

Institute of Physics Report

Girls in the Physics Classroom

A Review of the Research on the Participation of Girls in Physics

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Abbreviations

AAUW	American Association of University Women
APU	Assessment of Performance Unit
AQA	Assessment and Qualifications Alliance
CSE	Certificate of Secondary Education
DfES	Department for Education and Skills
ESRC	Economic and Social Research Council
GASAT	Gender and Science and Technology
GCE	General Certificate of Education
GCSE	General Certificate of Secondary Education
GIST	Girls into Science and Technology
IPN	Institut für die Pädagogik der Naturwissenschaften
NAA	National Assessment Agency
NAEP	National Assessment of Educational Performance
NFER	National Foundation for Educational Research
OECD	Organisation for Economic Co-operation and Development
Ofsted	Office for Standards in Education
PISA	Programme for International Student Assessment
SATs	Standard Assessment Tasks
SCAA	School Curriculum and Assessment Authority
SCRE	Scottish Council for Research in Education
SLIPP	Supported Learning in Physics Project
STS	Science, Technology and Society
TIMSS	Trends in Mathematics and Science Study
VCE	Victoria Certificate of Education

1: Introduction

Context of the review

The Institute of Physics is committed to maintaining quality in, and access to, physics education. It campaigns to increase the recognition of physics, its opportunities and its importance to the national economy and science knowledge base. The combined impact of the continuing decline in uptake of the physical sciences post-16 and the 30% reduction in physics departments in higher education institutions since 1997 has been a central concern of the Institute and a target for action. As part of this action in 2004 the Institute commissioned two pieces of work:

- *Yes She Can* – an investigation by Bob Ponchaud (ex-HMI for Science) into schools that are successful in attracting girls to study A-level physics and how this might inform other schools.
- *Girls in the Physics Classroom* – a review of the research literature by Patricia Murphy and Elizabeth Whitelegg at the Open University.

The aim of the review of the research literature was to establish current understanding of the nature of the problem of girls' participation in physics and the possible reasons found by research for girls choosing not to continue with their study of physics. It also tried to identify what strategies have been successful in increasing the number of girls studying physics post-16. The focus on girls' participation and recruitment post-16 was in recognition of the trends in entry patterns at A-level. The decline in entry to physics A-level has applied both to boys and to girls. However, the subject remains the most popular of the sciences with boys, as evidenced by the boys' entry rate to physics in 2004, which was higher than for chemistry and biology. However, the girls' entry rate is now very low compared with the boys', and compared with the girls' entry for chemistry and biology. This decline is significant because it impacts on the future workforce, which may lack important skills and knowledge, and this includes future teachers who may not have the qualifications and background needed to enthuse the next generation of potential physical science students. Indeed, without qualified teachers the decline may accelerate.

Nature of the review

The problem posed for the review was to provide evidence to inform policy-related decision-making. There were two fundamental concerns that informed the approach to the review. The first was the developing understanding in the research community about how to view and study gender. The view of gender increasingly advocated in the field is that it is constructed in social interaction and is not a fixed attribute of an individual. Therefore it is considered inap-

propriate to use the term gender when it is biological sex that is meant. Such a view also brings into question the validity of referring to gender differences generally as being about "girls" or about "boys", without recognising that within groups there may be great variation, and between groups considerable overlap. This style of reporting is referred to as an essentialist approach to gender, which assumes that any gender difference is attributable to boys or girls as a whole. It is very difficult to avoid this in both writing and reading a report like this, but every attempt has been made to note that the differences referred to are trends for a group and not attributable to all members of that group. Researchers have challenged the emphasis on the individual in the study of gender, arguing for a shift in attention towards the social relations in which gender is used (i.e. the situated meanings of gender). The consequence for the review is that this type of approach is typically associated with small-scale in-depth qualitative research. The review therefore includes both large-scale and small-scale and quantitative and qualitative research.

A second concern related to the field itself, as there is limited recent research into gender and physics, particularly in England. It was therefore felt that the absence of research evidence was as important as its presence. Consequently a range of research literature was explored to point up:

- where understandings about the nature of the problem of girls' participation in physics were emerging in a consistent way;
- how understanding about the issues and their impact had evolved;
- where there was limited research evidence and where there was an absence of evidence.

The researchers quoted in the review do not all share the same view of gender but, by including different perspectives and approaches, common issues emerge as well as new insights into the nature of the problem and how to engage with it. However, in writing up the findings and in the recommendations about action we have tried to maintain a view consistent with current research about how gender influences learning. The review is intentionally informed by our experience and knowledge of the field and is therefore a narrative that is detailed and thorough. It should be noted that the report in [section 7](#) also includes new analyses of performance data undertaken specifically to inform the review. The review process was informed by the practices of systematic reviews, in that the criteria for inclusion were identified, a systematic approach to key words employed, and the research area mapped out. These are discussed next.

“If girls were more proportionally represented, recruitment to physics A-level could be substantially improved.”

Scope of the review

To consider the contemporary issues concerning the participation of girls in physics post-16, the review focused on literature published in the timeframe from 1990 to 2005. It initially focused on UK-based research only. However, where research was lacking or limited, it went further. So research pre-dating 1990 was considered where there was little useful research after this time or where the earlier studies had important messages for the review and the research had not been replicated more recently, or not replicated on the scale of the earlier work. Research beyond the UK was included when consideration of UK-based research only would have made the review too limited. This non-UK research was only included if it was transferable and applicable in a UK context. Educational systems such as those in Australia, New Zealand, Canada, Scandinavia and Eire are not so different to negate the relevant research messages. Even research undertaken in different education systems, such as the US, have important messages for the review where they are independent of the education system but are concerned with the nature of the subject, the pedagogy, teaching styles, etc.

The brief for the review limited the literature search to the secondary compulsory education phase. This was extended to include significant studies of post-16 physics because many of the studies pre-16 are concerned with science rather than physics. It is also worth noting that the great majority of students in England and Wales currently study science via the Double Award General Certificate of Secondary Education (GCSE) syllabus up to age 16 rather than as separate subjects in the Triple Award GCSE. These students are not always able to distinguish between the three separate sciences, so research that investigates students' perceptions of science as a whole at this age has important messages for the review.

Criteria for inclusion of the research studies

The following criteria were taken into consideration:

- age of the students 11–16;
- contemporary nature of the research;
- relevance to the UK educational system;
- clarity of purpose;
- clarity of data-collection tools;
- attention to the validity of the analysis and its interpretation.

The following types of research, which met these criteria, were included:

- large-scale empirical studies with descriptive analyses;
- large-scale empirical studies (including longitudinal studies) that used analytical techniques such as factor analysis incorporating multivariate and univariate analyses to examine relationships between factors;
- small-scale in-depth follow-ups of large-scale studies or in-depth explorations that illuminated issues emerging from larger-scale studies;
- theoretical papers that offered well argued and theoretically justified insights into the nature of gender issues and effects.

Sources that were rejected included:

- opinion pieces, not based on empirical evidence or well grounded theories;
- research set in education systems culturally dissimilar from those in the UK;
- research not methodologically well founded.

The review includes references to 177 literature sources that range from books, research reports, book chapters, journal articles and conference papers.

Structure of the review report

The **executive summary** reports the main findings and policy recommendations, and it precedes the review. The review comprises eight sections. The first is this introduction, and in the following six the review findings are presented under the issue headings emerging from the literature. **Sections 2–7** each contain key messages in the form of summary statements emerging from the studies examined. These are displayed within each section in red. While each section emphasises a particular issue or set of issues on the participation of girls in physics, all issues considered by the report are interwoven and some repetition of issues within the different chapters is unavoidable – the research studies rarely isolate individual factors owing to the complexity and multivariate nature of the problem. At the end of each of **sections 2–7** the implications of the studies are identified and summarised. **Section 8** details the recommendations for action that follow from these implications, presented under the headings Policy, Practice, and Research.

2: Interests, motivation, course choices and career aspirations

This section of the review considers studies that examine the nature of students' interests in science and how these are seen to influence their motivation to study physics post-16, and it identifies what other influences research has established that affect students' course choices. The research typically refers to interests and attitudes without any clear distinctions made between them. Overall the research referenced is concerned with students' attitudes towards science and physics, and this tends to mean how students report they feel about the subject in relation to themselves. For the purpose of the review we are not critiquing the constructs that are said to represent students' attitudes or the measures used. This is done elsewhere in, for example, the review by Osborne *et al.* (2003). The section first considers the pervasiveness of the findings across English-speaking and European countries; then examines overlaps in findings from studies that use different approaches to the way in which the data are conceptualised and analysed.

Most of the data reported are collected by questionnaires using simple rating scales, ranking strategies and/or by interview data. Some studies use factor analysis to validate reporting constructs or composites. These studies usually employ multivariate and univariate analyses to determine the nature of effects and relationships between them, which allows insights to emerge into the complexity of the relationship between students' beliefs about physics, about themselves in relation to it and their motivation to engage with the subject. The section covers:

- Student interests:
 - the nature of students' interests;
 - the decline in interests.
- Influences on course uptake:
 - career aspirations, enjoyment and prior achievement;
 - student motivation and course uptake.
- The interrelationships of influences on students' choices:
 - students' social identities in relation to science;
 - what influences attitude development in physics;
 - differences within boys and girls.
- The implications.

There is overlap between this section of the review and the following one on relevance and context. This is because some of the measures used and the interpretations made include references to students' perceptions of the relevance of the subject to themselves and the characteristics of their experience of the subject that influence these perceptions.

Student interests

The nature of students' interests

Reference is made to the Assessment of Performance Unit (APU) data not only because of its relevance to the English context but also because the findings are for large representative populations of students, so they provide a useful context for later findings and those from other countries. More than two decades ago the national monitoring of student performance in science by the APU in England, Wales and Northern Ireland established for students aged 11, 13 and 15 years old that:

- boys in greater numbers wanted to know more about physical science topics whereas girls' interests lay more in the biological and environmental sciences;
- this divergence in interest extended to a wider range of issues by the end of compulsory schooling;
- girls' and boys' job aspirations across the ages reflected traditional employment patterns, and jobs traditionally undertaken by men were still those for which physics was considered most appropriate.

National surveys in other countries, such as the US, revealed a similar divergence (Johnson and Murphy 1984). A study of 425 students in year 11 in a school in Canberra, Australia, similarly found that students' enrolments in courses were polarised between the biological and physical sciences (Cameron 1989).

In a more recent US study, Farenga and Joyce (1999) examined the views of students of 9–13 years old (N = 427) in junior and senior high schools about course preferences. Students were asked to select from a range of courses (24) of which 12 were science related. The study found the expected polarisation between life science and physical science courses in girls' and boys' choices for themselves. In exploring students' beliefs the study asked students to select courses they considered suitable for girls and courses suitable for boys. The study found that:

- 69% of boys selected no physical science courses for girls;
- 59% of girls selected two or more physical science courses for boys;
- 52% of boys selected two or more life science courses for girls;
- 76% of girls selected life science courses for boys.

A liking for science and enjoyment of it are often considered to be synonymous with an interest. That is because researchers assume that one implies the other, which is

“Students lack knowledge of a range of science-related careers and...this influences their decisions about whether to study physics.”

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not necessarily the case, though a relationship is expected between these measures. Warrington and Younger (2000) surveyed students in year 11 (aged 15–16) in 15 comprehensive schools (186 boys, 176 girls) in England about their subject preferences and found that:

- 42% of girls enjoyed science compared with 63% of boys;
- 6% of girls reported that science was their favourite subject compared with 37% of boys;
- 63% of girls said they liked biology, and this fell to 37% for chemistry and 22% for physics.

Osborne and Collins (2000) surveyed students' views of school science using focus groups that involved 144 year-11 students (aged 16) across 20 schools in England. The students included a mixture of those who intended to continue with their science study and those who didn't. The authors noted that:

- overall, students reported more negative comments about the relevance and appeal of chemistry than they did for physics;
- girls continuing with their study post-16 commented more on aspects of physics than other groups;
- girls in both groups made many more negative comments about physics than boys did;
- girls' interest in physics was in the areas of light and electricity whereas boys' interests lay in forces in relation to cars and flight;
- both boys and girls were enthused by space, the Earth and the solar system;
- girls more than boys related their interests to themselves and their personal concerns;
- girls made many more comments than boys about the aspects of physics that they considered were not useful in everyday life, which included references to forces, potential and kinetic energy, friction, and electromagnetic fields and transformers.

Survey evidence uncovers a gender difference in reported liking for science, with more boys than girls reporting that they like the subject. In their interests and course choices, more girls than boys report a preference for the biological sciences and more boys than girls report a preference for the physical sciences. There is some evidence that, at the end of Key Stage 4, overall, boys and girls report more negative comments about the relevance and appeal of physics and chemistry than of biology. This is particularly true for girls commenting on physics, and includes girls who intend to study science post-16.

Such surveys tend not to report the overlap between boys' and girls' interests. Where they do, it is found at Key Stage 4 that boys and girls share interests in aspects of physics. They also report differences in their interests, and in the case of girls these appear to relate to their views of the personal relevance of physics topics.

A study by Breakwell *et al.* (2003) looked at students' gender representations in relation to science. It involved students aged between 11 and 16 ($N = 1140$) in schools in the UK. They randomly assigned two questionnaires that sought students' views about two imaginary students, a boy and a girl who liked science and a boy and a girl who did not. The questionnaires also asked the students to rate their liking for the subjects that they were studying and this was used to split the students into two categories: those who did or did not like science. The students had to rate themselves and the imaginary students on 35 positive traits. Twenty related to "masculine" traits (e.g. I am aggressive; I am willing to take risks) and "feminine" traits (e.g. I am sensitive to the needs of others; I am understanding). Fifteen were described as socially desirable traits that were not gender specific (e.g. I am friendly; I like being challenged; I am fair minded). It was expected that the questionnaires would reveal stereotypes that associated being good at science with masculine traits. However, the study found that this was not the case:

- Students who liked science, both boys and girls, rated themselves more positively on feminine and non-gender specific traits (but not masculine traits) than those who did not like science.
- The imaginary girl who liked science was rated lower on feminine traits, but the boy who liked science was rated higher on feminine traits.
- Students gave significantly more positive ratings to the imaginary students that matched their own liking or disliking of science.
- There was a "black sheep" effect in that, for example, boys who did not like science were more severe in their rating of the imaginary boy who did.

Traditional images of masculine science may have changed or become less significant in accounting for gender differences in science. To understand how boys and girls feel about themselves in relation to science requires a more considered view of how gender operates in classrooms.

The decline in interests

Results from National Assessment of Educational Performance (NAEP) studies in the US revealed consistent declines in attitudes toward science from earlier to later grades in school (Piburn and Baker 1993). Piburn and Baker's study, based on interviews with 149 students from US elementary, junior and senior high schools, concluded that children at the beginning of their schooling liked science. However, in high school, increasing alienation resulting from "the growing abstraction and complexity of science classes" (p402) emerged clearly as a negative influence on attitude:

"Many students reported that they were no longer able to understand science. They

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no longer enjoyed it and would not pursue it any longer or consider it as a career.” (p403)

Recent surveys, such as that of Northern Ireland students, which have compared attitudes towards science for different age groups (e.g. students aged 8–9 and aged 10–11 in primary schools (N≅1000)), reveal that a decline in interest in science is already evident among the older students (Murphy and Beggs 2003). Pell and Jarvis (2001) found a similar situation in primary schools in England. However, in the summary of the national report for England of the Trends in Mathematics and Science Study (TIMSS) (Ruddock *et al.* 2003) the findings suggest otherwise. For example, it was reported that:

- almost half of students in year 5 (aged 9–10) would welcome more science lessons;
- just over half of the students in year 9 (aged 13–14) would do so.

This difference between studies could have arisen because of the context in which the questions were asked, the nature of the questions or the sample, or a combination of these.

Reid and Skryabina (2002), reporting on the situation in Scotland, found that students aged 10–12 (N = 142) at the end of primary schooling were still very positive about science:

- Both boys and girls considered it to be an important subject in line with the national report findings for England.
- Boys reported significantly greater interest than girls, even though the views that the boys expressed were more polarised.
- The decline in the proportion of students wanting to study science from primary to early secondary was significant and the same for boys and girls.
- In early secondary school the difference between boys’ and girls’ views of science at age 13–14 (N = 373) had increased with girls’ interest in science declining along with their view of their competence in science (self-efficacy).

The findings for all studies confirm a general decline in interest in science, although the age at which this begins is not consistent across studies. Osborne *et al.* (2003) suggest that it might reflect that the decline is not linear and is more dramatic post-14. Gender may also be implicated in this increase in the decline post-14.

The other significant finding is that the decline is accelerated for girls, and the gender gap in interest increases across the phases of schooling. A study of 8000 physics students in Germany, undertaken by researchers from the Institut für die Pädagogik der Naturwissenschaften (IPN) from 1984 to 1989, found that girls’ interest in physics decreased as they grew older (Hoffmann 2002).

Table 2.1: The influence of various factors on students’ decisions to study science post-16, rated by heads of science in schools and colleges

Influence rating	Heads of science: schools	Heads of science: colleges
1	Career aspirations	Career aspirations
2	Students’ liking for physics	Students’ liking for physics
	–	Students’ prior achievement
3	Teachers’ enthusiasm for physics	–
4	Students’ prior achievement	Teachers’ enthusiasm for physics

There is considerable evidence that, overall, both boys’ and girls’ interest in science declines across the phases of schooling. The decline in interest may begin for some students in primary school and increase post-14, particularly for some girls and particularly in physics. For some girls the decline is linked to their increasing feelings of not being good at the subject (i.e. their sense of self-efficacy). This in turn leads them increasingly to experience physics as difficult.

Influences on course uptake

Career aspirations, enjoyment and prior achievement

Cameron’s case-study (1989) of student choices in a school in New South Wales found that:

- similar proportions of students reported that they chose physics and chemistry for career reasons;
- far fewer chose the subjects for interest and this was even lower for female students;
- in contrast, enjoyment of the subject was the main reason students gave for studying biology.

Sharp *et al.* (1996) at the National Foundation for Educational Research (NFER) in England carried out a large-scale questionnaire survey of A-level course take-up across schools and colleges in England and Wales for the School Curriculum and Assessment Authority (SCAA). They noted a relationship between the proportion of students who had taken the separate sciences at GCSE and the higher take-up of physics, chemistry and biology at A-level. Heads of science were asked to rate the influence of a number of factors on students’ decisions to study science post-16 (table 2.1).

Perceived strategic usefulness of physics is a significant predictor of the choice of physics for both boys and girls.

Osborne and Collins (2000) reported one geographical difference between students in the north and the south of England, which was that girls in the north continuing with their science studies post-16 made explicit links between enjoyment and career aspirations:

“It’s because I enjoy it and because I want to become a paramedic as well, in medicine, so I’m interested in it and I want to learn more about it because of what I want to be.” (p41)

Stewart (1998) examined the views of students who had

elected to study physics. Some 128 A-level students (27% girls; 73% boys) in year 12 (aged 17–18) in nine mixed and single-sex selective and comprehensive state schools and sixth-form colleges in England were included in the study. The study found that:

- girls studying physics were higher achievers than boys in terms of their GCSE achievements;
- 40% of the girls compared with 21% of the boys rated physics as their favourite subject at GCSE;
- of the 123 students who intended to go on to university study, only a small proportion intended to study physics (eight boys, two girls);
- the career choice for the majority of girls studying physics at A-level was medicine (46%).

Reid and Skryabina's (2002) study that was cited earlier reported on the results of a study that examined university students in Scotland studying physics and sought their views of what had influenced their choice of subject. Some 87% identified enjoyment of the subject in school as the main influence, followed by good grades (74%) and career opportunities (49%). These factors and their perceived influence are similar to those reported by Sharp *et al.* (1996), with the exception of teachers' enthusiasm for the subject, which teachers rated but students did not.

Teachers and students rate career intentions as an important influence on school students' course choices. Students report that they choose biology for interest but tend not to choose the physical sciences for this reason.

Difficulty and prior achievement are strongly linked to course uptake, and there is a relationship between them. In the survey by Sharp *et al.* (1996), teachers ranked perceived difficulty as the highest factor that discouraged take-up of science followed by negative subject image. Fitz-Gibbon (1999) examined the long-term consequences of course choice at age 16. The questionnaire data came from 543 students across five local education authorities in England. Students were allocated a score on the basis of the difficulty of the subjects that they chose. Physics, chemistry and maths were considered the most difficult. This was established by comparing the severity of grading (see section 6 for a discussion). The students' scores were referred to as the curriculum choice index. This index was strongly related to science performance at age 16.

Student motivation and course uptake

Student enjoyment and liking for the subject are reported to be very significant factors in course choice by students and teachers alike. Some studies have examined the nature of the courses that increase students' motivation to engage with physics.

Reid and Skryabina (2002) noted that in Scotland, in contrast with the rest of the UK and other countries, physics is the fourth most popular subject at Higher Grade, which

students take at age 18. They inferred from this that the prior physics course, the Standard Grade, which students took at age 16, was successful in engaging and retaining students' interest in physics.

The study compared separate cohorts of students at different points in their primary and secondary schooling, which means there may be sample effects because the samples were not sufficiently large to be representative. The research found that, in a sample of 152 students studying physics at Standard Grade (aged 14–16), 90% intended to continue their study at Higher Grade. The authors noted that the actual figure going on to study was 55%, but this reflected the grades achieved rather than any decline in student interest. Some 90% of the students attaining the required grades continued their study of physics, providing further evidence of the link between prior achievement and subject choice. This represented "the highest retention rate of any subject" (Reid and Skryabina 2002, p73).

