) about the influence of the English and Welsh National Curriculum on styles of teaching. Thus, an unintended consequence of national curricula, and teachers' pragmatic response to their assessment demands, is a negative outcome on many pupils' enjoyment of science.

When questions were raised by pupils about specific points of interest for further elaboration or justification, the shortage of time was sometimes used as a means of asking pupils simply to 'accept it'. Such appeals to authority as a means of justifying the scientific world view to pupils are disturbing for three reasons. First, arguing from authority makes the pupil in the science classroom of the so-called contemporary western society no different from those cultures that rely on the authority of oral assertion. In both cases 'the propounders are deferred to as the accredited agents of tradition' (Horton 1971). Second, it is particularly disturbing that a subject, which claims to be epistemically privileged because of its commitment to evidence as the basis for belief, forces its educators to resort to assertion as a means of convincing pupils of the scientific world-view. Third, to ask of other human beings that they accept and memorize what the science teacher says without any justification leaves pupils bereft of the reasons for belief, unable to justify their knowledge to others. As such, it is a failure to acknowledge the Kantian injunction to treat them with respect as persons, leaving them with knowledge that is of little more than superficial value. In addition, pupils' comments revealed that the unease of relying on authority—essentially an irrational form of argument for a scientist—was sensed often by the pupils with teachers teaching outside their specialist domain who were often reluctant to entertain questions.

Content dominated. One of the most pervasive comments about school science, mentioned by just less than half the groups, was that science was essentially a body of knowledge characterized by its content, with a particular emphasis on facts and learning, which distinguished it from other subjects:

> Cassie: With science it's solid information and you've got to take it down ... (GS4/76).
> Cheryl: ... so when they teach you science you know that this is it, okay? There is nothing, you can't prove it wrong.
>
> Leena: In what way does that make it different to other subjects though?
>
> Shakira: I mean you just have to accept the facts don't you? (GS5/61-63)

School science consisted of facts to be learned, where, 'you've got to print it into your brain' (GN2/83), or learning of 'straight facts which you have to repeat in the exams' (BN4/77), and by answers that were either right or wrong. The view was expressed that 'there's one answer and you've got to learn it' (BN2/18). This view of science was common to pupils across all the groups.

The negative consequence of the concentration on the 'facts' of science in its teaching for some pupils was well articulated by one pupil:

> Claire: I think the thing that is making us, everyone having negative opinions of it, is because it's so much, it's because it's so much to learn. And you ... suddenly, you're mind is just saying, 'Look this is interesting, but I really don't want to learn it like this, I don't want to pump it into my brain'. (GN2/203)

The poor affective outcome of a course, which is dominated by content supports Miller and Tesser's (1986) cognitive-affective mismatch hypothesis, which suggests that courses emphasizing cognitive outcomes have weak or negative affective outcomes. It is also of concern because affective outcomes are much more enduring than cognitive outcomes (Petty and Cacioppo 1986) and, if one of the primary residues of a good science education is to be an enduring interest and engagement with science, then school science courses need to give more consideration to affective aims. The comments of these pupils would suggest that, accompanying the attempt to squeeze more and more content into the curriculum pot, is an unintended (and possibly unrecognized) negative outcome, which may be seriously damaging the health of contemporary science education.

Repetition. A major contributing factor to pupils' lack of interest in science, particularly among continuing science groups, was repetition of work. Repetition was described as taking two forms: first, a number of pupils in non-science groups, and two continuing science groups, commented on the repetition of tests and experiments within given lessons:

> Asha: What's tedious is when the teachers sit there and they'll get a white liquid and they'll say. 'When I pour this green liquid in what colour will it turn?' The point is, 'Oh look it's an acid it's turned red'. And then they'll get the next one, 'This is vinegar, what colour will this turn?' And they won't just do one acid and one alkali they'll do six acids, six alkalis and you have to sit there and it's, like, we've done this about four times already. (GS3/247)

Whilst the repetition here is essentially a rhetorical mean to persuade pupils of the validity of the scientific world-view, its use, without explicitly addressing why it matters, is clearly a point of disengagement for pupils.

The second dimension of repetition, strongly articulated by continuing science groups, was in topics begun at age 11 or 12, which were then been repeated in subsequent years:

> Alice: Every year I've done science ... I have learnt about photosynthesis. It's not as if I learn it in more depth every year, I just do literally the same thing ... When you get to secondary school it's not that much more advanced and that's it, you learn the same things over and over again. (GS5/709)

Whilst progression was apparent in some topics in that 'there's a bit more information now' (GS5/257), it was perceived by continuing science groups, to be planned in small stages, where although 'it's more complex, ... it's basically the same' (GS5/259). As the following comment shows, a consequence of an apparent lack of progression in topics, particularly for girls non-science groups, was a growing disenchantment with aspects of science:

> Claire: We learnt all these amazing things in Year 7 and that we'd never heard of before, like molecules and atoms and electrons. I don't know about you guys but I got really excited about it, I rushed home and told my mum about it. And then in Year 9, we're doing the same thing, Year 10, doing the same thing, Year 11, doing the same thing ... and it's so repetitive. (GN2/670)

A number of continuing science groups acknowledged the need to revisit aspects of science. However, the point was made that too much time was devoted to revision and, as a consequence, 'we're never learning anything new—it's just revision and it gets so tedious' (GS5/153). The notion of a spiral model of curriculum planning (Bruner 1960) in which concepts are revisited and more clearly defined at intervals during schooling, was clearly lost on many pupils. More fundamentally, these comments raise many questions about how this state of affairs can be avoided. The English and Welsh National Curriculum assumes a steady progression where teachers build on pupils' previous understandings. There is little doubt that this poses formidable challenges for secondary teachers, partly from a lack of familiarity with the science teaching undertaken in primary schools and partly from a failure to take account of what pupils already know (Galton *et al.* 1999). However, this does not explain or account for the problem within secondary science itself. In part, the solution here lies in asking teachers to think more carefully about pupils' prior experiences and explicate how any topic they introduce will be different and build on their previous knowledge. In addition, these responses beg the question whether it is appropriate to sustain the same kind of science education over the 11 years of secondary education—and whether the fare offered lacks sufficient diversity to appeal. One way of eliminating this problem would be to offer a different science course in Year 10 and 11, possibly, as one of us has argued elsewhere, a course that emphasized the development of scientific literacy (Millar and Osborne 1998).

The lack of discussion. Another point raised was that there was a lack of time to diverge; no opportunity for the pupils to set the agenda themselves; to pursue topics of particular interest and, most importantly, no time for discussion.

> Tania: If you, like, give suggestions they just ignore it and go—'No it's written in the syllabus that you've got to do this'. And it's just kind of fixed upon the syllabus and you're like, 'Well can't we just find a gap for it?' And they're, like, 'No'. (GN3/658)

Pupils in non-science groups, complained that unlike other subjects in which 'you can use your imagination' (GN2/100), in science, 'there's no room to put anything of you into it' (GN1/53), and, 'everything else is more creative, even history' (GN4/205).

The perceived absence of creativity in science was a point developed among boys' non-science groups.

> David: It's more about testing your ability to learn than your ability to do science. (BN2/81)

Part of the problem for science is that the genres of writing it uses—the explanation, the experimental report or description—are all unfamiliar genres, which children find both alien and alienating (Wray and Lewis 1997). Writing in science then must be carefully structured and supported if it is to avoid generating such negative reactions.

Science was a subject in which there was 'less margin for error' (BS3/95), whereas in subjects like art, there were 'no boundaries' as 'you can draw whatever you like and still it could be a masterpiece' (BS3/113). Such comments suggest that school science offers little for those pupils who have a creative urge, or are interested in developing their capacity for self-expression. Whilst there are opportunities for a range of activities such as role plays, group-presentations or writing for different audiences, school science essentially deals with established consensual knowledge which is not open to critical examination or reinterpretation. Greater variety of activities within school science would help to break the one-dimensional view of science that such comments represent.

At the root of the pupils' disquiet is the lack of opportunity for control over their own learning experience. As Wallace (1996) has pointed out, in another recent study of pupils' views of their school experience, 'work where pupils had not felt in control of their learning, by definition, had little meaning and failed to engage them'. Opportunities for discussion are then, in addition to practical work, for many pupils, a point at which they regain some control of their educational experience, and a 'point of engagement' with the subject. In short, some personal ownership of a subject. Increasingly too, as issues of a socio-scientific nature force themselves into the political spotlight, some pupils would appear to find it strange that school science maintains a hermetic seal between itself and contemporary society. Their excision under the exigencies of curriculum pressure, therefore, may have a high long-term cost in pupils' interest in science.