Although take-up was high on the Higher Grade physics course, students rated the Standard Grade as more enjoyable, interesting and important. The Standard Grade is described by the authors as application based and the Higher Grade course as principle based.

Only 11% of students studying Higher Grade intended to continue with their physics study post-18. The authors argued that:

- the attitudes of students towards science deteriorated from the later stages of primary school to the second year of secondary, the effect being more marked for girls; this deterioration was halted for those who continued with physics at Standard Grade (Reid 2003);
- at the end of Standard Grade study, girls' views of physics being "their subject" (i.e. their self-concept in relation to physics) had declined in comparison with boys;
- the proportion intending to study physics post-16 was very high (92% of girls and 89% of boys).

In the sample post-16 there were 28 girls compared with 56 boys. While a high proportion of these students intended to continue study at university, the number intending to study physics was low – three girls and six boys.

There is evidence that prior achievement is a significant influence on students' course choices in school. Students, even if they are interested in the subject, need to feel that they can do physics and this may be more significant for girls than for boys. Studies have found that for some girls, as they continued with their study of physics, their self-concept in relation to it declined.

Reid and Skryabina (2002) concluded that if numbers of students studying physics is a concern, the differences between the Higher Grade course, where student interest

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and motivation declines, need to be compared with the Standard Grade course.

Sparkes (1995), however, suggested that the greater uptake of physics among Scottish students compared with students in England was due to the subject being taught by qualified physicists. The author noted the “virtuous cycle” implied by more students entering university to study physics was that it was more likely that the number of physics teachers would be maintained, thus sustaining the quality of physics teaching and the number of students entering university.

As part of their study of gender differences in examinations at 18+, Elwood and Comber (1996) surveyed 247 students from years 12 and 13 in England about their attitudes towards various aspects of the A-level physics syllabus. The study found that:

- a majority of the students reported high levels of confidence, motivation, enthusiasm and enjoyment;
- female students’ enjoyment of the subject was significantly more positive than that of their male peers;
- while female students considered physics would be relevant to their careers, they, along with their male counterparts, were not intending to go on to higher study;
- both male and female students believed that the subject was socially relevant.

Stewart (1998), in her study of A-level students in English schools, asked them to describe the characteristics of their physics course:

- Both males and females agreed that there was an emphasis on mathematical content and the development of practical skills, and an absence of sociological applications.
- Both males and females favoured an increased emphasis on IT and practical skills.
- Boys were more likely than girls to want an increase in the mathematical content of their courses.
- The main difference in views was that girls wanted more emphasis on sociological applications than boys.

This last finding is further supported by the findings of a survey of German students (Hoffmann 2002). This found that girls placed a high value on references to society and social involvement when learning physics and on the practical applications of theoretical concepts. The studies discussed and the findings reported by Elwood and Comber (1996) show no relationship between positive classroom experiences for girls and their feelings about the subject as being right for them (i.e. their self-concept in physics). Osborne *et al.* (2003) in their review of the literature on attitudes towards science also noted this apparent contradiction. Studies in other countries support this finding. From his in-depth interviews with science-proficient students aged 15–16 in New South Wales, Lyons (2004) concluded:

“It was decidedly not the case that science-proficient students choosing physics and chemistry courses...described a more, or less, attractive picture of the school science experiences than did those choosing not to continue with science study.” (p3)

There is evidence that the type of course studied is a significant influence on both boys’ and girls’ enjoyment of and motivation to learn physics, and this is linked, particularly for some girls, to the match between their goals for their learning and the goals of the course. More girls than boys report that they value social applications and want more social relevance in their physics courses, which can be linked to the higher recruitment and retention of girls to physics courses that emphasise real-life applications.

Studies at Key Stages 4 and 5 have found, however, that while interest in and enjoyment of physics are important influences they are not sufficient reasons for students deciding whether or not to continue their study of physics. While positive experiences might not impact on students’ course choices, evidence suggests that negative ones do.

The interrelationship of influences on students’ choices

There are a number of factors that studies have found influence students’ course choices but there is little information at subgroup or individual level. Nor is there research in an English context about how these factors work together to influence students.

Students’ social identities in relation to science

Social theories of learning have come to dominate the way in which the teaching and learning process is understood. They emphasise that learning occurs as individuals engage in and contribute to the practices of their communities. From this perspective, physics classrooms can be understood as communities of learners. Participants, to feel a sense of belonging or membership, must be able to engage mutually with the other participants (Wenger 1998). To engage, they have to draw on what they do and what they know, as well as feel able to connect meaningfully to what they do not do or do not know. This view of learning as a transformation of a learners’ sense of belonging to a community helps an understanding of how differences in experiences and interests might combine to create barriers to some girls connecting meaningfully with others in the joint enterprise of physics activity. For example, Osborne and Collins (2000) in their survey of English students replicated prior findings that boys were able to make links between physics and its relevance to everyday life through specific examples and experiences whereas girls were not able to do this.

Lips (2004) studied undergraduates and high-school students’ views of current selves and future possible selves

in relation to the arts/science divide. The high-school sample was from four schools in the US and included 447 students. The “current” self-view scale included 30 items that were categorised into composite scores to do with enjoyment of, and success in, maths, science and artistic/literary/creative subjects and the learning skills associated with them (e.g. for science: abstract reasoning, debating and arguing), which students had to rate themselves against. The “possible” future academic selves scale comprised 15 items that covered the studies that students intended to pursue, and these were categorised into four composite scores: natural science; business/maths; humanities/culture; and social/behavioural. The first two composites were aggregated into a higher-order composite “power” and the other two into a higher-order composite “people”. The students were asked to respond on a five-point scale from “not a possible me” to “definitely a possible me”. The higher-order composites were validated using principal component analyses.

Using multivariate analysis the author found a significant multivariate effect of gender/domain interaction across students. Overall the following sample stereotypical outcomes were found:

- More males than females rated themselves highly on the maths/science/business domain and low on the negative (i.e. limited ability in maths/computing).
- Females more than males rated themselves highly on the domain of arts/literature/communication and low on the limited ability in the arts/literature.
- Across both undergraduates and high-school students the gap between males and females was greater within the maths/science domain and the gap was bigger on the possible future selves scores compared with the current selves scores.
- High-school girls’ ratings on future selves are higher on the power composite (i.e. studies in the maths/science/business domain) than those of female university students.
- For high-school girls, current views of self were in line with future views in both arts and sciences; this was true for undergraduate women in the arts/culture domain but not within the maths/science/business domain.

The limitations of the Lips’ data are that they are snapshots and not longitudinal, but the findings suggest that, at high-school level, future possibilities are more open for females and reinforce other studies’ recommendations that secondary level is the critical point for interventions. The findings also add support to the view that students’ perceptions of the image of science may be shifting at secondary level.

This study provides support too for the finding from other studies that the divergence between males and females increases across educational phases. However, this divergence is not a simple matter of diverging interest between males and females but a more fundamental difference in students’ beliefs about what social identities are manage-

able and appropriate. In line with other studies, the findings also show that males at all levels were very open to pursuing academic study in the maths/science/business domain and comparing this with the self-ratings showed that this willingness was often not in line with their self-ratings of success. As Head (1997) notes:

“Choosing a career in science and technology is very different for the young female compared with the young male. The latter makes an easy and obvious choice. He enters a male-dominated field – one that will tend to attract approval from adults and peers, and confirms his masculinity. The girl has to make a more difficult choice. She has to do something that is unconventional and be willing to work in situations in which females are in a small minority. Such a choice requires some commitment and determination.” (p79)

Recent non-UK research continues to show that males are more likely than females to rate themselves as successful learners in maths and science. More males than females are willing to consider the possibility of further study in maths and science irrespective of their views of their success in the subjects. There is evidence that for young women there is a closing down of possibilities in maths and science domains in their view of their futures as they progress through secondary into tertiary education. This is irrespective of their views of their competency in these areas.

What influences attitude development in physics

The next study is included for several reasons. First, it considers the possible relationship between students’ beliefs and values and how these enable or make more difficult their participation in physics learning. Second, it attempts to model attitudes to physics by examining relationships between students’ self-views in physics, their views of the subject and how these together influence their attitudes to the subject. This approach changes the focus from a concern with science content differences to a concern with motivational differences between students. Third, the study is unusual in that it is longitudinal. It is also notable because in Denmark there have been numerous interventions to change the nature of school physics, and to enhance the social relevance and authenticity of the subject. However, the authors cite research that found that traditions within school physics have acted as barriers to these interventions because only very specific content areas are considered to be seriously physics.

Krogh and Thomsen (2005) report phase 2 of this large, longitudinal study of physics in upper secondary schools. This involved a subset of students (N = 789 of a total of 2247) balanced across classes and teaching styles. The students were presented with an 80-item questionnaire about attitudes towards physics and choice of A-level

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physics rated on 4 to 5 point scales. The questionnaire included a number of related attitudinal aspects that, by using a factor analysis, revealed a single factor with three components (i.e. inclination towards school physics; views of physics lessons; and views of physics relevance).

Three separate item scales under the heading were included to illuminate students' purposes for studying science. The "saviour" scale captured the extent to which students see scientific understanding as enabling them to do good or to help people. The "conqueror" scale addressed those students who study for personal independence and career aspirations. "Absorption" described the scale for those students who studied to become wiser. Nine-element content preference scales under the heading "Perceptions of knowledge" were used that addressed scientific and humanistic preferences:

- Generally students rated each physics content area equally, in contrast with Osborne and Collins' (2000) findings.
- Those students who studied physics to help people – the saviours, predominately girls – showed a greater preference for content related to human aspects.
- Students who studied physics for future careers – conquerors – preferred science and technology and society content. (Studies cited by Stokking (2000) also report that male students are more likely to emphasise the utilitarian values of physics, whereas female students stress intrinsic values.)
- Those students who studied physics to be wiser or to know more for its own sake – absorption – preferred content concerned with calculations and fundamental principles.

The correlations, while highly significant, were only moderate in size. The authors argued, therefore, that changing curriculum content was not sufficient to ensure purposeful learning and students needed opportunities in physics to establish personal relevance as well as out-of-school relevance.

Although the evidence is limited there is support for the view that students vary in their goals for learning in physics and girls predominate in the subgroup that study physics to do good and to help people. Students who study physics to do good tend to prefer physics content related to human aspects.

The authors used the concept of boundaries or border crossings to describe the congruence between the subculture of school physics and the other worlds or communities that the students participate in. The study was concerned with perceived barriers in the values and ways of being between "life worlds" and "school worlds" as a possible means of understanding attitudes and choice in relation to physics. Four factors described potential barriers that students might experience. These were to do with:

- the extent to which the students' family background was physics related (the study found that nearly 60% of parents had little or no association with physics and the authors considered that this might create difficulties for students engaging with physics);
- students' perception of the reputation of physics as strange, difficult, boring, etc. was another factor and more than 50% of students had experienced this as a barrier;
- negative feelings about physics as a subject;
- the amount of home, peer and school support for students (most students reported favourably on the support available to them).

In addition the study included items on future education plans, physics self-concept, general school self-concept, teacher characteristics of enthusiasm and personal support, and two scales on learning environment characteristics: constructivist/student centred and subject centred. Gender was a variable included in the modelling. The analysis modelled students' attitudes to physics and their optional A-level choice using the full range of scales and variables. Multivariate analysis was used to determine standardised regression weights. The full model found to explain attitude towards physics included all of the standardised regression weightings significant at the 0.05 level.

This model included:

- physics self-concept;
- physics reputation;
- personal teacher interest;
- future education plans;
- teacher enthusiasm;
- subject-centred teaching (e.g. practical work is used to verify theories that we have already been taught);
- general school self-concept;
- feeling about physics;
- student centred/constructivist teaching.

The full model accounted for 56% of the variation. However, three predictors dominated students' attitudes to physics and accounted for 51% of the variation. These were: physics self-concept; views of physics – its reputation; and teachers' treatment of students as people. These predictors were significant across boys and girls, and gender was not a predictor of attitude.

Stokking's (2000) large-scale quantitative study of the factors that correlated with the intention to choose physics in the Netherlands also found that choice motives were similar for male and female students, as did Li and Adamson's (1995) study of gifted high-school students (see section 6).

There is emerging evidence from studies outside the UK of the key determinants of students' attitudes to physics.

These key determinants are:

- physics self-concept (i.e. students' sense of

- themselves in relation to the subject), both currently and in the future;
- views of physics (i.e. how students experience school physics);
- teacher–student relationships (i.e. how personally supportive students experience their physics teacher to be).

Krogh and Thomsen’s study, like that of Lips (2004) discussed earlier, found some correlation between gender, the highly significant physics self-concept and the less significant “future education plans”, and the authors argued that attitudes to physics may be established “indirectly through these variables” (p295). Within the study sample, twice as many boys as girls planned an education within scientific or technical fields.

The authors provide an example from the interview data for the study of how the three predictors emerge in students’ experiences. A student described her love of science and how this was affected when she came to upper secondary school, where physics became “more complicated”, so she experienced “some hardship in physics”. She talked of her fantastic teacher in lower secondary and how she had not had this experience in upper school. She felt “just one among many clever ones”. She talked of physics now being “too dusty...too one tracked...Physics can be seen as very cold...I think it is important to get emotions into it” (p 296). This suggests that, for girls, the teacher factor and the way in which the subject is presented may be even more significant than for boys (see discussion in section 4).

The Stokking (2000) study reported no gender differences in choice predictors. This was not the case for the Krogh and Thomsen study, where gender became a significant predictor of choice with boys in the sample having three times the probability of girls of entering for A-level physics. Nevertheless, the three predictors of attitudes were still highly significant predictors of choice. Girls in the Krogh and Thomsen study were considered to be “extremely dominated” by the concern to learn physics for the purpose of helping people, and this was seen as a “value” border to be crossed in participating in physics. If the subject goals are not directed to this end, girls will struggle to find personal meaning and value in what they do. This effect can then be further exacerbated if the teachers do not consider it necessary to treat students with respect or as people. Hence the teacher factor (discussed in section 4), which is a strong predictor too, could make this crossing too big for some girls to navigate, particularly if in the process their sense of self-efficacy in the subject is being undermined.

Krogh and Thomsen (2005) concluded that the factors predictive of attitudes could inform teaching interventions. For example:

- to enhance students’ physics self-concept, a more supportive learning environment was needed with scaffolding of learning and formative feedback to students;

- students’ views and values in relation to physics could be used to promote discussion and reflection about the nature of physics and why it is represented and practised in particular ways.

The decline in student interests may well reflect the growing gap between students’ life worlds and the practices of school science classrooms – a gap that makes boundary crossings to access physics too problematic for students to engage with. The evidence from other studies provides support for this, particularly for girls.

In her doctoral thesis, Sharp (2004) conducted a longitudinal study of students’ experiences of science through compulsory secondary education, in three UK Schools. One of her cases described her experiences in ways that correspond closely with those of the Danish student, suggesting that the model of what predicts attitudes to physics may be usefully applied across cultures. Natasha talked about how she entered her year-11 single-science classes with enthusiasm and confidence with teacher predictions of grades A or A*. However, she found physics difficult and “lost her confidence”. She had felt very supported by her Key Stage 3 teacher but felt that her new teacher did not know her well. She wanted time to discuss and clarify her understanding and felt that the teacher considered the problems were her responsibility. “She goes, well if you don’t understand it you should not be in this group...she didn’t try to explain it. [She] doesn’t seem to care really,” (p176). The content of physics made little sense to her and she was not given the opportunities to learn about it in a more interactive and in-depth way.

Natasha achieved her A grade in physics but she did not choose to study the subject at A-level, choosing instead to study maths, biology and chemistry. Natasha could not be said to have failed at physics, however she never came to feel a sense of belonging in it as she did with her other science subjects.

Large-scale and small-scale studies indicate that girls, more than boys, are likely to experience a difference between the goals of physics and their personal goals for learning and views of their future possible selves. These experiences, it is argued, shape girls’ attitudes to physics. Research continues to show that gender is a significant factor in predicting students’ choice of physics.

Difference within boys and girls

Cleaves (2005) reported on her doctoral study into the post-16 science choices of high-achieving students conducted over three years in six comprehensive schools in a region in England. Her study was not concerned with gender but she provides some important corroboration of findings about choice predictors.

She also looked at subgroups of students as related to their choice trajectories. She identified five specific types of choice trajectory in all:

- “directed”, defined by early and specific career

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- aspirations;
- “partially resolved”, which reflected a less focused career aspiration;
- “funnelling identifier”, which is defined by a gradual narrowing of ideas over time;
- “multiple projection”, which described the students with constantly changing ideas;
- “precipitating”, which included those students with broad-based ideas and no vocational commitments.

Across her sample (N = 69), 10 boys and one girl opted to study A-level physics. The students were located in three trajectories but largely in two:

- Three boys and one girl had a partially resolved trajectory. Their main reasons for choosing physics was for the challenge and because it was a versatile subject. These students appear to coincide with Krogh and Thomsen’s category of students who choose physics to become wiser – the absorption students.
- One girl and one boy had a funnelling identifier trajectory and were the only students out of 16 with this trajectory who chose any science subjects. Two-thirds of these students rejected science because of a decline in interest in it and alienation from it. The boy reported being bored with his physics in year 11 but continued with his decision to opt for physics.
- Six boys out of 13 students with a precipitating trajectory chose to study physics. Their reasons were not for a specific career but to maintain breadth and balance in their study. These students often received parental advice about the value of physics, either in terms of their other choices (i.e. a knowledge perspective) or because of its commodity value in negotiating university places or future careers. Cleaves argued that for these high-achieving students parental advice was a significant choice factor.

Cleaves’ analysis highlights the funnelling subgroup of students, who gradually focus down on an idea about course choices, as particularly vulnerable to negative experiences of science in schools. She also argued that students with precipitating or partially resolved choice trajectories would be constrained if course choices had to be made early or became more restricted in Key Stage 4. Cleaves identified a lack of knowledge of science-related careers as a significant choice factor and this supports the findings that career aspirations are one of the major determinants of course choice. Krogh and Thomsen’s model highlighted students’ views of physics as a choice predictor and this might well be mediated by knowledge of relevant careers. The other powerful factor that Cleaves identified was self-concept. She described how students match possible selves with a personally evaluated self to make decisions about the future, and Lips’ (2004) study indicated the growing gap between this match as girls move into undergraduate study. Krogh and Thomsen see this gap occurring much earlier

and this is the case in the majority of studies reported in the section, whatever their scale and type.

There is evidence from in-depth studies that students lack knowledge of a range of science-related careers and that this influences their decisions about whether to study physics. Only some students have been found to identify a specific career early on in secondary school.

The implications

- The decline in student interests is linked for girls in particular to their perception of the relevance of physics to them and their concerns. Teachers need to monitor how students are relating to the physics that they experience.
- There is emerging evidence that boys and girls as groups do not share the same educational goals and there is considerable variation within groups. More girls than boys are found to want to understand in order to “do good” in the world. This may be associated with the reported greater concern of some girls to have social applications and issues covered in their physics lessons. Effective learning requires that students and teachers are committed to shared goals, goals that make sense to them and those in which they have a personal investment. Students’ views and values in relation to physics could be made explicit and used to promote discussion and reflection about the nature of physics and why it is represented and practised in particular ways.
- To understand how boys and girls feel about themselves in relation to science and physics requires a more considered view of how gender operates in classrooms and how peers can be influential in “policing” appropriate gender behaviours. There is a need for some UK-based qualitative studies that provide evidence and tools for teachers to use in dealing with gender differences in physics.
- To maintain girls’ and boys’ interest and motivation to study physics it is important that they experience themselves as competent in the subject. Teachers need to monitor students’ views of themselves as competent learners of physics. Students need to feel that they can do physics if they are to decide to continue to study it, and this is particularly true for girls.
- In England one study suggests that students no longer associate being good at science with having masculine traits. Other studies in the US suggest that, at secondary level, science is seen as a domain that is appropriate for both boys and girls. The implication of these findings is that interventions need to occur in the early and middle stages of secondary schooling. However, more UK-based evidence is needed on this.
- Students’ lack of knowledge of careers is a problem and increasing their awareness of physics-related careers would enable them to make informed course choices. However, students are motivated to study

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some subjects because they are interested in them and this needs to be taken account of in thinking about the physics curriculum and how it is taught.

- Teachers' treatment of students is very significant in determining students' feelings about physics and their self-concept in relation to it. Teachers' behaviours can marginalise or empower students. Teachers' practice is key to change in physics.
- More recent studies emphasise the significance of students' self-concept (i.e. the match between students' views of their present and future possible selves in relation to physics). Self-concept shapes students' attitudes to physics and is a predictor of students' decisions to study physics. Girls more than boys experience a decline in their physics self-concept as they progress through secondary school, though

this phenomenon occurs across boys and girls as groups. The above recommendations to monitor and engage with students' beliefs about physics and feelings about their experiences of their study of the subject will help to reveal this phenomenon. However, to prevent the decline requires action and more research to establish successful interventions. There are very few studies of this.

- Evidence about how students experience physics over time is limited and more research is needed.
- Very little research has explored subgroup differences within groups of boys and girls. Any interventions that make assumptions about all girls and all boys will have little chance of succeeding and may well have unintended negative impacts.

3: Relevance and curriculum interventions

This section includes a discussion of evidence from a number of studies that provide findings about students' perceptions of relevance and the importance of this for their participation in science and physics. The studies rarely isolate relevance as a factor that needs to be defined. Typically, students' views about their interest and liking for science and what motivates or demotivates them to learn science and physics are sought as a way of considering the issue of relevance in learning. Hence there is overlap between this section and the preceding one.

Relevance has emerged as significant either in the interpretation of such data or in students' use of the term. Other insights about students' perceptions of relevance come from their reference to what they consider to be barriers to them making sense of aspects of science and physics or in their explanations for why they believe that the subject is not for them.

This section also includes literature that discusses the characteristics of interventions that are considered to enhance relevance in learning for girls and examples where these exist. The examples are sometimes evaluated and in these cases evidence is discussed.

The introduction of the National Curriculum in science to England and Wales removed the issue of choice post-14. This solved the problem of differential uptake of science by girls and boys and allowed simple comparisons in the performance of populations of girls and boys to become public knowledge. What emerged as a consequence of girls' relative success in examinations at 16 was a concern about boys' perceived underachievement. From the mid- to late 1990s, both in the UK and internationally, interventions in the curriculum have focused on boys and the subjects where they are seen to be "failing" in comparison with girls. This effectively removed both science and girls from the research and policy agenda. For this reason, in the discussion of interventions there is reference to other subjects, in particular maths and English.

The section includes:

- Differences in views of relevance:
 - students' perceptions of the relevance of science;
 - sources of views of relevance and their consequences for learning.
- Incorporating relevance into the curriculum:
 - compensating for missed opportunities;
 - redefining the science curriculum and its teaching;
 - the characteristics of a context-based/humanistic approach;
 - evidence of impact;
 - evidence of the effectiveness of context-based approaches in other subjects.
- The implications.

Differences in views of relevance

Students' perceptions of the relevance of science

Qualter (1993), using APU national science survey data for students in England, Wales and Northern Ireland, found that it is not just applications *per se* that are of interest to many students, particularly girls; it is how relevant these applications are to their lives. So within physics there will be applications that are interesting to girls, but it may be the case that there are many more within, for example, biology. The study concluded:

"It seems that it is not the case that girls and boys are interested in biological and physical sciences respectively, nor that girls are interested in topics which are stated as applications while boys respond to more abstract statements. Both boys and girls respond to topics that they see as relevant to their interests; it is therefore the interpretation by pupils of what is relevant to them that determines interest rather than some broad categorisation of topics into biological/physical, abstract/applications." (p315)

More recently a large-scale quantitative study for the Commonwealth Department of Education, Training and Youth Affairs in Australia of post-16-year-olds (N = 4023), using open-ended and rating scale questions, reported that students experienced science teaching as being rarely relevant and not connecting with their interests and experiences (Goodrum *et al.* 2001). This view of science teaching was further supported by an in-depth study (Lyons 2004) in New South Wales, which surveyed 196 students aged 15–16 and interviewed 37 who were identified as being science proficient from their Intermediate Examination results. Students in interview reported that curriculum content was often presented in a decontextualised manner, leading many of them to consider the subject to be irrelevant and boring.

Osborne and Collins (2001) reported the views of 144 16-year-olds from schools in England. The sample included students who were planning to continue their study of science post-16 and those who were not. They were interviewed in focus groups about their views about aspects of science that they found interesting and/or valuable in their curriculum. The study found that:

- students regarded biology as relevant to them, their bodies and their concerns with health and disease, but they could see no use for the abstruse theoretical content learned in physics and chemistry;
- students holding a positive view of science subjects

"There is significant evidence that a context-based or humanistic curriculum increases students' motivation and enjoyment of physics."

were engaged by topics that they perceived to be of immediate relevance e.g. “understanding how a healthy body might be achieved and maintained through diet and exercise” (p456);

- girls, more than boys, were interested in the purpose of learning about the phenomena in the science curriculum (this latter finding is well established in the gender literature for science, technology and mathematics: Murphy 1995; Boaler 1997; Murphy and Elwood 1998).

While there is evidence that relevance is associated with students’ positive attitudes to science, it is clear from research that relevance is an individual perception and that what is considered relevant cannot be generalised about across students or across girls and boys as groups. For example, research by Woolnough (1994) found that:

- a small minority of academic pupils (usually boys) reported being stimulated to learn by the challenge presented by the abstract and mathematical aspects of science, particularly physics, and the desire to explore the subject in more depth.

According to Head (1997):

- there is a subgroup of boys who are willing to accept the abstract approach and these are the ones for whom the study of physics as it is currently specified remains a possibility.

Krogh and Thomsen’s study (2005), reported earlier in [section 2](#), related students’ preferences for different types of content in physics to their reasons for wanting to study the subject. They found that:

- students who studied for future careers preferred science and technology and society content; students who studied physics to know more for its own sake preferred content concerned with calculations and fundamental principles, and these students were more likely to be boys than girls;
- girls predominantly favoured the humanistic aspects of the subject and reported that physics lacked relevance for their learning goal (i.e. to help people).

Relevance is reported in terms of usefulness either to daily life or to students’ goals. The evidence from surveys indicates that both boys and girls (but more girls than boys), across the ages of secondary schooling, consider that the physical sciences are not personally relevant, in contrast with their views of biology. There is some evidence, though no recent research, that a minority of students, predominantly boys, are content with the abstract nature of physics and study it for its extrinsic value in securing a career or gaining them more knowledge about the world.

Sources of views of relevance and their consequences for learning

To understand how to enhance the relevance of a subject it is necessary to understand how students come to see things as relevant or not. Browne and Ross (1991) first reported on children’s views of “girls’ stuff” and “boys’ stuff” more than a decade ago. They studied a large sample of preschool children and observed that:

- from a very young age, children learn what activities are considered appropriate for them to engage in;
- activities that girls in preschool settings were observed to choose were labelled “creative” and included drawing, creative activity, reading a book or talking to an adult;
- boys were observed to choose constructional activities.

Browne’s more recent work (2004) confirmed these earlier findings, as she commented: “I found it somewhat chastening to hear children saying the same sorts of things other children had said to me more than 12 years ago.” She argued that the differences that children perceive in what are appropriate ways of acting and being for girls and for boys are not “natural”.

“Children have to learn how to behave and relate to others in gender-appropriate ways through interaction with others and through gaining access to and understanding of the dominant gender discourse.” (p70)

Murphy (1997) carried out a case-study of preschool children in a workplace day-care centre. Staff commented on the differences in the play of girls and boys as young as two to four years of age:

- Girls’ maternal instincts were said to influence their play, which often involved being a mother with a baby or other domestic scenarios.
- When girls were being fantasy characters, these were typically grand dames or princesses.
- Boys on the other hand were observed to “bring their own agenda – they get into some very active, very physically involved games – they do a lot of role play. Boys like to be people in authority, policemen, fire fighters or super heroes,” (Murphy and Elwood 1998 p96).

Differences in children’s play were either unchallenged or exploited to engage them in learning activities. Consequently boys would be encouraged to look at texts about building sites, trains, etc, further developing their understanding of, and interest in, mechanisms and constructions. Murphy (1997) argued that the different roles and activities children engaged in involved them in different forms of expression and required them to pay attention to different details. They therefore developed different ways

3: Relevance and curriculum interventions

of “seeing” and interacting with the world and this was a major influence on what children, as they grew, learned to take note of and consider to be of relevance.

The APU national surveys provided some evidence for the consequences of these different ways of seeing for what students learn about in science. For example, in tests of scientific observation:

- boys tended to note features to do with structures and mechanism, whereas girls took note of colours, sounds, smells, textures, etc (Murphy and Elwood 1998).

In the APU Design and Technology surveys, Kimbell *et al.* (1991) found that in tasks that allowed 15-year-olds to decide what was salient:

- girls focused on aesthetic variables and empathised with users’ needs more than boys;
- boys more than girls focused on manufacturing issues and were more competent in applying knowledge of structures.

When people observe, they take note of what has salience for them and in that sense is considered to be relevant to them. There is always more information available than people notice. Observation is fundamentally a selection process that is determined by familiarity. Familiarity is in turn determined by experience and our purposes for engaging with activities. Children’s gendered socialisation influences what becomes “familiar” to them. Girls’ and boys’ familiarity or lack of it can influence their beliefs about their capabilities or their self-concept in relation to aspects of science.

Evidence from national surveys and national assessment tests (Murphy 2000 a) have established that some girls and boys do not respond to questions that they consider outside their realm of competence. For example:

- some girls may not respond to a data-handling question in science or in maths if the data are about cars or about workshop parts (i.e. masculine content);
- some boys similarly avoid questions that emphasise feminine content, such as domestic situations, even though they can do the actual task set – what the task is about creates a barrier for them (Browne and Ross (1991) referred to these areas of perceived competence as gendered domains);
- in learning situations some girls and some boys will actively avoid activities that they consider outside their domain, which leads to “missed opportunities to learn” and to differences in actual achievement as a consequence.

Evidence from large-scale and small-scale in-depth studies show that gender differences in what students consider personally relevant affects their perceptions of their areas of competency. These perceptions influence

what they choose to, or feel able to, engage with in learning and assessment situations. The evidence indicates that what boys, more than girls, pay attention to and engage with is generally valued and judged relevant in physics.

A further finding about the impact of different perceptions of relevance from the APU national surveys that has been substantiated in later research concerns how students’ views influence the way they approach problems in science and the investigations they plan (Murphy 2000 b):

- Girls more than boys tend to value the circumstances in which tasks are set and take account of them when constructing meaning in the task – they do not abstract issues from their context.
- Conversely, as a group, boys tend to consider issues in isolation and judge the content and context to be irrelevant.

Boaler (1994) noted a similar effect in her small-scale study of mathematics involving 50 students from two schools. Girls and boys approached context-based questions in mathematics differently:

- Some girls took the real-world variables contained in the contexts into account and in some instances this led to lower achievement for girls compared with boys.
- Boys ignored the real-world variables and were more successful at focusing on the numbers given in the task.

Relevance is an essential prerequisite for learning. Developing a broader perception of relevance, however, should be part of learning about a subject and in this way gender does not have to function as a constraint in what students’ learn to pay attention to. Murphy noted: “Students and teachers alike need strategies to help them realise the way they filter and select data in different circumstances.” (p103).

Evidence from in-depth studies reveal that differences between what girls and boys have learned is relevant and valuable affects the problems they perceive. Girls are more likely than boys to give value to the social context in which tasks are posed in defining a problem; boys are more likely than girls not to “notice” the context. The approaches to problems associated with boys in the research evidence are more in line with approaches to problems in physics.

Incorporating relevance into the curriculum

Personal frameworks of relevance inform what we pay attention to and the connections that we make between new meaning and established meanings, and research evidence shows that there is an important gender dimension to this. If physics is presented in the context of abstract school activities, then many students have to make their

own bridges to relevance in order to create personal meaning in school tasks. Failure to be able to make these bridges is more problematic for girls than for boys.

Compensating for missed opportunities

Early interventions in the science curriculum to increase girls' access can be understood as attempts to address the outcomes of differential views of relevance. Girls were seen to have "missed opportunities" to learn and develop skills and knowledge relevant to science because, typically, compared with boys they engaged in different activities outside school and avoided activities in school that they were unfamiliar with.

Skill deficits

The first intervention programme in England that was aimed specifically at improving girls' attitudes to physical science was the Girls into Science and Technology (GIST) project (Richmond 1991), funded by the Equal Opportunities Commission and the Economic and Social Research Council (ESRC). The project worked with 10 coeducational comprehensive schools in the north-west of England. A main element of the GIST intervention was to compensate for girls' lack of access to particular experiences out of school that meant that they were less well able to cope with spatial tasks and mechanical reasoning tasks in school – skills that are considered essential for learning in the physical sciences. The GIST project was also concerned with girls' views of science and alienation from it, and this led to a concern with relevance and with the nature of the science curriculum. The researchers referred to the then-current science curriculum as abstract, ahistorical and impersonal. "Girl-friendly" science (Smail 1984) was developed as an outcome of the GIST project. This approach was described as compensatory or "recuperative" (i.e. it worked with the curriculum as given but altered the approach to the teaching of science and its content slightly). For example, it was recommended that:

- less stress was put on the dangers of experiments and more on their aesthetic appeal;
- content should be chosen in relation to its aesthetic appeal.

Girls often cited the dangers of science when asked about their perceptions of the subject and this was seen as a significant factor in their alienation from it. Aesthetics had been identified as the aspect of situations that girls found relevant and that thus engaged their interest. Girl-friendly science required little radical change, so it became quite a popular approach with teachers attempting to address equal opportunities in the classroom. The GIST project was never formally evaluated and was considered disappointing in its impact in the medium to long term.

Another example of this type of intervention was carried out in Ireland during the late 1980s (Aebischer and Valabrègue 1995). This project was designed so that

impact could be determined, and importantly it included a significant professional development element. It involved students aged 12–15 years in single-sex and coeducational schools. Four were the experimental schools and four the "control" schools. The curriculum intervention in the experimental schools included five modules, each lasting about seven weeks. These included:

- an introduction to a range of new media;
- the use of computers and their applications;
- tinkering activities involving electrical equipment and systems and soldering activities;
- modelling activities to improve visual and spatial reasoning and practical know-how.

The modules involved visits from women from industry as well as industrial visits. The questionnaire survey before and after the intervention asked about students' attitudes to the place and the role of men and women in the workplace, their personal involvement in masculine and feminine activities in the home and in leisure time, and their career plans. Teachers' and parents' views were also sought.

A year later it was found that:

- girls in the experimental schools had a less stereotypical view of the place of women in society and in the home compared with girls in the control schools;
- they had extended their view of what subjects should be available to girls compared with girls in the control schools;
- there were no statistical differences between the two groups in terms of their attitudes towards jobs and their personal career aspirations (girls' views remained traditional and boys' views were unchanged).

The researchers concluded that, while it is possible for girls to have positive views of women's roles and career possibilities, this did not translate into their personal plans, which remained traditional. An evaluation of science workshops undertaken in the US (Yanowitz and Vanderpool 2004) obtained similar results. It was found that after the workshops students were more interested in the science areas covered in the workshops but did not believe that women typically worked in these fields.

Early interventions to increase girls' participation focused on science rather than on subjects within it. One problem identified was that girls' participation was limited by their lack of appropriate skills and experience. Relevance was an issue but was typically understood and addressed through positive female role models. The evidence that there is suggests that neither the interventions nor their impact were sustainable.

Separating the sexes

The main discussion of this intervention strategy is found in section 5. The most common use for this strategy has

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been to compensate for differences in experience, as girls' lack of experience in certain aspects of science outside and inside school is seen to limit their confidence and feelings of competence (i.e. their self-concept in the subject). This same strategy has been employed more recently in attempts to address boys' literacy development. A review of 19 case-studies (16 in secondary schools) conducted by Sukhnandan *et al.* (2000) focused on the effectiveness of single-sex grouping for boys in English. The key findings were that:

- a significant factor in the reported benefits of the approach was that staff “who were comprehensively aware of the issues related to gender gaps in performance” (p38) were allocated to the boys-only groups and they built a rapport with the boys; the need for a committed and gender-aware teacher was also found to be critical in evaluations of the effectiveness of girls-only groupings for physics;
- boys reported that the change in teaching approach increased their motivation and confidence, which in turn increased their involvement in lessons; these findings reflect those reported by girls in single-sex science groups.

The research recognised the difficulty of accurately assessing the impact of single-sex groupings because of “numerous uncontrollable factors” (p39). At the time of the review, very few schools had quantitative evidence of the positive impact of the approach.

Early interventions used single-sex groupings to provide a safe learning environment for girls where their skills and confidence could be developed until they were able to participate in mixed groupings on an “equal footing”. There is evidence (section 5) that self-concept in physics is enhanced for some girls and some boys in single-sex environments, but the teacher is crucial in this.

Girl-friendly topics

Another compensatory approach to make the curriculum more accessible to girls is to exploit what they are considered to find relevant in order to motivate them to be engaged in the subject. This approach uses girl-friendly examples either as scene-setting devices or as illustrations of phenomena. For example, in learning about sound, ultrasonic scans showing foetal development are used; conservation of momentum is illustrated by the movement of female ice skaters; and moments are considered in domestic contexts rather than in typical masculine settings like building sites and garages. In attempting to shift towards a “feminised” version of physics in a simple and superficial way, girls' experiences can become restricted to what they are believed to consider personally relevant, even though this in itself is shaped by dominant representations of “femininity”. Furthermore, boys may, as a consequence, experience alienation similar to that previously experienced by girls.

A similar strategy has been employed more recently to support boys' literacy development with the recommendation that texts should be “boy friendly”. Millard (1997), for example, recommended that texts should include more action and humour to meet boys' perceived interest. However, she was at pains to point out that materials should be introduced that have direct relevance to children's interests, which build on “real rather than imposed textual pleasures” (p173). This is equally important in any intervention in physics (i.e. that relevance is established rather than assumed). Millard also recognised that such an approach could marginalise girls. She therefore argued for a boy-friendly approach to reading “that did not lose sight of practices that enabled girls” (p167). These caveats would apply equally to any attempts to build into the physics curriculum girl-friendly content or what is assumed to be girl friendly. The goal of the compensatory interventions was to produce equality between girls and boys and they focused on changing the girls to be more like boys (Gilbert 2001). They left the representation and presentation of science unchanged. Most also had limited impact, which is the case with more recent interventions or else the impact has been difficult to isolate because of the factors that could not be controlled. Few set up a controlled design.

Girl-friendly interventions recognised that for girls the lack of personal relevance in the science curriculum was a problem. To address this, topics were selected that exploited assumptions about what girls considered relevant. The interventions, however, did not differentiate between girls or develop girls' understanding of relevance and had limited long-term impact.

Redefining the science curriculum and its teaching

Unlike other parts of the review, this part is more a discussion than a report of findings. Here we consider the characteristics of what is defined as a ‘feminine’ framework of relevance applied to science and how different interventions prioritise these characteristics. The discussion continues with particular reference to approaches that attempted to move away from notions of masculine or feminine science and offer another view. The discussion includes examples of this approach and the evidence of their effectiveness.

Advocates of “feminist science” challenged both the representation of science and its practices (Bentley and Watts 1986). Bentley and Watts described feminist science as personal and subjective, in that the individuals practising it recognised that they were part of scientific inquiry and not separate from it. Feminist science was also holistic, in that natural systems and processes were not viewed as a collection of isolated variables – rather, the variables were understood in the context of the whole. Hildebrand (1996) offers a set of dualisms to portray images of science. A simplified set of these is shown in [table 3.1](#).

Hildebrand argues that the attributes on the left are given value and taken as the norm in physics, and create the

Table 3.1: Hildebrands' (1996) dualisms, which portray images of science

abstract	holistic
quantitative	qualitative
outcomes	process
competition	co-operation
objective	subjective
hierarchical	multiplicity
value-free	value-laden

masculine image of science. Those on the right can be seen as defining “what is not physics, the feminine image of science”. The interventions just discussed aim to change the girls, their knowledge and their skills to correspond more closely with the left-hand image. Another approach would be to try to bring more balance or symmetry between the two sides, and this is much in line with the type of intervention that Millard proposed in helping to improve boys’ literacy. Yet other interventions, often referred to as the context-based or humanistic approach, reject the oppositions and see them more as continua. These interventions challenge gender boundaries as constraints on all students.

Characteristics of context-based/humanistic approaches to teaching physics

Defining the term

Context is open to a number of definitions. That most relevant to the review is Hodson’s (1998), who defines context as the “problem situation” (p116). Aikenhead’s view of the role of context is also a key definition relevant to the review. He describes it as “an organiser for the science content” (1994). From these it follows that the social context determines what subject knowledge is likely to be needed and therefore also the opportunities for learning. In subjects like physics where most course specifications are based on a hierarchy of knowledge, such an approach is a challenge to both how teachers teach and how they consider students learn. What is meant by contexts that relate to students’ lives is also debated. Research by Angell *et al.* (2004) suggests that students see context as a topic that they are interested in and may discuss outside the classroom. They argue that “when pupils describe physics as related to the ‘everyday world’, they refer to their everyday conversations and ‘existential speculations’ rather than the phenomena they observe” (p691).

Early initiatives

Harding was a founder member of the international network Gender and Science and Technology (GASAT) and was one of the first in the UK to treat relevance from the students’ perspective (Harding 1986). She argued that the physical sciences had to relate more closely to the issues that young people recognise as important in their own and others’ lives. She challenged the applications approach to courses as the social issues were added on rather than

integrated. Her issue-based course for chemistry was presented in a framework of social context. The issues provided the purpose for the chemistry investigations and therefore addressed two problems for students’ engagement in science, that of purpose and relevance (Harding 1985). This approach had many advocates but it required a significant shift in how the curriculum was specified. The National Curriculum that was introduced shortly afterwards maintained a traditional content-led approach.

Mottier, another GASAT founder member, was responsible for a research project in the Netherlands that developed guidelines for gender-inclusive content for physics texts (Mottier 1987). Although dealing with texts, the project did much to redefine the content and approach to physics. The guidelines specified that:

- physics must be related to daily life and experience, and the human need to explain surrounding phenomena;
- physics should be shown as related to society and concerned with answering societal questions;
- texts must also show a relation to the professions that require a knowledge of physics;
- physics texts must pay attention to examples and phenomena to do with the human body;
- physics should be portrayed in its historical context.

In the guidance there are attempts to ensure relevance by connecting physics with the body, with society and with future possible careers. The concern with history is a concern to show physics as a human activity that is not fixed but changing and influenced by social, cultural and political forces of the time.