Fragmentation. Two components were mentioned in comments about its disjointed nature: first, the disparate nature of biology, physics and chemistry and a failure to see any commonality or unity between the subjects. Pupils found themselves 'constantly chopping and changing' between doing one thing one day and something very different the next day when they 'still haven't grasped' what they did last time. Not unnaturally, pupils found that this made science less coherent and therefore harder to understand, preferring instead the clearly identifiable separate sciences.

Second, pupils also complained that the forced unity of the subject disadvantaged them, especially when it was examined and assessed, as those that were able at one science e.g. physics, were penalized by weaknesses or lack of interest in another, e.g. biology. Another frustration for pupils was some of the limited explanations offered by teachers to their requests for more extended explanations:

> Natasha: In history, I mean, certain events, you ask why they happen, sometimes they actually backtrack to why it happened. I mean with science it's just, 'It happened, accept it, you don't need to know this until A level'. (GS5/130)

Such comments suggest that the school science curriculum is failing to construct a coherent picture of the subject, its methods and its practices, leaving pupils with fragmented pieces of knowledge. This is possibly unsurprising given that philosophers and sociologists of science have failed to construct any coherent picture of the scientific enterprise themselves (Laudan *et al.* 1986; Taylor 1996). However, more disturbing is the commonly used rationale that the pupils' queries can be answered at A level. In one sense, this could be considered an act of 'bad faith' when the teacher knows that only a minority (less than 10 per cent of the cohort (Osborne *et al.* 1996)) continue voluntarily with any one science post-16. In another sense, it is simply the result of a curriculum that has its roots in a foundationalist approach, which reserves the whole picture for those who stay the course to the end offering the mystifactory promise of future knowledge as an enticement for recruitment. Such comments suggest that it may have the obverse effect for the majority of pupils and leaves them lacking an overview of some of the major achievements of science.

As a counterbalance to this critique of their experience of science education, pupils were able to offer many examples of aspects of science they found that engaged their interest.

Aspects of science pupils found interesting

Pupils in the majority of groups engaged in discussions about their particular interests in science enthusiastically. In responding, pupils were encouraged to adopt a long-term perspective of their science education. Some measure of the relative interest in the three sciences can be obtained from the number of comments coded under this category (figure 2).

Figure 2 shows that both science and non-science girls' groups talked much more frequently about aspects of biology that interested them, followed by chemistry, and then physics, and that generally they had much more to say than the comparable boys' groups. The preference shown by girls for aspects of biology confirms the findings of other research on attitudes to science (Osborne *et al.* 1996). The interest shown by boys in biology was, however, unexpected given that boys in non-science groups, in particular, had difficulty recalling many aspects at all of school science they had found interesting.

The profile of interest for both boys and girls not continuing with science was very similar, and distinct from that of those continuing with science post-16. In both, biology was the subject predominantly talked about, followed by chemistry with very little enthusiasm for physics. These findings contradict the view that boys are a homogeneous group who consistently have a more positive attitude to physics than girls (Becker 1989; Weinburgh 1995). Whilst the levels of interest shown in chemistry by boys continuing with science was not unexpected, the relatively high number of examples offered by girls in both continuing, and non-continuing science groups, was, in the light of other research on attitudes, somewhat surprising.

Aspects of biology found interesting. Aspects of human biology generated the greatest number of comments and the least disagreement among girls' groups and boys' non-science groups. As the following comment shows, the attraction of human biology for pupils lay in its relevance to themselves:

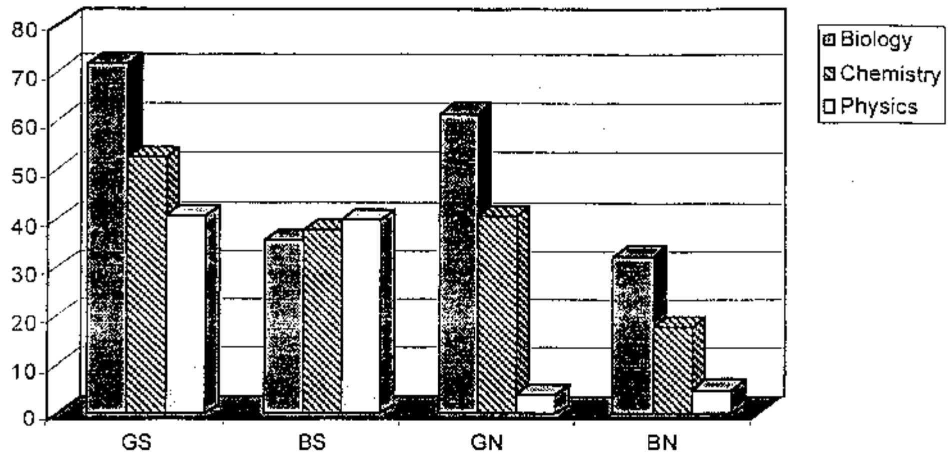

Figure 2. Number of text units containing expressions of interest in the three sciences.

> Sana: The main thing is that people relate it back to themselves, like I think most people like learning about themselves, like you said—puberty and everything like that. I mean whereas electrons ... (GS1/598)

Pupils developed the importance of relevance further, arguing that they would like to understand the ways in which a healthy body might be achieved and maintained through diet and exercise. These aspects of biology were also of interest because they were 'more modern' and contained elements of the 'unknown', for example, 'the effects of drugs' and 'cures for diseases', which made school science stimulating and more relevant to the lives of pupils. An understanding of various forms of illness also interested pupils as this enabled them to offer support and informed advice to members of their family. The sense of self-esteem gained from being able to explain everyday phenomena to their peers or family was a valued aspect of scientific knowledge.

Aspects of chemistry found interesting. Across the groups, the features of chemistry that generated interest among pupils were those which were concrete, observable and manipulable. Pupils talked with enthusiasm about 'mixing chemicals', the 'smells and colours' associated with chemical change, and of 'seeing the results for yourself', particularly when opportunities were presented for first hand practical involvement. The interest of continuing science groups was heightened when opportunities for autonomy were presented, such as choosing from a range of tests to be carried out, and in the selection of appropriate equipment. Pupils from all groups were stimulated by an element of danger associated with aspects of chemistry:

> Caroline: I was thinking about that one when you put the metal in the water and that. You know when ...
>
> Hannah: It went on fire.
>
> Suzanne: Oh, yeah ...
>
> Caroline: The alkali metals went ...

> Asha: . . . yeah, and the magnesium, or something . . .
>
> Suzanne: Put it in water, and the reaction, it was spinning round and it goes on fire, that was good (laughs).
>
> Jenny: And, like, the first I saw, like, magnesium being lit, it was really bright . . .
>
> Kim: Yeah, when that thing sparked . . .
>
> Asha: And they were saying, 'Don't look, don't look', it was, like, some sort of exciting moment. (GS3/224-232)

All groups of pupils recalled similar experiences, highlighting the affective aspects of chemistry that made them memorable.

Aspects of physics found interesting. Continuing science groups contributed the greatest number of comments on aspects of physics found interesting. Although, gender differences were apparent in the topics that engaged boys and girls, interest was rooted in the concrete and observable features of physics. Boys' interests focused on an understanding of forces in relation to cars and flight, whilst girls expressed a keener interest in aspects of light and electricity.

Despite these differences, an interest in 'space' was the one aspect of physics that united all continuing science and non-science groups. Even those pupils who claimed to have no interest in science entered into lively discussions on this aspect of science. As one pupil explained:

> John: I can remember learning about space and solar system. When you're younger that's something you're fascinated with is space isn't it? As you get older the fascination wears off, but it's still there. (BN2/209)

Pupils expressed a fascination with the Earth and the solar system, how they were formed and with the unexplored. Although aspects of the unknown intrigued several girls' groups, they related their interest more directly to themselves and the way it made them feel. For example:

> Hazel: 'Cause you think how small you are compared to everything in space. (GS2/372-375)
>
> Emma: Because that affects you. You look up and then you know what they [stars] are and you feel good, you think 'I learnt that at school'. (GS4/375)

Essentially, what school science offers here is a focus on fundamental, cosmological questions of who we are, what we are, and where we are. Such knowledge helps us to construct versions of self, identity and our role within any cosmic order. The universal success of this topic should not be underestimated as a valuable 'point of engagement' with science.

Practical work. Without exception, pupils expressed a greater interest in work that included opportunities for experimentation and investigation. However, the reasons given for this showed differences between continuing science and non-science groups.

As the following exchange shows, the issue of personal autonomy was an important factor for continuing science groups:

> Marlon: . . . you're in control of your own experiment . . .
>
> Justin: You're using your own initiative to do things really aren't you? (BS1/382-384)

This finding is supported by the work of Rudduck *et al.* (1996) who point to the fact that 'the meaningfulness of particular tasks is greater when pupils have a degree of control over the planning and execution of their work'. In the case of science, practical work provides this essential dimension offering pupils a greater sense of ownership.

Although non-science groups did not raise the issue of personal autonomy and decision making, it was the 'fun' element of some practical work in science that was emphasized. The example most commonly given was associated with dissection. Some groups bemoaned the fact that, unlike their parents before them, they were unable to carry out the dissection themselves. They spoke with enthusiasm about opportunities to see for themselves the part of a pig's heart, kidney and eye, as well as the function of the lungs.

Pupils across the groups made the point that scientific concepts were more accessible and more easily retained when supported by practical involvement, even if experiments produced incorrect results.

There was widespread agreement that there were too few opportunities for pupils to engage in practical work or discussion. The point was made by a number of groups that whilst practical work had been an integral part of science in the first three years of their secondary education, fewer opportunities had been presented in the final two years of compulsory education. For boys' non-science groups, a consequence of the decline in practical work was that subject matter became less accessible and interest waned. The watershed was said to be Year 9 (age 14). Prior to this science had largely held their interest and attention:

> Irfan: Before, when I was, like, say sitting in English, and you thought you had science next lesson, and you know you would do something good, and you know you would learn something and do something. Now with science you're sitting in English now and you think, 'Oohh no, science'. (BN3/329)

Challenge and stimulation. A significant factor in the generation of enthusiasm and interest in science among pupils in continuing science groups was personal challenge:

> Jake: It's got to be challenging, you can't have something that's really easy that you can do it first time, you've got to try something and if it doesn't work then keep trying it . . . (BS1/419)

Boys and girls in continuing science groups welcomed the challenges presented by the in-depth study of aspects of science. Boys expressed a strong desire to go beyond the basics of science:

> Robert: I meant . . . because it's more complicated compared to what we'd done in Year 9 and 10 [age 15 and 16], and I sort of didn't understand the book, and I thought, 'I want to learn that book, I want to understand it'. But once you've done it at that level then you want to keep going deeper otherwise it just gets boring, if you keep going over the same things again. (BS3/281-284)

Girls shared this desire for challenge, to 'keep going deeper', but they also expressed a desire to know why things happened in science (the causal question) rather than simply learning only what happened (the ontological question). The interest of girls in one continuing science group was stimulated by the personal satisfaction that accompanied an understanding of aspects of science:

> Layla: Every day there's something happening, you know, like with the comb and static electricity.... You've done it and you're thinking, 'Yeah, I know why that happens'. (GS1/62)

Allied to these feelings of personal fulfilment, continuing science groups expressed the view that their level of interest was related to their level of achievement. However, this was a more important aspect for girls than for boys. Girls' discussions centred on the premise that, if they were 'good at science' and 'achieved high marks in tests', their confidence was greatly improved and the subject was of greater interest to them.

In explaining the importance of personal achievement and confidence in science, continuing science groups rarely viewed science as a universal entity, but rather, distinguished the separate sciences. Gender differences were apparent in that boys expressed the highest levels of confidence in chemistry and girls in biology.

Aspects of the subject that 'amazed' or 'fascinated' were limited to those topics that had personal relevance, either to their everyday lives or those that dealt with existential questions of identity such as astronomy and cosmology. Responses that expressed awe, wonder or fascination for the subject were not as frequent as one might have hoped given that it might be argued that science is a significant achievement of western civilization.

Teachers and teaching. Attempts were made during the discussions to limit pupils' comments about individual teachers, as this was not a focus of the research. However, the importance of the role played by teachers in stimulating and maintaining pupils' interest in science was raised unprompted by pupils in every group, attracting the greatest number of comments from non-science groups, particularly from girls. Pupils in all groups identified approaches adopted by teachers that both appealed to them, and heightened their interest in aspects of science.