Another influential intervention that was disseminated through GASAT was the work of the McClintock Collective, a network of Australian educators. The collective began work in 1983 (Hildebrand and Dick 1990) and produced materials for students as well as undertaking professional development for teachers that aimed to embed science learning, and physics in particular, in socially relevant situations. The collective became very involved in the development of the Victoria Certificate of Education (VCE) in physics at post-16 in Australia. Consequently people with a strong background in gender and science became instrumental as course and textbook authors. This new course was introduced in 1992. The committee developing the course focused on both the curriculum and assessment practices, and social situations were the central organisers for both. Hart (1997), one of the course designers, observed about the course:

“In the early draft, physics was presented as a tool and its ideas were to be studied, not as ends in themselves, but because they were relevant to, and illuminated, particular contexts taken from the students’ physics and social worlds.” (p1)

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In addition, the course materials engaged students in ways that gave value to personal and subjective responses to scientific issues and included projects with research and investigative work as central activities.

By the time the course was introduced the context approach had been weakened. The intention was that the links between the social situations and the relevant physics concepts would be specified and prescribed. This position was retreated from and it was left to the teachers to decide how to relate the physics content and concepts to the social contexts. Teachers using the VCE course varied in their understanding of what context-based learning meant. In a study of teachers' views, Wilkinson (1999) found that "many think it simply refers to the teaching of physics concepts with applications and everyday examples included as an 'add-on'" (p64). The success of the course depended heavily on the teachers' enthusiasm for the approach. Some chose to ignore it, and though they appreciated that the approach made physics more interesting for their students, some did not believe that it helped understanding.

UK initiatives

A UK intervention study (Boaler 1997) compared a project approach to mathematics learning with traditional approaches, and as such the study, although into mathematics learning, is relevant to this discussion because a project approach shares some of the same pedagogic approaches and knowledge goals as context-based/humanistic approaches. Boaler (1997) compared the maths teaching in two schools that taught maths in very different ways. The study was conducted with whole year groups of year-9 to year-11 students. One school used a traditional approach where the teacher instructed the students in procedures to be learnt from the board and students practised these by doing examples from their textbooks. The other school adopted a project-based approach where students worked on open-ended projects in groups over a period of weeks. Teachers guided the project work and taught the mathematics that students needed for their projects when it was needed. In this way the project, like the context, determines what is learned. Boaler found that the project-based approach had much more success with the girls, who were more motivated and interested in learning than were the girls experiencing the traditional approach. She also found a significant increase in students' achievements compared with the traditional course.

The Supported Learning in Physics Project (SLIPP) (Whitelegg 1996) was one of the only recent UK curriculum interventions in physics that adopted a social context approach. SLIPP introduced physics to students through case-studies that were taken from real-life situations. The contexts served as an ordering structure for the physics concepts in that only the concepts needed to understand the specific context of a unit were covered in each unit. This was the intended approach in the VCE course but the SLIPP project adhered to this. The use of the context was maintained throughout each unit. The context was therefore

integral to the learning and not separable from it as in an applications-led approach. For example, in one of the eight units, *Physics for Sport*, the concept of equilibrium of forces is taught through the way rock climbers use hand and foot holds at various angles on a climbing wall. Pressure laws are taught through a discussion of scuba diving. Circular and simple harmonic motion are taught through a context of springboard diving. Females and males engage in these sports in equal numbers.

A consequence of the context approach was that some concepts appeared in more than one unit, which reinforced students' understanding and aided transfer across contexts. SLIPP was designed to develop independent learning skills, so students would study it with teacher support, rather than being teacher-led. A small-scale (N = 38) evaluation of the use of the materials was carried out in three schools (Whitelegg and Edwards 2001). The researchers found that:

- the context approach was recognised and valued by the girls, who reported that it made the physics more interesting and helped their understanding – this was particularly the case in the school where the teacher reinforced the approach;
- boys in a more traditional single-sex school were reluctant to engage with the approach and along with their teacher wanted to strip away the context, which they saw as extraneous material that would not help them pass their exams.

The take-up of the SLIPP materials was limited as it did not have a specifically designed assessment system alongside it. It was applicable to all of the exam specifications but teachers had to make the links.

There is an emerging consensus in the literature about the characteristics of a curriculum that increases girls' engagement and achievement in physics. The following characteristics are key:

- social situations organise and determine the content studied and assessed;
- the situation and the problems within it provide the purpose for learning;
- situations vary between those of relevance to students' daily lives and concerns, and wider social issues of concern to societies generally;
- physics is represented as a social practice, physics knowledge as a social construction that is open to change and influenced by social, political, historical and cultural factors;
- the values implicit in physics practices and knowledge are matters for examination.

Evidence of impact

In the first year of the new Australian VCE physics course the following outcomes were noted:

- There was a 25% increase in numbers of students

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taking physics and this was linked to the course's new approach (Wilkinson 1999).

- There was an increase in the proportion of girls choosing the new physics course (Hildebrand and Allard 1994).
- In the year prior to the introduction of the course 87% of girls and 84% of boys passed the old-style examination. In the first year of the course there was a 10% increase in pass rates for both boys and girls and this was the case in the following two years. There was also a dramatic difference in the A grades achieved by girls, with the gap closing between them and the boys.

However it was also noted that the course and its assessment did little to improve the access and achievement of working-class girls (Hildebrand 1996).

Boaler (1997) also found a significant impact on students' performance with a project-based approach that embedded maths use in context compared with traditional approaches, which relied on teaching abstract knowledge and a didactic approach.

- The GCSE maths results for all students taking the project-based approach were significantly higher than they were for the students taking the traditional approach and there was parity of achievement between the girls and boys.
- Similar proportions of girls and boys taking the traditional approach passed but significantly more boys than girls attained grades A*–C.

Aikenhead (2003) used the term "humanistic" in preference to context-based science to refer to science courses in which the canonical knowledge is embedded in socially and culturally relevant contexts. He argued that the learning demands involved in this approach were more complex, commenting:

"The greater the social or cultural relevance associated with canonical content, the greater the student motivation to learn but the greater the complexity to learn it meaningfully." (p53)

However, he cited research from the TIMSS survey data (see p5), which indicated increased achievement on traditional science questions for students who had studied humanistic content:

"Students benefit from studying science from a humanistic perspective provided that: the humanistic content is integrated with canonical science content in a purposeful, educationally sound way; appropriate classroom materials are available; and a teacher's orientation toward school science is in reasonable synchrony with a humanistic perspective." (pp61–62)

Reviews of evaluation studies carried out by Aikenhead show that humanistic science courses significantly improved students' understanding of social issues both external and internal to science, and of the interactions among science, technology and society; but this achievement depended on what content was emphasised and assessed by the teacher. It was also noted that students made modest but significant gains in thinking skills such as applying canonical science content to everyday events, critical and creative thinking, and decision-making, if these skills were explicitly practised and assessed in the classroom. The teacher made the difference.

Across studies in England and elsewhere there is significant evidence that a context-based or humanistic curriculum increases students' motivation and enjoyment of physics, especially for girls. This is evident in the increased uptake of physics post-16 and in students' level of achievement in external examinations and in their range of achievements. The teacher, however, is critical.

A context-based/humanistic curriculum assumes a particular view of physics knowledge and an approach to teaching and learning where the teacher guides students but students have responsibility for, and autonomy in, their learning. There is evidence across studies that some teachers struggle with the approach either because their view of learning and knowledge is in conflict with it or because they need more support to teach and assess using this approach. Some students reject the approach, particularly some boys, as they have learned not to pay attention to social contextual features and feel disadvantaged when required to do so.

Evidence of the effectiveness of humanistic approaches in other subjects

The evaluation evidence from physics interventions is limited but an independent evaluation of the applications-led Salters Chemistry A-level project was carried out (Hughes 2000). This warned of the dangers when teachers undermined the approach by separating off the applications from the core body of facts. This was observed with the Australian VCE intervention and happened when teachers did not understand the view of knowledge behind a context or applications-based approach. In the case of Salters' Chemistry another problem was the lack of time available for discussion of social aspects with students, which also undermined the approach. As with the SLIPP experience, some "academic" boys were turned off by the approach because they wanted the body of facts and did not want to spend time considering social aspects. However, a systematic review of the effects of context-based and science, technology, society approaches that examined a pre-16 physics course (PLON), Salters Science (a GCSE course) and Salters Chemistry (post-16) found no evidence that context-based approaches adversely affected students'

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understanding. Evidence was found to support the claim that such approaches motivate students and develop positive attitudes to science (Bennett *et al.* 2003).

National initiatives in the US to create equitable mathematics classrooms to support gender equity share many of the characteristics of the context-based and humanistic approaches (Goodell and Parker 2001).

For example the curriculum included:

- real-world problems set in a variety of contexts;
- a focus on issues of social justice.

Students used their maths to understand:

- real-world problems such as poverty;
- social conditions and to engage in social action.

Teachers:

- used an inquiry-based approach where students were responsible for constructing their own knowledge;
- connected mathematics with the real world;
- used learning situations that drew on students' experiences, were hands-on, project based and involved group work and whole class discussion;
- encouraged and supported student autonomy.

An evaluation study collected teachers' reports and questionnaires from a random sample of schools that included those undertaking the reforms (N = 100) and those that were not (N = 400), and this was supplemented with observational and interview data from seven case-studies.

The authors concluded from this data that:

- teachers in the intervention classes implemented at least some of the inquiry teaching practices in comparison to teachers in the non-intervention classes.
- students in the intervention classes achieved significantly higher results than did the students in the non-intervention classes;
- subgroup analysis showed that female students achieved most of the gains;
- students enjoyed the approach;
- teachers reported that the pedagogy enhanced students' long-term retention of concepts.

The authors established some factors that made implementation problematic:

- Some teachers struggled with the approach and wanted more resources to support them, and funding was an issue.
- Where teachers had low expectations of students the approach was often not used.
- Teachers in schools without a cohesive staff, with an unstable ethos and with unsupportive heads were less likely to be successful.
- Teachers would forgo the approach and resort to more traditional teaching methods in order to meet external assessment requirements. They considered that this

kind of approach was simply too time-consuming in these circumstances.

Evaluations of context-based approaches in subjects other than physics report either no disadvantage for students' learning or improved achievements for both boys and girls, but particularly for girls. These studies highlight the need for changes in the curriculum to be matched by changes to assessment practices. Even then change is dependent on teachers understanding the need for change and how to implement it effectively.

The implications

- Perceptions of relevance are closely linked to and influence what students find interesting and motivating. There are gender differences in perceptions of relevance but also similarities between boys and girls as well as differences within groups.
- Just as it is important to elicit students' prior science-related knowledge, it is also essential to elicit their world views and how these influence what they find interesting in the topics and activities that they are given in physics. Simple strategies exist to make students' views of relevance explicit and available for discussion.
- Teachers set activities but it is the students who make sense of what a task is, and their views of relevance influence this reformulation and can alter what is available to learn. It is important for teachers to monitor students' understanding of tasks as they work and if necessary help them to focus on what to pay attention to or, in the case of some students, how to take wider account of what might be significant.
- Interventions that focus on a particular pedagogic strategy or an element of curriculum change can have a short-term impact but it is rare for them to significantly alter achievement levels and students' motivation to pursue a subject.
- There is evidence from interventions in physics, chemistry and mathematics that a context-based or humanistic approach is successful in enhancing student motivation, retention and achievement, especially for girls but also for boys. However, for this to occur there is a need for a combined approach that changes the curriculum and the assessment approach and is taught in a way that is consistent with the view of learning and of knowledge that underpins this approach. This approach requires systemic change.
- Not enough is yet known about how to support all subgroups of students using this approach. There is a need for research into subgroup effects for any intervention in the future science curriculum.
- Teachers are key to the success of these interventions. A context-based approach represents a significant challenge for teachers. Teachers who see learners as passive and knowledge as abstract and hierarchical will need to be convinced of the need for change,

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understand the reasons for change in terms of views of learning and knowledge, and receive appropriate support. The same will be the case for those students, typically boys, who have learned to succeed with the

traditional approach.

- All teachers will need support to understand the evidence about how gender operates in classrooms and constrains learning. More research is needed here.

4: Teacher effects

Teachers' behaviours and attitudes are a key influence on student attitude, motivation, achievement and continuing participation (Labudde 2000); an examination of the effects teachers have on their students is, therefore, an important part of this review. However, the review of the literature revealed that there were no recent UK-based empirical studies in science, consequently this section examines evidence from studies from other countries and some earlier UK-based studies where they still have relevance today. Studies across subjects are also included where these are large in scale and illuminate the issues.

In this section the following issues are considered:

- Teacher–student relationships.
- Teachers' questioning and feedback strategies.
- Students' and teachers' expectations.
- Teaching strategies to encourage participation.
- The implications.

Teacher–student relationships

Many of the earlier studies, particularly those from the 1980s, examined how teachers' behaviour towards boys and girls differed. Kelly (1988) undertook a meta-analysis of the international research on gender differences in teacher–student interactions across all school subjects by re-evaluating the data presented in 81 studies from the UK, US, Canada, Australia and Sweden. This meta-analysis found that:

- teachers on average spend 44% of their time with girls and 56% with boys, so that by the end of a school career a girl will receive 30 hours less individual teacher attention than a boy (although this was across all school subjects, these differences were particularly noted as occurring in science and social science subjects);
- girls play a more active part than boys in volunteering (i.e. raising their hands in class) by participating in 52% of these types of interactions.

Kelly implied that this finding showed that girls were willing to take part in lessons but were not being enabled to do so. Boys' tendency to call out answers to questions before being selected by the teacher might be part of the reason for the discrepancy between girls' willingness to participate and their lower participation rate.

This was backed up by studies specially focused on science (Galton 1981; Spender 1982; Clarricoates 1987; Stanworth 1987; Tobin 1988; Delamont 1990). These studies found that:

- teachers spent more time interacting with boys, valued

boys' experiences more in the classroom and generally treated boys more favourably than they treated girls;

- teachers had higher expectations of boys' success in science studies;
- there was evidence that teachers were more intellectually encouraging to and demanding of boys (Maccoby and Jacklin 1974; Matyas 1985; Spear 1987; Wilder and Powell 1989).

While these studies were mostly concerned with science in general rather than physics in particular, the effect of this very different behaviour and perception by teachers is particularly important in physics where girls are likely to already feel marginalised in relation to boys.

Tobias in her case-study of college students in the US found that humanities students had closer relationships with their teachers than the physical science students had with theirs. The humanities students felt that their teachers were more interested in what they were doing than teachers in the large physics and chemistry departments. (It is interesting to note that according to Tobias (1990), liberal arts colleges in the US produce a larger share of physical science majors than the large research universities, and she claims that this is due to smaller classes and more accessible teaching staff.)

Lee (2002) in a US study of 340 students in summer science, maths and engineering programmes found that the quality of relationships to significant others was an important influence on female students' choice of subjects. This is in line with Krogh and Thomsen's (2005) findings that personal teacher support was a key predictor of attitudes to physics. If teachers are detached or uncaring and friends do not discuss science this will particularly affect girls' choices as they move to college.

In her doctoral study, Sharp (2004) examined the science teaching experiences of students during years 7 to 11 in three UK schools. Sharp noted that the relationship with the teacher was more important to girls than boys and was frequently mentioned by girls during interviews. Boys rarely commented on the quality of this relationship, only saying that their teacher could have been stricter. This again corresponds to Krogh and Thomsen's (2005) findings referred to in [section 2](#), where it was suggested that in physics girls' relationships with their teachers are more significant for their learning than are boys' relationships with teachers.

There is substantial evidence that teachers' practices are key in determining students' experiences of and attitudes to science and to physics in particular. Research supports the view that the nature of the teacher–student relationship is central to this effect. The

“Teachers’ practices are key in determining students’ experiences of and attitudes to science and to physics in particular.”

supportive quality of teacher–student relationships are important for all students, but more so for girls than boys and this will be particularly acute in physics where girls’ self-concept is less positive relative to boys.

A large-scale study (N = 1105) of physics teaching was undertaken in the Netherlands over a nine-year period from 1984 to 1993 using 15-year-old students in 66 physics classes. This study examined whether the interpersonal behaviour of teachers had changed over that time (Wubbels and Brekelmans 1997). The study reported on how students’ perceptions of teacher behaviour influence how they feel about their teaching and learning environment. The study examined the behaviour of teachers through the students’ eyes, and matched characteristics of teachers participating in the study rather than conducting a longitudinal study using the same teachers.

The great majority of teachers in the sample (97% in 1984 and 95% in 1993) were male. Although the study did not analyse teacher effects according to gender, they reported a positive effect on student attitude when:

- teachers showed leadership and used friendly and understanding teaching styles;
- students were given responsibility and freedom in physics lessons.

An earlier comparative study (N = 792) using the same methodology and conducted in Australia reported similar findings (Wubbels 1993).

Studies that examined teacher behaviour from a gender perspective found that the sex of the teacher affects girls and boys differently. Kelly’s meta-analysis (1988) of student–teacher interactions indicated that:

“Male teachers directed fewer of their interactions at girls than did female teachers and the gender differences were larger in science, social studies and mathematics than in other subjects. The major result is that across a range of countries, ages, dates, subjects and social groups, boys consistently received more attention from their teachers than did girls in the same class.” (p17) “...This is particularly true of feedback – praise and criticism – where male teachers virtually ignore their female students.” (p18)

A US study (Levy *et al.* 2002) of 3023 students and 74 teachers in 168 classes in seven secondary schools using the same research instruments as the Wubbels *et al.* studies cited above (Wubbels 1993; Wubbels and Brekelmans 1997), found that:

- boys who were taught by male teachers found them more helpful, friendly and understanding than girls taught by teachers of either gender (the study does not

relate these findings to specific subject areas, so this is not due to perceptions of science being more appropriate for male students);

- students in science and mathematics classes found that their teachers exhibited less leadership and understanding than students reported for teachers of other subjects. However, class size mattered. Students in larger classes perceived fewer of the positive characteristics of their teachers.

In order to understand this finding it is helpful to again examine Kelly’s meta-analysis (1988). She found that teachers did not believe that boys received more of their attention and thought that they interacted with boys and girls equally. They did not realise that they tended to select boys more often than girls or at least did not compensate for boys’ tendency to self-select and demand attention. Kelly suggested two possible reasons for this situation:

“(i) male domination is so normal in our society that it is literally invisible... (ii) the strongly individualistic element in teachers’ philosophy, with its emphasis on helping each child to fulfil her or his potential blinds them to the implications of their actions for groups.” (p14)

Kelly also found that girls only received their fair share of a teacher’s attention when they were in a minority (less than 40%), but girls were likely to be ignored when they constituted only a slight minority (40–47%).

There is no recent English-based research into teacher–student relationships in physics classrooms. Past research and research from other countries suggest that boys receive more teacher attention than girls do in science classes although teachers are not aware of this. Boys find male teachers more helpful and understanding than girls find teachers of either sex. There is some evidence that science teachers show less leadership, friendliness and understanding towards students than teachers of other subjects, and their relationships with students are poorer than relationships in humanities subjects. The size of the class is significant here.

Teachers’ questioning and feedback strategies

Boys’ classroom behaviour in science lessons is typified by their use of questioning to gain the teacher’s attention. In an in-depth case study of gender and physics/chemistry in a Swedish secondary school, boys vocalising dominated the classroom and they were able to discourage girls from participating. Girls were frequently put into mixed-sex groups for practical activities in order to subdue the boys, which had a negative effect on the girls’ learning (Staberg 1991). The use of gendered seating – alternating girls and boys, is still practised in some science laboratory settings in the UK as a control mechanism for unruly boys. Students

4: Teacher effects

are acutely aware of even subtle differences that teachers may unconsciously make in favouring boys to answer questions. This perceived “favouritism” may be the result of a lack of classroom control, allowing boys to call out answers rather than waiting for the teacher to pick a student to answer. Classes where teachers were sensitised to this issue and who undertook gender monitoring were viewed by students as more equitable, and this was reinforced if teachers also used teaching strategies such as small group work and co-operative learning activities (Scantlebury and Butler 1991).

In a characterisation of a typical science classroom in Australia, boys were represented as monopolising the teacher’s attention by their ability to answer questions before other students had an opportunity. The complicity of the teacher (given the name Hank) with the boys’ behaviour is suggested by the authors as a control strategy in line with Staberg’s findings. The quotation below is given as a representation of a typical male teacher – female student interaction in an Australian science classroom:

“[Hank] directs a plethora of knowledge-level questions to a few vocal males...When he lapses from his control strategy to help Judy, the males capitalize on his shifting attention and misbehave to get it back...[Judy] internalizes what she perceives as his rejection of her and...plans to avoid asking questions in class if she can possibly help it. Hank... misinterprets her fatalistic silence as understanding and praises himself for efficient teaching and control of the class...He does not see his teaching as inequitable, or the irony of the myth of control he perpetuates.” (Bailey *et al.* 1997, p33)

In a Canadian interview study concerned with gender and teacher–student interactions, Haggerty (1995) described differences in male and female science teachers’ (N = 26) reflection on their practice. The study suggested that:

- female teachers had a better developed sense of relating to students and this was demonstrated by the way they spoke about students’ understandings of concepts they had taught them;
- male teachers’ views of successful teaching incidents involved getting a concept across to students, using more of a transmission didactic style of teaching;
- women’s ways of relating to the world and their feelings of being connected to others leads them to adopt different teaching styles to men. (This notion is discussed extensively by Belenky *et al.* 1997.)

Perhaps some female scientists and science teachers may have had to reject these feeling of connectedness in order to embrace the abstract nature of physics as a con-

sequence of their own physics learning experiences. Therefore, although some female teachers will practise different teaching styles from their male colleagues, as found by Haggerty’s study, many will not, unless these different pedagogies are given value in teacher training and development programmes, as suggested by Haggerty.

Boys are often criticised about their behaviour rather than the quality of their work, so they are able to retain confidence in their ability despite this higher frequency of criticism. Dweck *et al.* (1978) found that this leads girls to have low expectations of their abilities and for boys to overestimate theirs. In a subsequent study where both girls and boys were given the sort of feedback most often given to girls, Dweck *et al.* found that both sexes tended to lose confidence in their academic abilities (Dweck in Kelly 1988). Parsons *et al.* (1982) also found that it was the absolute level of criticism that mattered, not its discriminate use, and that criticism about academic work conveys the message that the teacher has high expectations for the student. Teachers’ use of feedback was also highlighted in a more recent study by Howe (1997). Howe was commissioned by the Scottish Council for Research in Education (SCRE) to review the findings of gender and classroom interaction studies across subjects. She reported that:

- boys dominated class interactions and received more feedback, both positive and negative, than girls;
- girls received less negative feedback than boys but the feedback they received focused on their work (this type of feedback, it was argued, influenced their expectations of themselves and their perceptions of their abilities negatively);
- negative feedback for boys was generally about their behaviour and so tended not to influence their expectations of themselves and their abilities.

These findings suggest that teachers may be providing a better learning environment for boys, even though they criticise their behaviour.

In their review, Kahle and Meece (1994) summarise research findings about teacher–student interactions in science classrooms and report similar findings:

“Compared with girls, boys are more likely to initiate teacher interactions, to volunteer to answer teacher questions, to call out answers, and to receive praise, criticism, or feedback to prolong teacher interactions. These classroom interaction patterns result in greater opportunities for boys than for girls to learn in science and may reflect [teachers’] favourable achievement expectations for boys.” (p550)

There is evidence of differences in the amount and type of feedback that teachers may provide students. What evidence there is suggests that boys are more likely than girls to dominate class interactions and that girls are

more likely than boys to receive feedback on the quality of their work rather than their behaviour, and the converse is the case for boys. However, these findings need to be considered in light of the lack of research into physics classrooms particularly in an English context.

The Kahle and Meece (1994) study compared teachers' responses to a questionnaire with their classroom behaviours, and found like Kelly that while teachers may say they are aware of equity issues, that awareness had not changed teacher actions. More recent studies provide similar evidence of teacher–student relationships in physics classes. A recent Israeli study of 25 physics teachers of year-10 students in different secondary schools (Zohar and Bronshtein 2005) about their knowledge and beliefs reported that 64% of physics teachers did not see the participation of girls in physics as a problem that required any action. A recent Swiss study on the influence of teacher effects on students' participation in 31 physics classes found that interventions can enhance teachers' knowledge and sensitivity towards gender issues in physics classrooms (Labudde 2000). By asking teachers to explore and integrate individual students' preconceptions in classrooms, the study found evidence of increased communication between teachers and students and that this was the most effective of the intervention strategies employed.

The evidence from research suggests that it is likely that most UK physics teachers are aware of the issue of gender and classroom interactions but are not aware of how classroom interactions are mediated by their own and students' beliefs about gender-appropriate behaviours in relation to physics.

Students' and teachers' expectations

A supportive learning environment

In her doctoral study, Sharp (2004) found that a central concern of students was a perceived lack of understanding and respect by teachers for students' difficulties. Teachers assumed that students understood and gave limited responses to student questions seeking understanding. Students' lack of understanding only emerged in mock GCSE results, by which time it was too late for students to make up the lost ground and damage was already done to student's self-concept in science. This effect is particularly important when students may not have support from parents, and parents do not understand school assessment procedures (e.g. tiering practices at GCSE – this is discussed fully in section 7). Sharp argued that teachers must provide students with appropriate encouragement and that student learning needs must be identified and treated with respect.

On the basis of their large-scale qualitative and quantitative study in Israel (N = 400) Zohar and Sela (2003) considered that girls' poor self-concept in physics was a reason for their low participation, together with girls' greater concern to achieve high grades. (These findings reinforce those

reported in section 2.) They argued that students need to feel respected and be comfortable with the learning environment to be able to participate, and not be afraid to take risks that may expose them to criticism and ridicule.

Other researchers (Beyer 1991) recommend a similar approach, suggesting that teachers need to create a warm and supportive “climate of teaching” and make the students conscious of their own cognitive and affective reactions in order to support students who want to “learn meaningfully”.

Teacher expectations

A small-scale study, carried out by Spear (1987) with 165 teachers in coeducational secondary schools in the UK, illustrated some of the different expectations that teachers held for boys and girls in science. Although this study is now rather old, its outcomes were so significant that it is worth including here. In the study each piece of written work in science was attributed to both a boy and a girl, and teachers were then asked to mark a sample of the work. The study found that:

- teachers' rating of “boys' ” science work was higher than that of an identical piece of work attributed to a girl;
- “boys' ” work was given a higher ranking for richness of ideas, scientific accuracy, originality of ideas, interest in subject and suitability for GCE O-level courses;
- “girls' ” written work was only ranked more highly than that of “boys” on neatness;
- the teachers in this study tended to hold higher expectations in terms of science qualifications for boys than girls;
- both science and non-science teachers in the study thought that science was more important for boys, this effect being greatest among the science teachers.

This finding was supported by Walkerdine (1989) where she argued that her research in maths education showed that even when girls performed equally well as boys, teacher interpretation of their work was less good and unintentionally influenced by the student's sex. (This is in line with Elwood and Comber's (1996) findings discussed in section 2, where teachers perceived weaknesses in girls' physics understanding but not in boys', and this was not related to achievements.) A key finding from another study in Israel (Zohar and Bronshtein 2005) was that girls with average grades were not encouraged to study physics whereas boys with similar grades were. If teachers hold different perceptions of girls' and boys' abilities in physics based on their gender and if they also see physics as primarily a boys' subject, these subtle and not so subtle messages are likely to be transmitted to the students. In the UK, school league tables may also have an effect. If it is believed that it is more difficult to gain a higher grade in physics than in other subjects, as shown in section 6 of the review, students whom teachers believe will succeed better in other subjects may be advised against studying physics A-level.

Past research has shown that teachers' expectations of students have a significant effect on students' self-concept in physics. Although recent research is limited, there is evidence that teachers hold expectations for girls generally in science and physics that are lower than for boys. These expectations are not supported by girls' performance in the subject.

Teaching strategies to encourage participation

In [section 3](#) the general characteristics of courses that enhance girls' engagement and achievement in physics, and the implications for teaching generally were discussed. Here the focus is on pedagogic strategies and includes research into students' views of these. There is no recent research into pedagogic strategies and gender in physics in an English or a UK context at secondary level other than small-scale in-depth studies. Alting and Wagemans (1991) presented the results of a literature study that aimed to develop a model of teaching and a definition of "ideal" physics teaching for girls. The intention was to provide a basis for research on the influence that physics teachers may have on girls' appreciation and choice of physics. The model of "ideal" physics teaching derived from the literature included teacher behaviours (de-stereotyping physics as a male domain; accounting for gender differences; treating girls and boys equally but not the same) and learning environment characteristics (non-competitiveness; accommodation to individual needs, interests and skills; structure; and material surroundings).

Kahle and Meece's review (1994) cites two studies by Kahle that showed that teachers who had a high proportion of girls continuing to enrol in high-school chemistry and physics used specific teaching practices:

"[Compared with other teachers] they emphasized laboratory work and discussion groups, they quizzed their students weekly, they stressed creativity and basic skills and they used numerous printed resources rather than relying solely on one textbook. The teachers, mostly females, also provided their students with career information and informal academic counseling. They all had attractive classrooms, decorated with posters and projects, and kept live plants and animals in their laboratories." (p551)

The research discussed in [section 3](#) noted that a constructivist approach that maintained students' agency and autonomy in learning and involved project and investigative work were key characteristics of context-based and humanistic science and physics courses that supported girls' engagement in their learning. A US study (Freeman 2002) investigated the effect of laboratory work on achievement and attitude to physics of grade 9 (14- to 15-year-old) students using an intervention and control groups. The research found that:

- girls who had taken part in the laboratory work intervention improved their science achievement compared with the girls who had received traditional teaching with no laboratory component;
- there was no difference between the achievement of boys and girls in the laboratory group, whereas the achievement of girls in the group that had not undertaken any laboratory work was less than that of the boys in that group.

The study suggested that the laboratory component of the physics course (which consisted of 36 weekly classes) demanded active participation by all students in the class, including the girls, and that this participation was responsible for the girls' higher achievement. This provides further support for the need to enable girls' and boys' active engagement in physics but needs to be seen as just one helpful strategy to increase girls' achievement in physics. The decline in practical activity in secondary science noted in Sharp's 2004 research is a matter for concern in light of findings such as these.

Another strategy suggested by Hildebrand (2001) advocates alternative and more creative ways of writing in science using a range of styles such as anthropomorphic story writing, poetry/songs, newspaper articles, detective stories, legal reports, travel brochures, etc. to help students present what they know in creative ways that may overcome some of the barriers to studying science for many students. From a study of 20 teachers who used these techniques in Australian classrooms over three years, Hildebrand reported that teachers who used the creative-writing techniques found that they helped students present what they knew and encouraged them to be more divergent in their thinking. Teachers also claimed that the techniques can support deep and meaningful learning, as opposed to shallow and surface rote learning. The study reported that the techniques aided memory work, helped to pick up misconceptions, supported the synthesis of concepts, enabled students to use their own words and so support learning, and enabled them to demonstrate learning to their teachers and other students. (This research emerged out of the work done by the McClintock Collective in Australia in the 1980s, which used intervention strategies to develop gender-inclusive pedagogies that aimed to increase the numbers of girls in science. The collective's work is introduced in [section 3](#)) Some of these creative-writing strategies are now embedded in the Key Stage 3 strategy for science in England.

The five Learning in Science Projects conducted by researchers at the University of Waikato in New Zealand during the 1980s and 90s (Bell 2005) also investigated teaching strategies that have the potential to improve learning in science. Again small group or whole class discussion was shown to be a key aspect of an effective learning strategy. Discussions of students' alternative conceptions were core to this process. The review suggested that teachers should organise social groupings for learning and defined new roles for teachers, such as being co-researchers and learners. This is in line with Sharp's findings (Sharp 2004)

where respect for the learners, in the sense of listening and taking notice of each learner's views, is important for all students' learning in science. In addition, the review also suggested that teachers promote conceptual change by emphasising study skills; proposing a counterview; supporting further inquiry; reflecting, eliciting, accepting and testing out ideas; linking old and new ideas; and promoting new ideas in new situations (Bell 2005).

In their study of year-12 and year-13 physics students (N > 1000) in Norway, Angell *et al.* (2004) reported that students want lessons to be more varied and more student centred. Students disagreed with teachers about the frequency a variety of teaching approaches was used, particularly "chalk and talk", which was reported as being used more frequently in physics and mathematics lessons than teachers admitted and more frequently than in English and social science. Students emphasised that variation in teaching methods is vital. The findings from the VCE project in Australia (Hart 2002) referred to in [section 3](#) and the outcomes from an in-depth doctoral study (Sharp 2004) in the UK provide additional evidence for this. Sharp's study outlined students' views of how they would prefer to learn in science. Students in the study felt that their learning in science would be supported by:

- undertaking practical activities that involved problem solving rather than following recipe-type instructions, because it enhanced their interest in the subject;
- group-based activities, because they recognised the pedagogical value of collaboration and dialogue with peers, which provided opportunities for interpretation and re-evaluation of their own understanding;
- being given more responsibility for their own learning, rather than all learning being teacher directed.

Students in this study disliked being treated as passive receivers of knowledge rather than as active learners, and the girls in particular valued understanding of the subject over success and achievement.

The study added additional evidence to the other research referred to above that supports students' desires for variety in teaching styles, and teaching which gives recognition to the different prior learning experiences of different students. This is a key finding from the review as it has implications for the way teachers structure the learning experiences of different students. In particular, as discussed in [section 3](#), when students' interpretation of tasks differ, due to gender differences, it is important that teachers are able to recognise this and adjust their teaching styles accordingly.

Studies that have examined pedagogic strategies that increase students' motivation and enjoyment to learn science have found that students give value to approaches that are typical of teaching and learning in a humanistic science curriculum. The strategies that maintain students' autonomy and responsibility for their learning include investigative laboratory work, group and

class discussions where alternative views are considered and valued, problem-solving and project-based activities where students are the decision makers, and creative writing involving a wide range of genres in which science understanding is communicated to the public. There is emerging evidence that these strategies impact positively on the achievement levels of girls as a group relative to boys and have no negative impact on boys' overall achievement.

The implications

- Questioning strategies that are sensitive to girls' participation and that take note of who is involved in class discussion and how they are involved have been shown to be effective in encouraging girls' participation in science and in physics.
- Regular monitoring of teachers' interactions with students may be useful to show whether girls are actively participating or whether they have become invisible to the teacher.
- The strategies for assessment for learning such as "wait time" for question responses and "no hands up" questioning techniques have been shown to aid the creation of a gender inclusive pedagogy for girls and boys. It is a matter of concern that formative assessment reviews and developments of formative assessment practice in science have failed to consider a gender perspective.
- Research suggests that positive feedback and encouragement from teachers during the lesson and in personal conversations, and respect for students' learning needs would encourage girls' participation in physics. In addition, feedback to girls needs to be monitored so that they are praised for their achievements and potential in physics, not only for their diligence and discipline.
- Student responsibility and control over learning has been shown to positively affect interest and learning in science and physics. Practical work involving problem-solving activities has the potential to empower all students, particularly girls.
- Students benefit from opportunities to discuss their ideas with their peers in order to see the value of different perspectives, refine their ideas and enhance collaboration in learning. Girls in particular report that they value this approach.
- The monitoring of girls' participation in laboratory work can demonstrate whether they are participating actively, what might be constraining their participation and whether they are being supported appropriately.
- The pedagogic changes that enhance girls' participation and maintain that of boys alter the teaching role and the teacher-student relationship. Successful teacher-student relationships demonstrate:
 - leadership and understanding in the classroom;
 - the use of a variety of teaching and learning strategies.

5: Single-sex schooling and groupings

There have been numerous studies, both large-scale quantitative and smaller-scale qualitative, examining the effects of single-sex schooling on participation and performance. Of particular interest for the review is the effect of different schooling experiences on the uptake and achievement in science and physics. This section of the review examines the literature using the criteria applied across the review and with a focus on UK findings but looking to international research for support for these findings or additional illumination. There is more literature available about single-sex schooling effects in relation to science and physics than literature about single-sex groupings. This section looks at:

- Single-sex schooling effects:
 - achievement patterns;
 - achievement and self-concept;
 - take up of physics.
- Single-sex groupings in coeducational schools:
 - achievement patterns;
 - pedagogy and single-sex groupings.
- The implications.

Single-sex schooling effects

Achievement patterns

Most studies of achievement in relation to school type particularly in the UK have tended to generalise rather than report by subject. The findings of general studies from England are reported first, followed by studies from other countries. The most recent studies are then discussed.

Smithers and Robinson's report on coeducational and single-sex schooling (1995) was based on an analysis of the 1994 examination results and focused on school effects on achievement patterns. The unit of analysis was the school not the student. They concluded that:

- the high achievement levels of students in single-sex schools in comparison with students in coeducational schools were associated with the nature of the schools rather than the segregation of the sexes;
- three significant features of single-sex schools were identified:
 - they are highly selective;
 - they recruit from higher socio-economic backgrounds than other schools;
 - they have long-established academic traditions.

The report quoted from Sammons *et al*'s (1994) earlier study, which argued that 30% of the variation in examination results could be explained by the ability of the schools' intake, 6% by social and cultural background, and 9% by school effects.

In their follow-up study, which was in response to con-

tinuing challenges to their findings, Smithers and Robinson (1997) re-analysed the 1995 GCSE examination results for English schools. They compared the performance of girls from girls' schools with girls in coeducational schools, and boys in boys' schools with boys in coeducational schools. They found again that:

- students in single-sex schools did achieve higher levels than their counterparts in coeducational schools;
- girls from coeducational comprehensives were found to perform at the same level as girls from single-sex comprehensive schools.

The research also reanalysed the 1997 GCSE results for different types of independent schools. This revealed that:

- girls in coeducational independent schools performed as well or better than girls in single-sex independent schools;
- the performance of a school had much less to do with the segregation of the sexes than with other factors.

As part of the study Smithers and Robinson interviewed 100 students in their first year at a high-ranking university about their school experience. The results showed that:

- students in coeducational independent schools rated their academic experience as positively as their single-sex counterparts;
- girls in single-sex schools were more likely to consider that they had been stretched academically than girls in coeducational schools but the actual school did matter.

The Association of Maintained Girls' Schools funded a review of evidence about single-sex schools carried out by Elwood and Gipps (1999). They reported on findings in the UK, Australia, US, Ireland and developing countries and concluded in line with Smithers and Robinson that:

- social class and prior attainment remained the most powerful predictors of educational achievement;
- the type of school, i.e. independent, selective or comprehensive, had more impact on achievement than whether the school was single-sex or not.

The findings from early studies pointed to the need to treat with caution the findings that single-sex organisation on its own was a significant factor associated with enhanced achievement in examinations at age 16. Social, cultural and institutional factors have to be taken into account as well as the prior achievements of the student populations.

“Evidence about the impact of single-sex schooling and groupings is limited but it is clear that these organisations alone do not enhance girls' interest in or motivation to study physics.”

5: Single-sex schooling and groupings

In a longitudinal study of 5300 students in 37 schools in New Zealand and analysis of national data banks Harker (2000) found that girls in single-sex schools were more likely to have higher socio-economic backgrounds and be European or Asian than girls in coeducational schools. When these factors were accounted for in his analytical model he found no residual effects for single-sex schools.

One large-scale study that looked in particular at physics achievement involved the reanalysis of the Australian database of the Second International Science Study (Young 1994). The strength of this study was in the rigour of the multilevel analysis applied. The limitation is the database itself, which used multiple-choice measures of achievement that have been found to be biased in favour of male students (Gipps and Murphy 1994). The analyses confirmed the findings above:

“These results suggest that, while students attending single-sex schools in Australia have outperformed students attending coeducational schools, the increased physics achievement of such students may be due to such factors as the home background of students attending single-sex schools.” (p323)

At the same time as the Elwood and Gipps review, the American Association of University Women (AAUW) Educational Foundation published its report on single-sex education for girls (AAUW 1998). The studies in the US have tended to be restricted to Catholic or private schools and the report therefore drew on international findings in making its conclusions. These were that:

- there was no evidence that single-sex education in general “works” or is “better” than coeducation;
- the long-term impact of single-sex education on males and females was not known;
- single-sex education was very broad and therefore defied generalisation. Account had to be taken of social, cultural and institutional factors, as one single-sex environment may be very different to another.

Mael (1998) carried out a similar but far more extensive review and examined the evidence for the various hypotheses of effects associated with single-sex education. He concluded that when the studies were taken as a whole there was some evidence that females benefited, particularly in maths and science, from single-sex education. He noted that findings were mixed and that there was a need for research that examined the dynamics of single-sex classrooms.

The second NFER study (Spielhofer *et al.* 2002), commissioned by the Local Government Association, reviewed published literature on impact on performance of (i) school size and (ii) single-sex education. This review was critical of some of the studies reported above, such as Smithers and Robinson’s, because the data reported was collected at school level rather than student level and prior attain-

ment was not taken into account. Prior attainment is seen as a way of controlling for ability. Two criticisms of the use of prior achievement as a surrogate measure of ability are that (i) it takes no account of students’ learning potential and (ii) the measures used to define prior achievement may be limited representations of individual achievements. The NFER study used national value-added data sets that allowed performance at Key Stage 2 (students aged 10–11 years old) to be linked to GCSE outcomes (students aged 16). The study used multilevel modelling to assess progress through secondary schooling. This analysis found that:

- even after controlling for prior achievement and other background factors, girls in single-sex comprehensive schools achieved better results than their peers in mixed schools for all the outcomes measured, except the number of GCSEs taken;
- the measured difference was particularly striking for average GCSE science score, for which girls in single-sex schools could be expected to achieve over a third of a grade better than similar students in mixed schools (a similar finding was reported by the Girls’ Schools’ Association (GSA 2004) based on an analysis of their exam results, though this took no account of variations between populations);
- single-sex schooling particularly benefited girls at the lower end of the ability range (this finding was also reported in a study of single-sex and coeducational schooling in Ireland (Hannan *et al.* 1996));
- no performance gains were detected for girls attending single-sex grammar schools.

While the study represents an important step forward in establishing effects, the authors noted the limitations in their analyses. Account was not taken of the ethnic background of students (ethnic inequalities are found to persist even when controlling for gender and social class) and levels of parental support, which the authors cautioned might contribute to the differences in achievement between single-sex and mixed schools.

More recent studies that control for some student variables and social and institutional factors indicate that achievement at GCSE is significantly enhanced by single-sex educational organisation, particularly for students at the lower end of the ability range. In international studies of single-sex organisation, the learning environments vary considerably and the findings do not support those established in the English context.

There is some evidence from these studies that single-sex organisation has a positive effect for girls in maths and science but only in some school contexts. No studies have considered the effect of ethnicity and parental support on comparative patterns of achievement. There have also been no published studies of teaching and learning of physics in single-sex organisations in England.