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 organization of work, which immersed pupils in practical activities. This was particularly significant for boys' non-science groups, for instance:

> Toby: I think it's the teachers that are different really, 'cause some teachers you go into, they've been doing loads of experiments, but the other ones just like doing—you sit down and they just say, 'Get on with this, do the writing'. (BN1/710-711)

The interest of pupils in continuing science and girls' non-science groups was raised by teachers who devoted time during lessons to the clarification of content. Pupils valued individual attention from teachers who were prepared to 'explain' and, when difficulties were experienced, were able to 'help you through it' (BS3/208). The point was strongly emphasized by pupils that teachers who provided opportunities for them to take an active role in their own learning enhanced their enthusiasm for aspects of science.

Girls in continuing science groups highlighted the importance of building a rapport or relationship between pupils and teachers that developed through opportunities to raise questions and discuss aspects of science. Several girls commented on the value of humour during science lessons, for instance:

> Angela: It's good when teachers can have a laugh with you, 'cause you're learning at the same time as you're having a laugh. (GS2/244)

Boys in one continuing science group made a similar point, but their focus was upon the creation of a 'relaxed environment' (BS2/582) in science lessons which made them more enjoyable and increased pupils' motivation. The point was made that 'when teachers realize that then I think it will all be all right' (BS2/587).

Many of these comments simply reinforce the findings of work found elsewhere on effective teaching that children like teachers who maintain order, make learning interesting through the use of a range and diversity of activities, and sustain an atmosphere of mutual 'good humour' (Cooper and McIntyre 1996). Humour was valued simply because it helped to sustain a happy atmosphere in the classroom that was conducive to learning. Within these comments also, can be found an evaluation of the teacher's role in their success with the subject—an aspect that increasingly dominated children's thinking as public examinations loom into view. Teachers who simply relied on 'writing on the board' and textbooks were viewed as weaker than those who offered an opportunity to 'do the experiment' and 'to talk about the bits you don't understand in the experiments' which provided a 'better opportunity for learning'.

Summary and discussion

This research offers an important window on the pupils' perspective of school science education and their reactions to their experience. A decade after the introduction of the National Curriculum in England Wales and the compulsory imposition of 'Science for All', aspects of this research would suggest that this may have been a Pyrrhic victory.

Emerging clearly is a number of discontents about current practice, particularly in the latter stages of compulsory schooling. Dominant amongst these is a sense that, whilst science is considered to be an important subject, that message is communicated to too few pupils by their experience of school science. Missing for far too many pupils, from far too many of the topics they were taught, were those vital ingredients—relevance and greater autonomy. School science engages when it makes connections to the pupils' everyday lives. Hence the success of human biology—knowledge whose application is immediate, transparent and unquestionable. Physics and chemistry, in contrast, have less points of contact with pupils' experiences and, even when technological applications are introduced, they are often done as a postscript whose illustrations appear archaic to some pupils. The privileging of science over technology, within the English and Welsh National Curriculum, is akin to introducing the grammar of a language before practicing its use. In both situations, the abstractness of the science over the relevance of technology is simply incomprehensible to pupils. Rather, the findings of this research would suggest that courses that privilege technology over science—introducing the applications first such as Salter's Science should be the natural first choice for any school. Any other curriculum course should require careful justification.

Vital to any such course, as well, would be a component that allowed for the exploration of aspects of contemporary science. From the pupils' perspective, such an element is essential to constructing a connecting thread between school science and the 'real' world of the adults, endowing the subject with a relevance that no other mechanism can. Whilst pupils will accept a curriculum diet that consists largely of the received wisdom of uncontested and pre-established knowledge, contemporary science offers a glimpse into the world of here and now. This is a world of science-in-the-making, of future possibility and uncertainty where their views can begin to matter providing an essential dose of salience and significance. Just as good English teachers have always drawn parallels between the plays of Shakespeare and contemporary life, so effective science teachers make links between the science they teach and today's technology. But the strength of the views expressed in these data suggest that the link between science and contemporary events is too often ignored, or alternatively, crushed by the weight of an overloaded curriculum. Therefore, curricula need to institutionalize such links either through the programme of study, schemes of work, or formal assessment.

The data here suggest that the diet offered by science courses of a content dominated nature such as that found in the English and Welsh National Curriculum is both insufficiently varied and overwhelming. In a climate of 'high-stakes' assessment where many teachers feel compelled to cover the entire content to maximize their pupils' chances of success, the experience is too rushed, forcing teachers to use techniques such as 'copying', which are both mentally stultifying and of little educational value. The other unintended effect is the elimination of anything extraneous of a time consuming nature such as practical work or opportunities for discussion. Yet, it is exactly these components that are highly valued and prized by pupils for the interest they generate in the subject. In such circumstances, it is hard to avoid the conclusion, that the imposition of such pedagogic practice by current policy, intentionally or otherwise, is simply harming the long-term interest of science in our culture. Moreover, it is highly anomalous, that in an age when society increasingly places a premium on the higher order cognitive abilities to retrieve, sort and sift information, that such curricula continue to place an emphasis on lower order abilities of recall and comprehension of basic concepts. The contrast between the political rhetoric, which places a high premium on the value of education for the skills that contemporary society prizes, and its 19th-century emphasis on an ability to recall the 'facts' of science is very stark.

In one sense then, our data merely confirm previous research about pupils' views and attitudes to school science reviewed elsewhere (Osborne *et al*. 1996), albeit using a different methodology. For instance, Claxton's (1991) findings that the experience of secondary school science was 'like being on a train in carriages that had blanked out windows', one where only the train driver knew where you were going and nobody gave you any map or overview of the journey. In essence a magical mystery tour, which rapidly lost its initial enchantment. Likewise it confirms the critical value and significance to pupils of the opportunity to experience physical phenomena first-hand—the opportunity to engage in apparent autonomous discovery' (Solomon 1980). However, in another sense, we would suggest that it offers new insights into the specific features that generate such discontent, such as repetition, copying, and the rushed experience, which are the products of the recent introduction of a national curriculum and system of 'high-stakes' assessment. In addition, this work has exposed that the mismatch between science-in-society and science-in-school is a much stronger feature of pupils' experience. Thus the value of this research lies not so much in its originality, but as an aid in identifying how the situation might be remediated so that both the pupils' and the teachers' experience is improved.

In our findings (reported fully in Osborne and Collins (2000)), all groups of pupils, parents and teachers, independently suggested a post-14 curriculum consisting of a core plus optional modules. The core would provide an essential element of breadth, whilst the options would both permit study in depth of topics that interest pupils, and reduce the content to manageable proportions. The idea that a single, universal Procrustean curriculum would be an appropriate solution to the diverse needs of age 14-16 pupils never has had any justification, either psychologically or historically, and for that matter, never will do. In addition, it would allow some flexibility to provide a curriculum fare that could, for instance, provide more biology and less physics and chemistry. The data presented here show that whilst biology still retains its traditional appeal for girls, it is also appealing to boys. In such a context then, there seems little justification for insisting on an equal division of curriculum time between the subjects, especially when large elements of physics and chemistry have been previously covered by age 14.

The issue of repetition also needs to be addressed. There is good evidence that secondary science teachers are still failing to recognize the strengths of science in the primary schools (Nott and Wellington 1999). In addition, the hierarchical nature of the subject means that many topics will be revisited, albeit in a more complex and sophisticated form. A strong finding from this research is that neither the need for repetition, nor the distinction between current and previous approaches is self-evident to pupils. The apparent simple repetition of a topic, which fails to build and develop pupils' knowledge, and to make its new insights distinctive, has the potential to alienate many pupils from the subject. In the short term, teachers need to be more aware that the repetition within the existing spiral structure of the curriculum is a point of disengagement for many pupils. Determining the nature of pupils' prior experiences is, therefore, an important process if repetition is to be avoided.

In the longer term, it begs the question whether science is best taught in this manner. An alternative would be to cover fewer topics in each key stage in more depth, eliminating much of the potential for repetition. If variety is truly the 'spice of life', then a curriculum which, unintentionally or not, offers a uniform diet and enhances the opportunities for repetition is doomed to generate some of the negative affective outcomes that we have reported here.

Whilst the science education community saw national curricula as a means of ensuring all sciences were taught to all children from the point of entry to the point of exit—a deliberate, uncontested and positive outcome—they failed to recognize that policy changes are often accompanied by unintended, or unrecognized outcomes, and in this case often negative. If so, and our data would suggest that there are significant concerns about the affective outcomes of current practice, then these should not be ignored. In the current *realpolitik* which demands systemic measures to assess the performativity of education, to argue for the removal of a national curriculum or its assessment system would, in our view, be pointless.