5: Single-sex schooling and groupings

Achievement and self-concept

In other sections of the review, self-concept (i.e. students' sense of themselves in relation to physics) was a predictor of take up and achievement in physics. There is some research that has considered the impact of single-sex schooling on self-concept. The AAUW (1998) review concluded that there was some evidence of more positive perceptions of cognitive competence and higher self-esteem for girls in single-sex education. Brutsaert and Van Houtte (2002) compared girls' and boys' sense of belonging and integration in school in 25 mixed and 43 single-sex schools (21 were girls' schools and 22 boys' schools) in Belgium. All the schools were academic and had a similar curriculum. The study employed multilevel analysis and was able to control for pupil and school factors. They found that:

- girls in single-sex schools reported a greater sense of belonging and integration in school than did their peers in mixed schools, and socio-economic background did not affect this finding;
- there was a positive effect between grade achievement and girls' (but not boys') sense of belonging;
- the quality of parental support was found to strongly affect both girls' and boys' perception of feeling integrated but these factors were not considered in relation to type of school.

There is some evidence from international studies that single-sex organisation can have a positive effect on girls' self-concept and feeling of belonging and this correlates with overall performance.

Subject preferences and take up of physics

Elwood and Gipps (1999) reported the findings of two studies that considered subject preferences and attitudes to subjects in relation to type of school (Stables 1990; Colley *et al.* 1994). Stables (1990) compared the attitudes of 13- to 14-year-olds and found that:

- attitudes of both boys and girls were more strongly polarised in mixed schools than in single-sex schools (this repeated the earlier findings reported by Ormerod and Duckworth (1975));
- physics was more liked by girls in single-sex schools compared with girls in mixed schools.

Colley *et al.* (1994) found that preference for less stereotyped subjects was age related:

- Girls aged 11–12 in single-sex schools showed a much stronger preference for science than girls from coeducational schools.
- This difference disappeared by the age of 15–16 to be replaced by more stereotyped preferences.

Francis *et al.* (2003) provide further support for Colley *et al.*'s findings and also demonstrated that while single-

sex schooling may benefit females in the sciences, students' liking for and interest in subjects like physics as they are currently taught remains problematic. The study surveyed students in year 10 and year 11 (i.e. aged 14–16) in eight state-maintained girls' schools in England. Half the girls were in top-band groups and half in middle-band groups. The questionnaire asked girls to rate their favourite and least favourite subjects. The authors compared students' responses with those of girls from mixed schools involved in an earlier study and found that:

- science subjects were more disliked than liked by girls in the single-sex schools;
- 30% of girls in single-sex schools compared with 20% of girls in mixed schools selected science as their least favourite subject – of the 30%, 7% selected physics;
- 43% of top-band girls selected science as their least favourite subject compared with 21% of middle-band girls.

The authors suggest that this might reflect the learning environment of top groups, as other research into mathematics teaching and learning had found that girls disliked the approach in top sets, which were seen to be competitive, fast paced and not conducive to developing deep understanding (Boaler *et al.* 2000). This is in line with general findings that fast-paced coverage of content is an aspect of students' science experience that makes science more difficult than other subjects. These findings also reinforce the view that it is not the single-sex characteristic of a learning environment alone that enables girls' learning, other factors within that environment also have to be taken into account.

There have been few recent studies into the effect of school organisation on subject preferences. What evidence there is shows that gender differences in subject preferences continue irrespective of school organisation, though there is evidence that differences emerge at the older rather than the younger ages in single-sex schools in contrast to coeducational schools. There is emerging evidence that a significant proportion of girls studying science in single-sex schools report that they dislike the subject and that this is more marked for girls in top bands. This is attributed to the curriculum experience rather than the school organisation.

The Youth Cohort Study (Cheng *et al.* 1995), undertaken by the Policy Studies Institute and funded by the Department for Education and Employment, examined data from nationally representative cohorts of 16- to 17-year-old students attending a variety of schools and colleges in England and Wales. The study found that comparing populations of girls from all girls' schools with girls from mixed schools:

“A-level candidates who attended all girls' schools in year 11 were more likely than girls

from mixed schools to opt for mathematics or physical science.” (pp11–12)

However, this difference in uptake was reversed when the home background of students and their achieved grades in maths and science was controlled for to enable similar populations to be compared. The study also showed that girls from coeducational schools were more likely to take physical science than girls from single-sex schools, although the effect was on the margin of statistical significance. The study did find, along with other studies reported in [section 2](#), that achievement in maths and science was the most significant factor associated with the choice of A-level subject and that this was more significant for girls than it was for boys. A good grade in GCSE maths was associated with the choice of physics and chemistry. The research also found that those students who had taken Double Award Science were significantly less likely to opt for physical science A-levels compared with those taking separate sciences. However, it should be borne in mind that Double Award Science was still relatively new when the research was undertaken.

Research shows that prior achievement in maths and science is a very significant factor in students’ take up of physics post-16 irrespective of school type and organisation.

Sharp *et al.* (1996) at the NFER conducted a large-scale study of course take up for the SCAA. The study examined data from 722 schools and 136 colleges and found no evidence for increased take up of physics for girls in single-sex schools. A negative effect of Double Award Science was mentioned by fewer physics teachers (20%) than biology or chemistry teachers, with a greater proportion of physics teachers (25%) citing poor maths preparation as a reason for low take up of physics post-16.

The second NFER study (Spielhofer *et al.* 2002), reported above, used regression analysis to assess the impact of single-sex education on the chances of entry to certain GCSE subjects and to higher tiers at Key Stage 3 maths and science. (A tier of entry defines the levels of achievement covered by the test, the higher the tier the higher the level that can be achieved – see [section 7](#) for a detailed discussion.) The study found that:

- girls in single-sex schools were more likely to take nontraditional subjects, i.e. those typically dominated by boys, and this included the separate sciences;
- after controlling for prior attainment, both boys and girls in single-sex schools had a greater chance of being entered for higher tiers of Key Stage 3 mathematics and science than their peers in mixed comprehensives;
- the greatest difference was in science, where “girls in girls’ schools had a 40 per cent greater chance of being entered for the higher tier” (p47);
- 44% of boys’ schools offered separate sciences (Triple Award) compared with 23% of girls’ schools, a similar

proportion to that of mixed schools offering separate sciences. However, being in a girls’ school increased the odds of girls taking the separate sciences by 30–40%.

The authors, taking account of the increased likelihood of girls in girls’ schools being entered for the separate sciences in the Triple Award compared with the likelihood of girls and boys in mixed schools being entered, concluded that girls in single-sex schools were: “least as likely to take separate sciences as boys in mixed schools” (p154).

In a recent doctoral study (Moore 2004), a case-study of a single-sex school found that girls believed themselves to be pushed academically and perceived themselves as able as boys to do any subject including physics:

“Katie: We went to a physics conference and we were like the only girls! There were hardly any girls there and we were the only girls’ school.
Niamh: It made me feel proud...because you’re in a girls’ school you kind of forget that maths and physics is a male dominated area and you are encouraged to do it. It’s not like the boys are that and the girls are this so it’s only when you go to things like the conference when you go – ‘Oh my God’.” (p85)

The head teacher in the school also reported on beliefs about single-sex schooling:

“Some university staff and this is anecdotal, have said you can spot a girl from a girls’ school at once, she defends her arguments, she doesn’t give way, you know. You can spot someone who went to a girls’ or a boys’ school and was a winner – did physics, took on the boys and beat them...” (p100)

The study findings suggest that teachers’ expectations of their students are higher in single-sex schools than coeducational schools. This is supported by students’ reports of being stretched (Smithers and Robinson 1997; Moore 2004). These are significant findings as performance at Key Stage 3 is an important factor in influencing teachers’ decisions about award allocation and tier allocation in science. It is a critical point at which students’ access to the science curriculum and to opportunities to study physics either in Double Award Science or the Triple Award Science is decided. Girls in single-sex schools are less likely, therefore, to experience the consequences of having ceilings placed on their achievements at Key Stage 3 than their counterparts in coeducational schools (Elwood and Murphy 2002).

There is evidence from national test and examination entry patterns for maths and science that teachers’ expectations of girls in single-sex schools are higher than those of teachers in coeducational schools. There is a

5: Single-sex schooling and groupings

tendency for girls in single-sex schools to be entered for the higher tiers of Key Stage 3 maths and science tests more than their peers in coeducational schools. They are also at least as likely to be entered for Triple Award Science as boys in coeducational schools are and more likely than girls in coeducational schools.

Single-sex groupings in coeducational schools

Achievement patterns

In the discussion in [section 3](#) of interventions to increase girls' participation in science, the use of single-sex groupings was referred to as a strategy to increase girls' confidence and self-concept in science. Studies to determine the effectiveness of this strategy are difficult, as the strategy is rarely applied in isolation from other changes or with control groups to compare effects. One large-scale study conducted in Germany (Hoffmann 1997) of 8000 physics students aged 10–16 showed higher achievement for girls who were educated in single-sex classes. Similar findings were reported by Australian research that examined the advantages of single-sex classes in a large-scale study of 700 students (Parker and Rennie 2002). Both studies found that girls' achievement increased when:

- single-sex teaching was accompanied by changes in the curriculum, changes that made physics interesting to girls by relating their learning to real-life contexts;
- single-sex teaching allowed smaller class sizes, which helped teachers to use gender-inclusive strategies;
- single-sex teaching allowed girls to be taught by committed teachers who were aware of gender issues.

UK-based studies undertaken by researchers at Bristol University (Gillibrand *et al.* 1999) examined the effects of single-sex classes on physics achievement in a mixed comprehensive. Though small in scale the study used control groups, though students self-selected which group to participate in. Students were given the option of which type of organisation, either single-sex or mixed, for their physics lessons. The study looked at two cohorts of students:

- 32 girls in the first cohort studied higher-level physics and 25 opted for a single-sex class;
- 26 girls were in the second cohort and 22 of them chose the single-sex class.

Classes were taught by male physics teachers. The research found:

- confidence gains for all groups in both cohorts, which correlated with a higher GCSE achievement in physics;
- before the intervention two to three girls compared with 11 to 18 boys studied A-level physics; in the single-sex classes the number of girls rose to 22 and the number of boys rose to 34 in both cohorts;
- girls in the single-sex classes who did not achieve an

A or B grade continued with the subject in contrast with students in the mixed classes.

The authors argue that this finding reflected the way the girls in the single-sex classes came to experience themselves as able to do physics rather than as comparatively weak at physics, i.e. there was a change in their physics self-concept. This is supported by the studies, discussed in [section 2](#), that show that self-concept is a key predictor of course take up.

A later study by the Bristol researchers (Robinson and Gillibrand 2004) based on a year-9 cohort who were taught science for a year in single-sex classes showed that only higher-set girls and boys showed higher achievement. The researchers concluded that single-sex teaching offers some benefits but in itself was not enough to ensure increases in achievement for all students.

Work in Sweden with single-sex groupings showed that the girls in interview reported that they favoured single-sex teaching in physics and maths only, as these were subjects where boys' superiority and power in the classroom was taken for granted or their presence was considered to be the norm (Staberg 1992). This is similar to Kelly's findings (1988), discussed in [section 4](#), about the normality of boys' presence in the science classroom.

Warrior (2003) looked at case studies of single-sex groupings for science in seven coeducational schools, which included state comprehensive, selective and independent schools. While the interview evidence from teachers suggested that the strategy was considered positively with a strongly expressed belief that girls benefit, there is uncertainty about the impact on achievement. There was no conclusive evidence that the strategy led to an increase in uptake and achievement at A-level.

Pedagogy and single-sex groupings

One of the criticisms of studies of single-sex schooling effects is that no studies have looked at the classroom dynamics. There is also a lack of studies that examine the pedagogy in single-sex groupings in mixed schools. Where these exist, the purpose of the single-sex grouping has often been to support students as they learn about gender in order to empower students (Kruse 1996; Kenway and Willis 1997). Hence the emphasis has not been on subject-specific pedagogic strategies. In the UK the small numbers of studies at classroom level that do exist have tended to focus on effects, i.e. achievement rather than the pedagogy employed. This has shifted in recent years but the focus has been on other subjects and not science or physics, and on boys rather than girls. Consequently there is increasing documentation about subject-specific strategies of effective inclusive pedagogy for boys in areas like English (Iverson and Murphy 2003).

What evidence there is suggests that the strategy needs to be applied with caution. The AAUW review (1998) concluded that single-gender classes could reinforce sex stereotypes as much as coeducational classes. More recent research in England that has examined subject-

specific pedagogic strategies in the context of English teaching also points to the potential that gender differences can be exaggerated in single-sex groupings to the detriment of girls' and boys' learning. This arises if single-sex teaching is not combined with a gender-inclusive curriculum and pedagogy employed by aware and committed teachers (Parker and Rennie 2002; Murphy and Ivins 2004).

Longitudinal studies of individual schools that are using single-sex groupings across the main curriculum including science are emerging, but there is little evidence about the pedagogy employed in the different organisations. Furthermore there is no specific evidence about science or physics achievement, though one school claimed that:

“on the basis of results, performance and confidence levels up to 16...the school has been extremely successful. All the evidence suggests that girls in the school achieve outstanding results and feel very comfortable and stimulated to learn in the school.” (Younger and Warrington 2002, p18)

What this research has established is the variation between teachers in their responses to how to best teach boys and girls. This was noted too by Martino and Meyenn (2002) looking at single-sex groupings for teaching English in an Australian context. They observe that this:

“raises critical questions about the relative absence of qualitative research into an examination of the specificities of teachers' pedagogical practices within the context of the implementation of single-sex classes and single-sex schooling”. (p321)

There is very little research into the impact and effectiveness of single-sex groupings and achievement in science in the short term or the long term. What limited evidence there is suggests that only where the pedagogy and the curriculum are effective and inclusive can single-sex groupings enhance girls' achievement, self-concept in physics and their motivation to continue their study of the subject. The research does not claim effectiveness across all subgroups of girls.

The implications

- The evidence that access to physics is increased because of teachers' different expectations of girls in single-sex schools compared with teachers in coeducational schools is significant and warrants further research.
- The evidence about the impact of single-sex schooling and groupings is limited but it is clear that these organisations alone do not enhance girls' interest in or motivation to study physics. What has an effect is the combination of single-sex grouping, inclusive curricula, high teacher expectations and effective inclusive pedagogy.
- There is a need for research to examine the pedagogy in physics classrooms where single-sex organisation is applied and this should be compared with the pedagogy employed in successful mixed classes in order to establish what effect if any the single-sex organisation has.
- Furthermore there is a need for a coherent programme of staff development before any wider implementation of such strategies.

6: Measures and perceptions of difficulty

This section of the review examines how perceptions of the difficulty of science and of physics are reported to influence access to and achievement in physics. There have been numerous attempts to establish a measure of difficulty and it is generally agreed that technical procedures to compare grades and measure subject difficulty are problematic. Nevertheless common-sense beliefs about which subjects it is easier to get a good grade in continue to circulate in schools and influence students' choices and teachers' practices, and test and examination entry decisions. The section looks at the following:

- Subject difficulty:
 - comparability;
 - validity of comparability findings.
- Teachers' perceptions of difficulty:
 - teachers' entry practices.
- Students' perceptions of difficulty:
 - content overload.
- Attributions of success and students' expectations.
- The implications.

Subject difficulty?

Comparability

Comparing students' examination performances in different subjects has been criticised because of the shortcomings of available statistical treatments. No statistical procedure alone could inform policy decisions about how to deal with comparability of examination grades because of the numerous variables that cannot be taken into account. These variables include the differences between examination populations, the difference in nature of individual subjects and how each examination is constructed and graded, and the quality of students' curriculum experience within and across subjects.

In spite of these limitations there has been concern at school level to explore the comparability of grades. League tables compare schools on a number of indicators including the percentage of the school population achieving 5 A*–C grades at GCSE. Comparisons of students' examination performances are commonly used for entry to university and access to other educational and employment opportunities.

The A-level Information System provides schools and colleges with feedback on their performance and effectiveness. It is a particularly influential body as the information provided is now widely used by schools to inform their planning and their practice. Fitz-Gibbon and Vincent were key people within this project. Using 1993 data Fitz-Gibbon and Vincent compared the difficulty of maths and science subjects with others in the A-level curriculum (Fitz-Gibbon and Vincent 1994).

Mathematics and science subjects were found to be between half and one grade more difficult than other subjects, apart from foreign languages.

- Physics was shown to be one grade more difficult than non-science subjects, and more difficult than chemistry, biology and maths.
- Predicted achievement in maths and science A-levels based on prior achievement was less than for other subjects at A-level, indicating either that these subjects were inherently more difficult or were more severely graded.

For 1993 A-level data, the apparent "cost" of including a science subject at A-level in terms of total points scored across three subjects was about 1.5 grades for girls (or three points on the UCAS scale in which each grade is two points) and about one grade for boys (or two points on the UCAS scale) (Fitz-Gibbon and Vincent 1994, p10). The findings of this study were confirmed by analyses of national data sets published in the Dearing Report (Dearing 1996).

The Fitz-Gibbon and Vincent study suggested that because of league tables schools may advise students to avoid difficult subjects as the tables do not distinguish between subjects in grading schools. Recent press reports provided support for this speculation and noted that students who were not expected to achieve the highest grades in subjects like physics were being disallowed access to study the subject post-16. Furthermore it was reported that entry requirements for subjects like physics were now inflated. Consequently students achieving a B grade in physics at GCSE may not be allowed to study the subject in some sixth forms (Beckett 2005). This, it is reported, is because of schools' concerns to maintain their position at the top of league tables to guarantee their recruitment levels.

A recent doctoral study (Benson unpublished thesis in preparation) attempted to compare the difficulty of the separate GCSE sciences but with control of the population of students, analysed by gender and supplemented by interviews with teachers about their assessment practices. Students' GCSE results from three Welsh Joint Education Committee (1993–1995) and two Southern Examining Group (1994–1995) consecutive examination sessions were used to identify populations of students that took all three science subjects at the same tier level. The study used the traditional technical approach to comparing students' performances including the subject-pair method.

This study found that:

- students tended to do less well in their science subjects than in their other GCSE subjects and this could be the equivalent difference of a whole grade;

“The perception of physics as difficult is widespread and part of the ‘common sense’ knowledge of teachers and students.”

6: Measures and perceptions of difficulty

- the attainment of high grades in biology, chemistry and physics were all individually associated with an overall high performance in GCSE subjects with correlations ranging from “moderately” to “strongly” positive;
- no one particular science subject was identified as being most severely or leniently graded for all of the populations under scrutiny;
- for the female subpopulations physics was significantly the most severely graded science subject and this was not the case for the male student populations;
- for males, biology was the most severely graded of the sciences, a situation that was sustained across the years of the study;
- overall there was a trend for boys to outperform girls in physics and for girls to outperform boys in biology and chemistry;
- overall a high performance in one science subject was moderately associated with a high performance in another science subject;
- students were more likely to obtain identical grades in physics and chemistry and least likely to in physics and biology;
- although both English and mathematics correlated positively and significantly with the individual science subjects, the correlations were overall more positive for mathematics than English. The order of positive correlation between the students’ achieved mathematics grades and science grades was in the order biology (least positive), chemistry, physics (most positive).

Both the Fitz-Gibbon and Vincent study and the Benson study reported that there is a measured difference of up to a whole grade lower for physics achievement and other science subjects compared with most other subjects at A-level and GCSE. The difference is sometimes less dramatic, as both studies report. Another large database of 73 000 students provides information on value-added scoring for different A-level subjects. Though this is not published data the researchers report a smaller 0.4 grade difference for physics than the difference reported by Fitz-Gibbons and Vincent. They stress as a consequence that the size of the difference in grading is educationally not as significant as the difference in the quality of teaching of maths and physics, which they consider to be less adequate nationally than for other subjects (Conway personal communication, 2004).

Validity of comparability findings

Fitz-Gibbon and Vincent used two main statistical procedures, one of which was also used in the Benson study. Subject-pair analysis compares groups of students who take both maths and science subjects and non-maths and science subjects. So for example the pairings might be those students who take physics and French. If the grade for physics is lower on average than the grade for French, physics is judged to have been more severely graded.

Goldstein and Cresswell (1996) in their critique point out several problems with the approach. For example, the groups of students taking such pairings may be atypical. The analysis assumes the same pedagogical treatment has been received, i.e. that the teaching was equally effective. Another concern is that the average grade might be lower for the group of students, but for some students the physics grade will be higher than the French grade and therefore for those students physics is “easier”. These within-group differences are particularly significant if systematic and related to variables such as social class and ethnicity.

The other procedure used was to compare each subject with the average of all other GCSE subjects taken by the student. The difficulties with this approach are similar in that the analysis assumes similarity in curriculum access, experience and student motivation across subjects. The measures are also population dependent and take no account of systematic within-population differences. Goldstein and Cresswell are also critical of the way the subject differences are averaged over the range of GCSE scores when subject differences may vary with GCSE score. For example, those students taking separate sciences may do better than other groups of students, hence the relationship will not be linear and to treat it as such distorts the findings.

Both large-scale analyses and smaller-scale studies report that there is a measured difference of up to a whole grade lower for physics achievement and other science subjects compared with most other subjects at A-level and GCSE. These findings are challenged on technical and educational grounds. Nevertheless there is evidence that the perception of physics as difficult is widespread and part of the “common sense” knowledge of teachers and students. There is some evidence of a correlation between mathematical achievement and physics achievement.

Teachers’ perceptions of the difficulty of physics

Sharp *et al.* (1996) surveyed year-11 students in 20 schools and colleges in England. They reported that heads of science considered that students’ perceptions that science A-levels, and in particular physics, were harder than other subjects was the main influence on their decisions not to study science post-16. In the survey physics teachers reported their views of the factors that made study of physics at A-level difficult for students.