Rather, we would suggest that curriculum developers and science educators, in their obsession with prescribing the 'intended' (Robitaille 1993) curriculum, have forgotten that the 'implemented' curriculum is determined, as much if not more, by the measurement of the 'attained' curriculum—particularly when those measurements may be related to job security or performance-related pay. The emphasis on transmissive modes of teaching, copying, and the lack of time for a broader range of activities, suggest that teachers' reading of the salient and significant aspects of the existing curriculum, as defined by its assessment, is extremely astute and well-measured. Therefore, it is imperative, that the skills and knowledge measured by the formal assessment system should accurately reflect the intentions of the curriculum, and that the science education community should devote as much energy and attention to the development of an effective and appropriate system of assessment as they do to specifying curricula or developing support materials. For too long, assessment in science education has been a forgotten feature of the landscape—an extraneous feature, which has appeared to merit little attention. Our contention would be that the improvement of contemporary science education is dependent upon the community elevating its importance to the central position that it occupies for teachers. To do anything less would be a grave error. Thus if the skill of critical scientific literacy is such a prized aim of contemporary science education then, at the very least, one would expect to see assessment items that expected pupils to critically interpret data sets or to evaluate claims advanced by others for errors and omissions.

The other message we see in this data is that teachers 'read' from the increasing plethora of national curricula, prescribed schemes of work, or prescribed textbooks that their professional judgement is not to be trusted—that experience prescribed in such texts are not so much to be interpreted as 'delivered' regardless of their professional judgement (Ball *et al*. 1992). Given such an ideological message, albeit implicit, is it any wonder, that the data in this study show that the experience offered to the pupils is one that accords with the message. And just as the removal of the opportunity for personal autonomy is resented by pupils, so it is likewise by teachers who become similarly alienated and disengaged. We would, therefore, suggest, that national curricula that left more of the detail open to interpretation by individual teachers, by prescribing areas of content only in broad terms and offering at least limited opportunities for choice and selection, would be more likely to result in a positive appropriation by the science teaching force, and in a positive outcome for pupils.

In this respect, it is worth noting that emerging spontenaety and unsolicited, from interviews with both pupils and parents, was a plethora of comments about the importance of 'good', enthusiastic teachers of science for sustaining their own interest in the subject. Maintaining school science as a vibrant, stimulating and lively subject within schools, in our opinion, is critically dependent on the ability of the education system to recruit and retain competent and confident teachers of science who are justly remunerated for their skills. The current recruitment crisis (at least in England and Wales), particularly in physics and chemistry does not bode well for the future of school science. In the long term, the failure of school science to engage its pupils will inevitably lead to a greater exacerbation of this problem as fewer and fewer pupils choose to return to a subject that lacked appeal. In the short term, this is a problem that requires urgent attention and reconsideration to make the profession of science teaching both valued and financially viable, if school science is not to enter a spiral of decline.

Our core concern is that the negative affective experiences, of the type described in these data, may remain long after any cognitive achievements. The consequence may be disenchantment with science, which is seen as a subject of little interest; a domain which is hermetic, exclusive and 'not for me'—essentially one that is beyond the comprehension of the average individual. In an era where scientific issues such as genetic modification of foods, global warming and others continually surface as the political and moral dilemmas confronting society, the disengagement or disenchantment of our youth with science may increase the separation that currently exists between science and society. Such a consequence is one that an advanced industrial society can ill afford to pay, both at the individual level where it might lead to the rejection of sound scientific advice, or at the societal level where limitations may be imposed on scientific research that could have potentially beneficial outcomes for humanity. Perhaps, more tragic, will be the simple rejection of a body of knowledge that must, on any account, represent one of the greatest cultural achievements of Westerrn societies. As a society, we ask, is this a price we can afford?

Notes

1. A report of the full findings is available in Osborne and Collins (2000).
2. All of the names used in this research are pseudonyms.
3. All of the references here are to the specific text unit in the transcript. In coding the transcripts, paragraphs were chosen as the basic text unit of a response.

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Appendix

Questions used in focus group interviews

The value of school science

Q1 What was your favourite subject at school and why?

Q2 Comparing science to your favourite, or other subjects you studied at school, in what ways would you say that science was different from your favourite, or other subjects?

S2 In today's society science is one of the most important subjects to study at school.

The application of science to everyday life

S1 The science I learnt at school has been of little use or value to me in my life to date.

Visions of school science in the future

S3 If I had a free hand to decide what young people learnt in school science, I would not change anything.

The appeal of science in everyday life

S4 The science that I read in the newspaper and see on TV is of no interest to most people.