- They ranked first students’ lack of depth of knowledge of mathematics, which was noted by 25% of heads of science in schools and 45% in colleges.
- Heads of science in colleges ranked next students’ lack of understanding of algebra, followed by inadequacy of Double Award Science as a preparation for A-level study and students’ lack of basic arithmetic skills (noted by 13% and 12% of teachers, respectively).
- Teachers in schools ranked second in significance

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students' depth of knowledge of physics (13%), which was ranked fifth by teachers in colleges; followed by inadequacy of Double Award Science (7%).

The next study reported is one of the only major studies of English students' physics A-level experience. Elwood and Comber (1996) were funded by the Nuffield Foundation to study gender differences in examinations at age 18. Two hundred questionnaires from heads of department and nine case-studies complemented the analyses of 3000 examination scripts. Three subjects were studied: English literature, mathematics and physics. Both teachers and students felt that physics at A-level was uninteresting and "very difficult" (p59). Teachers were asked to rate their level of agreement or disagreement to 18 statements about male and female students:

- The majority of teachers thought that male students were more confident than females and disagreed with the statement that females were more confident than males of succeeding.
- Two-thirds disagreed that girls were more confident than males verbally and two-thirds agreed that males were more likely than females to join in discussions.
- The teachers were strongly of the opinion that males rather than females would go on to higher education study in physics (70%).
- Some 76% disagreed with the statement that females were more likely than males to pursue a career in physics.
- There was a belief that girls' low expectation in physics was a deficit in them and not to do with the subject.

In relation to content:

- There was a majority view that there were no gender differences in performance across most of the physics syllabus.
- There were no learning objectives in physics that were identified by teachers as more difficult for males than females.

Teachers identified content that they considered female students found more difficult than males:

- Over half the teachers thought females found electric circuits and electromagnetism more difficult than males.
- Mechanics was seen as an area of difficulty for female students by maths teachers and was also perceived to be difficult for females by a quarter of the physics teachers.
- A quarter of the teachers thought female students had more difficulty than males applying knowledge and understanding and in designing and planning experiments.
- Teachers in their comments seemed to consider that girls lacked flair or sparkle compared with their male

counterparts, terms used perhaps as surrogates for creativity and risk-taking.

There is significant evidence that teachers consider that the mathematical demands of physics have a major impact on its difficulty. One study has found that while teachers do not consider girls and boys to perform differently in A-level physics they do agree that there are content areas that only girls in their view would find difficult. The basis for their beliefs is not clear and there has been no recent research to corroborate this.

Teachers' entry practices

Of the three physics teachers interviewed in the Benson study, two who had taught for many years considered that the GCSE was less difficult than the prior GCE examination. The teachers considered the following factors to have reduced the demands in physics:

- Students were provided with formulae.
- The examination no longer required extended writing.
- The mathematical demand was reduced.
- Students were now led through questions.

The issue of difficulty though was closely associated with mathematics in these teachers' views about physics. All three teachers felt that the physics examination was mathematically demanding and that the maths component distinguished the higher-tier physics paper from the lower-tier paper. There was a belief that students needed motivating to study physics and that only a particular type of student could do well in physics, students with a "logical, analytical, mathematical brain" (p51). These teachers believed too that there was a decline in students' mathematical ability, a finding in line with those reported by Sharp *et al's* survey (1996).

Both national tests and GCSE examinations in the sciences and mathematics are tiered. That is, the papers are differentiated by difficulty. Although there is overlap between tiers in the levels or grades that can be achieved, entry to a particular tier can set floors or ceilings on students' achievement. The issue of tier entry is discussed in detail in the next section. However, as teachers' views of difficulty influence their entry decisions these decisions can be sources of evidence about their perceptions of difficulty and are therefore relevant to the discussion here.

In section 5 we discussed the difference in entry patterns that indicated that girls in single-sex schools were more likely to be entered for the higher papers (tiers) in the Key Stage 3 national science tests than their counterparts in coeducational schools. There are no studies into teachers' tiering practices in relation to girls' and boys' entry to GCSE physics. There is some research into teachers' entry practice in mathematics. In mathematics there are three tiers of entry: foundation, intermediate and higher. Research has found that in spite of girls gradually closing the performance gap at GCSE, teachers still tended to allocate more girls to the intermediate tier than boys, and the converse was the

case with the foundation and higher tiers (Elwood and Murphy 2002). Evidence from earlier studies suggests this is because of teachers' beliefs about girls' lack of confidence (Stobart *et al.* 1992). This lower expectation of girls has also been found to affect girls more than boys in physics (sections 3 and 4). Given that teachers accept the link between mathematical demand and achievement in physics, perceptions of the difficulty of mathematics may compound teachers' perceptions of the difficulty of physics and be one factor that limits girls' access to the higher tier of Double Award Science and Triple Award physics GCSE. This may be a particular issue in coeducational state schools. The Youth Cohort Study (Cheng *et al.* 1995) of nationally representative cohorts of 16- to 17-year-old students in England and Wales found that even in single-sex schools:

“The fear of mathematics is clearly still a factor in young women's reluctance to study physics and chemistry.” (p35)

The issue for the review is whether teachers' expectations of girls and perceptions of difficulty serve as a source for this fear about their competency in mathematics.

There is emerging evidence that a relationship between achievement in mathematics and physics is an accepted part of teachers' professional knowledge about physics. Both subjects are understood to be “difficult” and together these beliefs may influence teachers' decisions about tiers of entry and award entry in national tests and examinations.

Students' perceptions of difficulty

The perception by students that physics is more difficult compared to other subjects was noted as early as 1935 (Ormerod and Duckworth 1975).

Content overload

Content overload is often linked to perceptions of difficulty in the research literature, and sometimes it is difficult to separate the two. Tobias's qualitative research (1990) of the types of students who do and do not take physics and chemistry in the US used a radically different approach to other studies and had a major influence on interventions to improve access to the physical sciences in the US. The study involved seven case-studies of successful postgraduate students who had completed their degrees in other subjects and who were paid to undertake introductory undergraduate courses in physics and chemistry. The study was in depth and over time, and the students reported in detail on their experience. The graduate students noted that physics and chemistry students were typically taught techniques in problem solving rather than how to think about the subjects. They were given no access to a holistic and coherent understanding of the subject, and the pedagogic approach was considered patronising. The pace of teaching was judged to be too fast and it left many students

behind. Once left behind there was little chance of catching up. The study suggested that teachers should “cover less and uncover more” (p60).

More recent UK studies confirm that the problem of content overload remains and is a significant influence on students' enjoyment of science and their perceptions of its difficulty. Osborne and Collins' (2000) survey of year-11 students across 20 schools in England found that:

- the predominant explanation for students' disenchantment with science was the need to learn and understand an excessive amount of content;
- teachers in the survey commented on the lack of time for science and the pressure to rush through topics to concentrate on exam preparation;
- students struggled with the pace of the coverage;
- girls noted that things were often explained too quickly without time to assimilate difficult or unfamiliar concepts.

Havard (1996) in his small-scale examination of take up of science A-levels in four schools in the UK concluded that the main factor influencing students' decisions not to study science post-16 was the perceived difficulty of the subjects. Spall *et al.*'s large-scale UK study (2004) involving 1395 students aged 11–16 compared liking for physics with biology. They found, along with other studies reported in section 2, that students' liking for physics and biology declined over the years, but the decline in the popularity of physics was much greater than for biology. Students' liking for physics declined because of their perception of the increasing need for maths and the increasing difficulty of the subject.

In the Elwood and Comber study (1996) 247 students from year 12 and year 13 were surveyed about their attitudes towards various aspects of the A-level physics syllabus.

- The majority of the students reported high levels of confidence, motivation, enthusiasm and enjoyment.
- Both males and females identified electric circuits and electromagnetism as difficult, yet teachers saw these areas as only difficult for females.
- Female students did not consider themselves to be more able than males but did judge their motivation to be higher in line with their teachers' views.
- Some females commented in interview on the difficulties of being the minority sex in a mixed group whereas males studying English literature A-level considered this a bonus.

The authors noted that overall students saw issues in individual terms rather than gender terms.

There is evidence from surveys that content overload affects students' ability to gain depth of understanding and increases their sense of the difficulty of science and physics. This appears to be particularly the case for girls relative to boys. Students' perception of physics as being

6: Measures and perceptions of difficulty

difficult increases with age and is related in part to the increase in mathematical demand but also, as noted in section 2, to an increased sense of inadequacy in the subject, which is noted particularly for girls and affects their physics self-concept.

There is a discrepancy between teachers' more cautious views about girls' performance and confidence in physics and the students' own views, both males and females. This may well be one influence in the web of influences that lead some girls who are well able to study physics to decide not to.

Attributions of success and students' expectations

Murphy's (2000 b) summary of some of the findings of the research literature noted that generally across subjects males tended to attribute success to their own efforts and failure to external factors. Females, however, did the converse. In sections 2 and 3 evidence was reported that boys more than girls were likely to rate their performance in maths and science more highly relative to girls irrespective of achievement. Furthermore males more than females were prepared to study maths and science whatever their rating of their potential in the subjects. The significance of these findings is their effect on students' expectations and emerging self-concept in relation to physics, which is a major determinant of attitudes and course uptake (section 1). Dweck (1986), one of the key researchers in this area, argued that girls more than boys had unduly low expectations, avoided challenge, considered that they failed because they were not sufficiently able and found failure particularly debilitating.

These reported findings generalise across girls and boys as groups, and Li and Adamson's (1995) US study is selected for discussion because they considered the subgroup of students labelled as gifted, to examine whether Dweck's hypothesis was supported. They examined gender differences in achievement-related motivational patterns in 169 gifted students in grades 10 and 12 in senior high schools. A range of instruments was used to measure factors considered to influence achievement in maths, science and English. The factors included students' perceptions of their ability; learning style preference; their attributions for success in mathematics, science and English; their self-concept; intrinsic motivation; and attribution for responsibility for positive and negative outcomes. The data were subjected to factor analysis followed by multivariate analysis of variance to allow patterns to be discerned. The study found that:

- the motivations mediating mathematics and science achievements operated in similar ways for gifted students irrespective of gender;

- gifted girls, more than gifted boys, tended to attribute both success and failure in mathematics, science and English to effort and strategy (this, the authors concluded, implied among girls "a sense of personal responsibility and control" (p291) for learning);
- there were no differences in male and female students' confidence and interest in mathematics and science.

Based on these findings, which contrast with other studies, the authors recommended that more research needed to be carried out on within-group comparisons to better understand which girls and which boys the general findings about gender differences apply to.

There is some evidence that for those students labelled as successful or gifted gender differences in self-concept, confidence and interest do not arise in science. This is further supported by the similarities found between male and female students studying A-level in their expectations, confidence and enjoyment of physics.

The implications

- The findings about the absolute difficulty of physics are technically questionable. Nevertheless it is common practice to treat these findings as valid and as such they exert considerable influence on teachers.
- More research is needed to find out what teachers' views are about which students are capable of studying physics post-16 and how these views influence their award and tier entry practices at GCSE. It is either at the end of Key Stage 3 or during Key Stage 4 that students will generally decide to opt out of further study.
- The change to two-tier entry for mathematics currently being piloted will help demonstrate to teachers and students the similarity in mathematical achievement of boys and girls. This may influence teachers' views of girls' potential in physics and needs to be monitored.
- Teachers need help to challenge their beliefs about what girls and boys can and cannot do in physics in Key Stages 3 and 4. Girls' potential in the subject needs to be recognised and valued to enhance their confidence.
- If higher grades in physics continue to appear to be more difficult to obtain than in other subjects and physics continues to lack interest for students, then they may not be encouraged to study it post-16, however confident they feel about their abilities.
- League tables, which do not discriminate between subjects taken, may discourage teachers from encouraging girls to take physics if they or their teachers consider they are of moderate ability. This effect should be brought to the attention of the DfES in a discussion about the value of league tables.

7: Entry and performance patterns in physics: the impact of assessment processes and techniques

“The content that is more likely to arise in tests and examinations in physics reflects the interests and values of boys more than girls.”

Introduction

Since the early 1990s there has been a continuing decline in the uptake of physical sciences post-16 (Osborne *et al.* 2003). Since 1992 the entry to biology has increased for both boys and girls. In the same period the entry for chemistry declined overall but a similar proportion of girls and boys entered for the subject. The decline in entry over the period has been most severe for physics and it occurred for both boys and girls. Figures indicate that currently boys' entry rate to physics is higher than boys' entry for chemistry and biology. However, girls' entry rate is now very low, compared with that of boys and compared with girls' entry for chemistry and biology.

The figures in table 7.1 for the UK are taken from the Joint Council for Qualifications tables and show the percentage gap in favour of girls at A-level physics in the period 2000–2004. The percentage gap is derived by subtracting the percentage of girls from the percentage of boys achieving A–C grades. A negative sign indicates a female advantage. The results show girls ahead of boys as a group and that the gap in performance is maintained across the years. There is therefore no performance evidence that girls who choose to study physics post-16 are in any way disadvantaged or less competent compared with boys.

The concern about the low levels of uptake of physics post-16 arises because of the impact on take up of undergraduate study in physics-related science and engineering subjects. Attention has therefore been focused on ways to increase the entry of girls to A-level study. Prior achievement has been identified as a predictor of course choice post-16. Therefore of interest for the review in this section is girls' performance in physics during compulsory secondary schooling.

Two aspects are explored in this section. The first is performance patterns at age 16 and younger to establish what evidence there may be of girls' alienation emerging in performance differences between girls and boys as groups. International survey data are examined to consider evidence that supports or contradicts emerging performance patterns in national data. Second, literature about research

into the techniques of assessment, including the effect of item characteristics and different forms of assessment on the performance of girls and boys, is examined to determine to what extent any gender differences in performance in physics are artefacts of assessments themselves, or are further evidence of representations of physics knowledge that privilege boys' ways of knowing relative to girls and which act as barriers to girls' access.

The section includes:

- Entry and performance in examinations at age 16:
 - physics performance;
 - Double Award Science in England.
- Entry and performance in national science assessment at age 14.
- International achievement patterns in science and physics.
- Assessment processes and techniques:
 - Assessment techniques:
 - item format;
 - item content;
 - item context;
 - Forms of assessment.
- The implications.

Entry and performance in examinations at age 16

In discussing patterns in performance it should be noted that given the large entry population, small differences in overall performance are statistically significant. There has been debate about how to define a gender gap in performance. This has arisen when overall pass rates are compared, and any significant difference between girls and boys is interpreted as a difference in achievement for all girls or all boys depending on the direction of the effect. The review is not concerned to identify a specific numerical gender gap. The analysis of performance presents performance overall accompanied by a breakdown of performance by grade by gender, and where appropriate, by tier of entry and subject on GCSE examinations at age 16 and on national science tests at Key Stage 3. It is the patterns in performance that illuminate the issue of gender and achievement in physics.

It should also be remembered that any analyses of population performance show that there is far more overlap than difference between girls and boys in their achievements. Nevertheless the issues addressed here are whether those differences are artefacts of the assessments used and

Table 7.1: Performance at A-level physics by year and by gender

Difference in percentage A–C grades (boys – girls)				
2000	2001	2002	2003	2004
-7.4	-6.9	-9.4	-8.8	-9.1

7: Entry and performance patterns in physics

sources of invalidity or indications of where support is needed to enable students' access to physics, particularly girls.

Physics performance at age 16

Before the introduction of a National Curriculum, which made the study of science compulsory for all students in England and Wales up to the age of 16, the number of girls entering for physics examinations at the end of Key Stage 4 was very much lower than the number of boys.

- In 1978 in England nearly 40 000 girls compared with 167 000 boys took GCE/CSE physics at age 16. The pass rate was 40% for boys and 49% for girls.
- In 1988, the year before the introduction of the National Curriculum, boys' entry to physics was 158 500 compared with 63 500 for girls (the pass rate was 46% for boys and 49% for girls).

Whether the increase in female entry from 1978 to 1988 was the effect of the interventions to support girls' access to science and physics in particular is not known. The higher pass rate for girls is associated in the literature (Willingham and Cole 1997) with the restricted sample. It is assumed that the smaller sample of girls is more highly selected, and therefore more able and motivated girls predominate, than in the boys' sample. The award system introduced with the National Curriculum for science allowed students in Key Stage 4 to take either combined science as a Single Award (i.e. one GCSE) or a Double Award (i.e. two GCSEs) or as single science subjects – physics, chemistry and biology as part of a Triple Award (i.e. three GCSEs). The examination papers are also differentiated into foundation and higher

papers. All the grades up to grade C, which is generally understood as the pass grade, are covered by the foundation paper. The higher paper covers grades D–A* (an E grade can be assigned but rarely is). Entry to different papers therefore places ceilings and floors on students' performance. The results for physics presented next are for those students entered for the Triple Award.

- In 1993, five years after the introduction of the National Curriculum in England, 29 800 boys compared with 14 400 girls entered for GCSE physics. The pass rate for boys was 74% compared with 76% for girls.
- Overall the 2000 and 2001 GCSE results showed that physics was the only subject where boys achieved a higher proportion of A*–C grades, the pass rate, than girls. Boys also gained proportionally more A* and A grades than girls in physics and mathematics. However, more boys than girls are entered for the higher tier paper in maths, which allows access to these two grades (Elwood and Murphy 2002).
- In 2003 for students in England, 25 600 (8%) of boys compared with 16 900 (5%) of girls attempted physics GCSE. The pass rate was 92% for boys and 91% for girls.
- In 2004 the entry figures were 27 193 boys and 17 748 girls, and boys achieved a pass rate of 90.4% and girls achieved a pass rate of 89.8% (figure 7.1).

Table 7.2 shows the percentage by gender achieving A*–G grades in physics in 2004 for England. Boys achieved more of the top grades A*–B than girls. The figures reveal that more boys (N = 13 000) compared with girls (N = 8200) achieved A* and A grades, which are usually required for



Fig. 7.1: Cumulative performance by grade and gender for physics, England 2004.

7: Entry and performance patterns in physics

Table 7.2: percentage of boys and girls achieving grades A*–G in physics, England 2004

Gender	A*	A	B	C	D	E	F	G
M	20.4	27.3	23.4	19.3	6.9	1.6	0.4	0.2
F	19.2	27.2	23.4	20.0	7.7	1.5	0.5	0.1

Table 7.3: Percentage of boys and girls achieving grades A*–G in Double Award Science, England 2004

Gender	A*	A	B	C	D	E	F	G
M	3.6	7.8	13.1	28.5	19.7	13.5	8.0	3.5
F	4.8	9.0	13.3	28.0	18.6	13.3	7.7	3.3

study of the subject post-16. Because of the restricted and selected sample that the girls taking physics represent, these results suggest that girls are not achieving as well as would be expected in physics relative to boys. This performance trend is also found in relation to Welsh students where there is a similar though proportionally smaller discrepancy in entry between boys and girls, and yet boys outperform girls marginally.

The patterns of performance in physics at age 16 differ in Scotland and Eire as do the examinations and the assessment process.

- From 1999 to 2004 around 70–71% of the biology entry for the Scottish Standard Grade was girls compared with 28–31% of the physics entry.
- By 1999 the results showed that girls were more likely than boys to achieve grades at the higher levels of attainment, with 68% of girls compared with 57% of boys achieving the top grades 1–2. This gap was maintained over the years until 2004. The gap arises because of the proportion of girls achieving grade 1 (42% females; 30% males).

In Eire the Leaving Certificate is offered at two levels, higher and ordinary. Only students who achieve a higher-level pass in the earlier examination at age 14 (Junior Certificate) are entitled to enter for the higher level in the Leaving Certificate examination.

- The figures for 2001 show that 85.4% of the entry to ordinary level physics in the Leaving Certificate was boys compared with 14.6% of girls.
- At the higher level 69.9% of boys were entered compared with 30.1% of girls.
- In 2001 the percentage difference in grades A–C attained in favour of girls was 7.8% for ordinary level physics and 9.2% for higher level physics.

The Scottish Standard Grade is said to be associated with higher female performance because of its applied nature (section 2). The Leaving Certificate in Eire is, however, a very traditional examination and there is no attempt

to relate physics to social applications and contexts (Elwood and Carlisle 2003).

In England and Wales far fewer girls than boys are entered for physics in the Triple Award, and their performance relative to boys is lower across the pass grades and on the top A* and A grades. Entry to physics examinations in Scotland and Eire show a similar gender gap in favour of boys to that in England and Wales. However, girls outperform boys on the top grades, which would be expected for this restricted sample in contrast to girls in England and Wales.

Double Award Science in England

- In 1993, 54.9% of the total science entry was entered for Double Award Science with slightly more girls (8.4%) than boys (7.7%) entered for Single Award Science.
- The pass rate in 1993, i.e. A–C grades, achieved by boys in Double Award Science was 45.1% compared with 45.5% for girls.
- Ten years later, in 2003, 52% of boys and 54% of girls achieved grades A*–C.
- In 2004 the same proportion of girls and boys entered for Double Award, accounting for about 83% of the total science entry. The pass rate for boys was 53% and for girls 55% (figure 7.2).

Table 7.3 shows the percentage achieving A*–G grades in Double Award Science in 2004. In Double Award Science proportionally more girls gain A* and A grades than boys, with boys gaining more C grades than girls. Prior achievement is a significant predictor of course choice post-16 and based on these results there are significantly more girls than there are boys attaining the high grades. Yet this does not translate into take up in A-level physics by girls.

Bell (1997) in his analysis of performance in a GCSE coordinated science examination reported that 11% more males than females gained grade C or above on questions assessing physics. To consider if within the Double Award girls' performance overall masks a difference in performance in physics, an analysis of one board's results for coordinated Double Award Science examination papers which are differentiated by subject was considered¹ (N = 75 874).

- For those students taking the higher paper (N = 38 380; M = 17 673; F = 20 707), overall performance showed that 90.5% of the boys compared with 94% of girls achieved an A*–C grade.
- On the physics component of the Double Award for the higher paper, the boys' and girls' pass rate (85%) was similar. Compared with 32% of boys, 34% of girls achieved an A* or A grade. More boys than girls achieved B–C grades.
- Girls' performance on the biology component was significantly higher than that of boys, with 38% of girls achieving an A*–A grade compared with 26% of boys, and an overall pass rate on the biology component of

1. The data was supplied by AQA and the analysis by Helen Jones, Research Fellow, Faculty of Education and Language Studies, the Open University.

7: Entry and performance patterns in physics

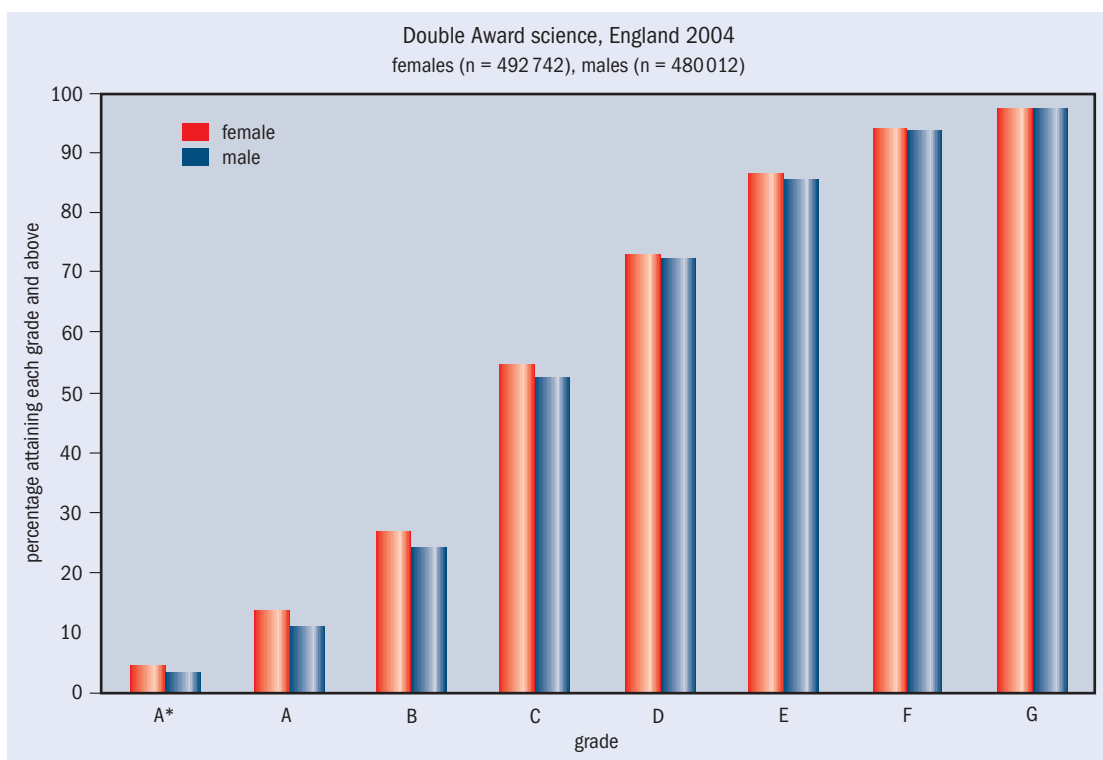


Fig. 7.2: Cumulative performance by grade and gender for Double Award Science, England 2004.

- 87% for boys and 92% for girls.
- On the chemistry component there were differences in performance in the achieved top grades ($M = 29\%$; $F = 37\%$) and pass rates in favour of girls, though the gap was less than in biology.

These results are not compared at the individual level but suggest that within this sample of girls there are high achievers in chemistry and biology who do not achieve at the same level in physics. There are also boys who are high achievers in physics who do less well in biology and chemistry than girls. There is a large gap in the performance on coursework for the students entered for the higher paper in this sample, with 47% of boys compared with 64% of girls achieving an A*–A grade. The pass rates overall though, on this component of the overall examination, are much closer ($M = 93\%$; $F = 97\%$).

On the foundation papers ($N = 37\,494$; $M = 18\,528$; $F = 18\,966$) the highest grade that can be achieved is a C, which is a pass.

- In 2004 on the overall foundation examination, 56.6% of boys compared with 60.2% of girls achieved a pass grade C.
- On the physics component 32% of boys and 26% of girls achieved a grade C.
- Girls' overall better performance relative to the boys was attributable to their higher performance relative to boys on the biology component ($M = 30.5\%$; $F = 33.6\%$ achieving grade C), the chemistry component ($M = 27\%$; $F = 28.5\%$ achieving grade C) and the coursework component ($M = 51\%$; $F = 65\%$ achieving grade C).

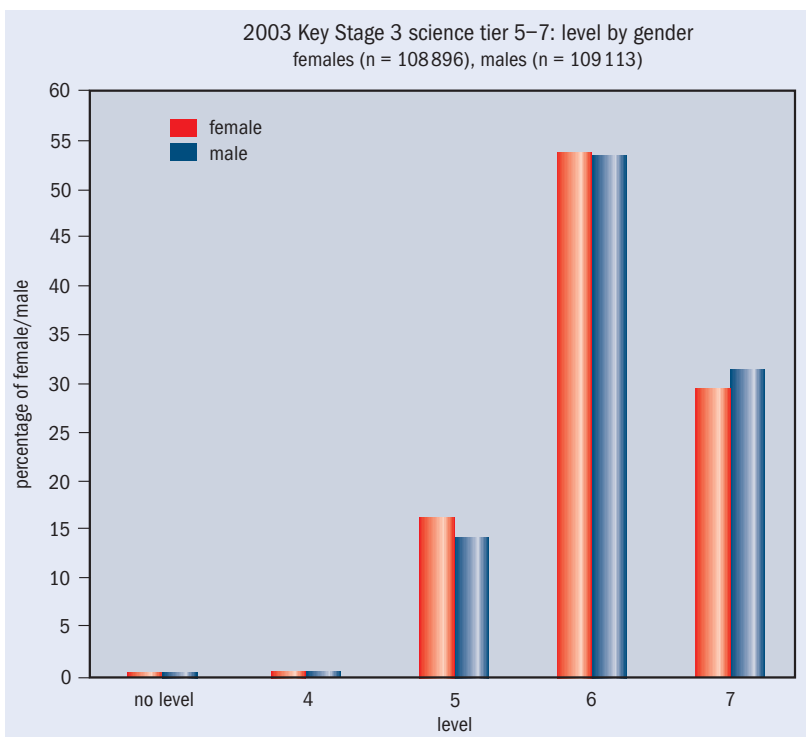
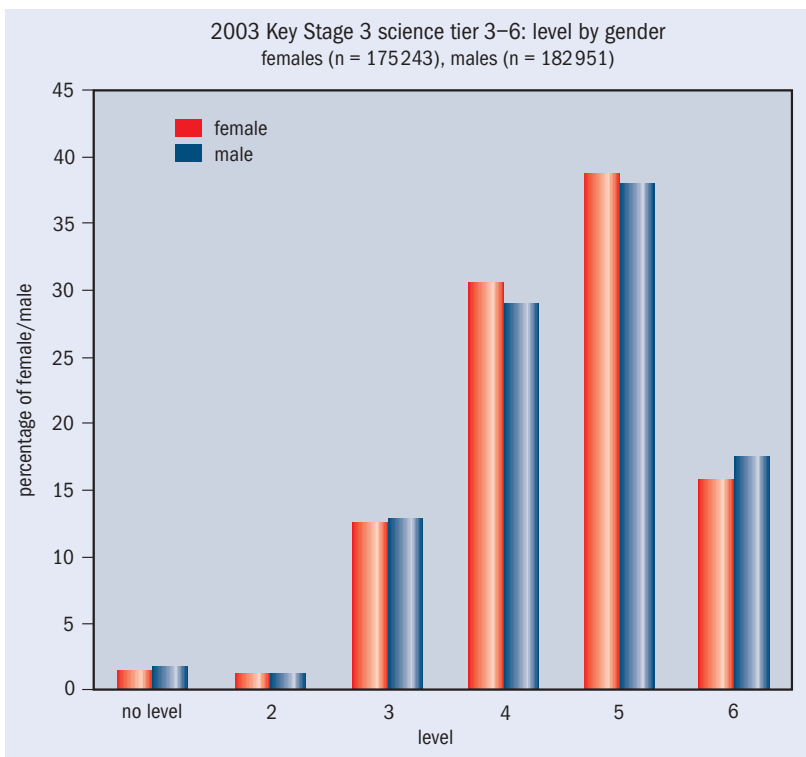
Though the gaps here were less dramatic than those for the students taking the higher papers.

There is some evidence of a gender dimension to the achievement patterns in Double Award Science in relation to physics. The analyses show that boys' performance relative to girls' on the physics component is higher than for chemistry and biology for both the higher and the foundation papers. Girls' overall superior performance is associated with the biology and chemistry components of the examination.

Entry and performance in national science assessment at age 14

Students take the national Key Stage 3 Standard Assessment Tasks (SATs) at the end of year 9. Entry is differentiated and two papers are available. The lower-tier paper covers levels 3–6 and the higher-tier paper covers levels 5–7. In an Ofsted report on boys' achievement (Ofsted 2003) national test results in science were reviewed for the period 1999–2002. An analysis of entry patterns revealed that in the period up to 2002 more boys than girls were entered for the lower tier and more girls than boys were entered for the higher-tier paper. It was noted that similar proportions of boys and girls achieved levels 5 and 6, with boys slightly ahead in most years. For example, in 2000 more boys than girls gained a level 5 or better ($M = 60.6\%$; $F = 57\%$). A comparison of overall performance for the same population at the end of Key Stage 2 (age 10–11) in 1999 and Key Stage 3 (age 13–14) in 2002 revealed a small decrease in the relative gap between boys and girls in science. Across the same period more boys than

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Figs 7.3 & 7.4: Key Stage 3 performance by level and gender for the lower (levels 3–6) and higher paper (levels 5–7) science, 2003.

2. The data and analyses were made available by the NAA and were provided by Michael Quinlan.

girls consistently achieved level 6 or better (i.e. the expected level for the population or above).

The evaluation of the 1999 Key Stage 3 science tests (ATL 1999) surveyed teachers' views (N = 345) of the tests. One of the findings reported was that some teachers were concerned that the physical science questions were more difficult than those for biology, and that a high level of physical science in the higher paper (level 5–7) might discrim-

inate against girls. Teachers' expectations have been highlighted as a significant influence on students' self-concept in relation to physics (see section 4 for a discussion). This evidence suggests that even in lower secondary school, teachers believe girls are less competent than boys at physical sciences and there is further evidence of this in teachers' entry decisions (section 6).

In 2003² 5% of students did not take the national science assessment tests at Key Stage 3, 59% of students were entered for the lower-tier paper (levels 3–6) and 36% for the higher-tier paper (levels 5–7). Significantly more boys than girls were entered for the lower tier and the reverse was the case for the higher-tier paper.

Comparing lower and higher level performance

Figures 7.3 and 7.4 show performance by gender by level for the students entered for the lower-tier paper (levels 3–6) and the higher-tier paper (levels 5–7).

The large samples mean that the performance differences are significant at the 5% level. As more boys than girls were entered for the lower paper you might expect that more boys would achieve the higher levels of this tier and this was the case. There were 7708 more boys than girls entered and 4145 more boys than girls (17.4% of boys; 15.8% of girls) gained a level 6. More girls than boys achieved level 5 – 38.6% compared with 38% for boys, a difference of almost 2000 students. Whether these students could have achieved the same level in the higher paper is a matter for speculation.

As a higher proportion of the girls than the boys were entered for the higher paper the boys represent a more selected sample and it would be expected that they would achieve more highly than girls, and 31.5% of boys compared with 29.2% of girls achieved level 7. Slightly more girls than boys achieved level 6 (M = 53.6%; F = 53.8%). The gap between boys and girls increased at level 5 (M = 14.2%; F = 16.1%).

Preece *et al.* (1999) analysed 1996 Key Stage 3 science test results for a large representative sample of schools and found that the largest gaps in performance occurred on questions assessing physics, where boys outperformed girls. The majority of these questions required the interpretation of diagrams. To establish whether this effect continues, analyses by subjects, i.e. on the scientific enquiry, biology, chemistry, and physics items within the key stage tests, were carried out using a selected representative sample. Figures 7.5 and 7.6 show the scores achieved on the subject components by gender for the lower- and the higher-tier papers respectively for 2003.

The t-test results on the mean scores achieved by boys and girls show:

- significant differences in favour of boys on the lower paper on physics questions at levels 4, 5 and 6; on the higher paper, boys significantly outperformed girls across all the levels on physics questions;
- girls achieved significantly higher scores than boys on

7: Entry and performance patterns in physics

biology questions at levels 4, 5 and 6 on the lower paper, and at levels 6 and 7 on the higher paper;

- girls' and boys' performance was more equivalent on the chemistry questions in the papers; girls' advantage in chemistry was restricted to level 5 in the lower paper and level 6 in the higher paper;
- girls achieved significantly higher scores on scientific enquiry questions than boys at levels 3 and 5 in the lower paper, and at level 5 in the higher paper.

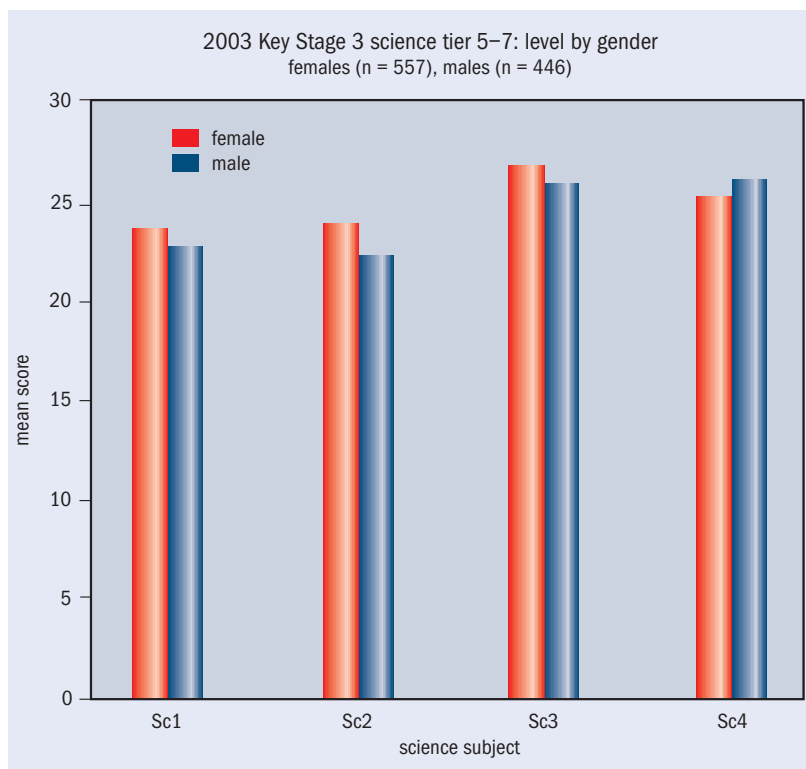
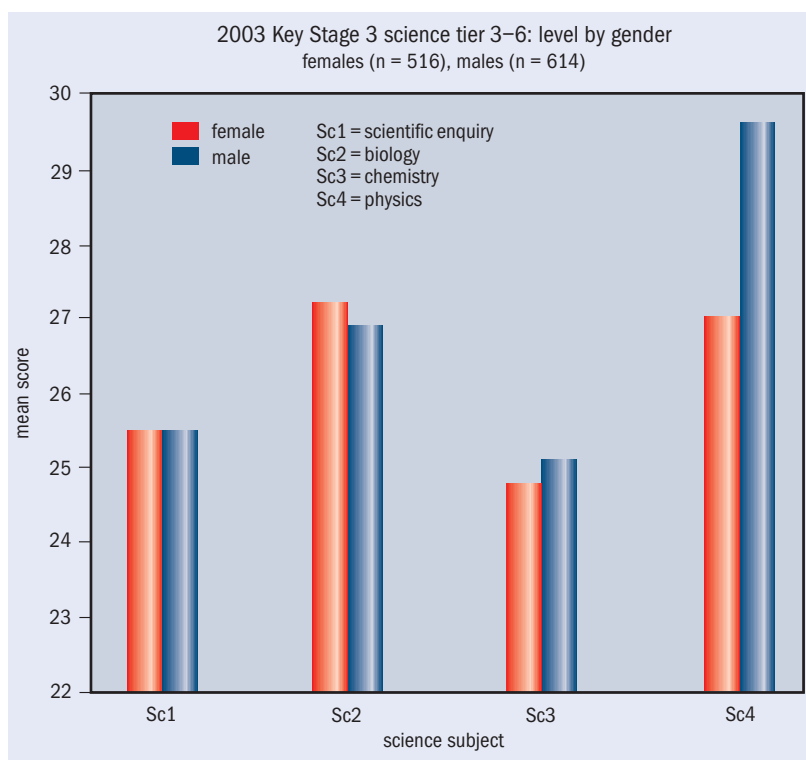
There is evidence that at the end of Key Stage 3 performance differences emerge in favour of boys on physics questions and in favour of girls on biology questions on both the lower and higher national science tests. The publication of results by level and overall points achieved across papers and subject components masks these findings.

International achievement patterns in science and physics

The performance of secondary school students in science in England is among the highest in the world. The TIMSS (Martin *et al.* 1999) found a significant gender difference for science, with boys performing at a higher level overall than girls across all participating countries. There was also evidence that more boys than girls achieved the higher scores, which is consistent with performance patterns in Key Stage 3 SATs. In TIMSS (2003) boys at grade 8 continued to significantly outperform girls, and this gender difference was found for 10 of the 12 participating countries (Ruddock *et al.* 2003). It was noted that girls' scores relative to boys' had significantly improved from 1995 to 1999 to 2003. Boys' better performance was found in four content areas – chemistry, physics, earth science and environment. There was no gender difference in performance on life science. This reflects some of the findings reported for the national assessments. It should be noted that the national tests for England are different in item style and content to those used in the TIMSS surveys.

There was evidence in the TIMSS surveys of variation in the relative performance of boys and girls by country. This is also evident in national assessment programmes, for example the NAEP (2002) in the US reported an advantage for boys in science at grades 8 and 12. The national assessment of science performance in Canada (School Achievement Indicators Programme 1999), however, found no significant gender differences at most levels.

The Programme for International Student Assessment (PISA) assesses the scientific literacy of 15-year-olds. The test items are concerned with the application of scientific knowledge and skills to real-life situations. General item formats include both structured and open written responses rather than multiple-choice items, which dominate in the TIMSS assessment. The findings for England were reported for PISA 2000 (Gill *et al.* 2002). The score for students in England was above the average for the Organisation for Economic Co-operation and Development (OECD) as a



whole. There was a high correlation between scores on the reading literacy scale and the scientific literacy scale. There were no statistically significant differences between girls' and boys' performance for England or any other country, except Korea and Denmark where boys outperformed girls. Although scores for England were not reported in PISA 2003 (OECD 2004) because of sample size, there were

Figs 7.5 & 7.6: Key Stage 3 performance by subject and gender for lower (levels 3–6) and higher paper (levels 5–7) science, 2003.

again no systematic differences reported between boys' and girls' performance, and similar proportions of girls and boys were found to achieve "particularly high and particularly low results" (p37).

International findings provide further evidence of boys' advantage on science performance measures in relation to physics curriculum content, though the trend shows that the gap between boys' and girls' performance is decreasing. The results for England mirror those in many other countries, but there is considerable variation between countries. The PISA results reveal no gender differences but assess different skills and understanding and use different item formats.

Assessment processes and techniques

There is limited research into assessment processes in science but it is expected that teachers' decisions to enter students for different awards and for differentiated papers will be influenced by their expectations of students in science and physics. What evidence there is suggests that teachers have lower expectations of girls relative to boys in both subjects. Furthermore, teachers' entry decisions will place ceilings on performance that will further influence their views and students' views of future potential in the subject.

Research reviewed in [section 6](#) has demonstrated the link between teachers' perceptions of the relationship between maths and physics, and there is evidence that more girls than boys are entered for the intermediate tier, denying them access to the top grades A* and A (Elwood and Murphy 2002). Andrews *et al.* (2004) in their review of the evolution and determinants of the educational gender gap in performance in England concluded that: "unobservable differences between schools, such as discipline, tiering, streaming, are important explanations of the gender gap" (p2). Gillborn and Youdell (1998), researching teachers' entry decisions at GCSE, have argued that gender and race and tiered entry decisions interact and negatively impact on the educational opportunities for black students. This limits these students' access to pass grades at GCSE. The evidence is from a small-scale ethnographic study in two schools and science was not reported on specifically. There is no similar research about entry patterns for ethnic groups at Key Stage 3.

It would be informative to examine entry patterns across the key stages and teachers' bases for this, and the impact of prior achievement in national tests of mathematics and science on students', particularly girls', access to physics at Key Stage 4 and beyond.

Assessment techniques

The way that differences in the performance of girls and boys as groups are understood is determined by understandings about the nature of learners. If assessment tasks are seen as neutral devices that all students understand in the same way then differences in performance can be attributed to either innate differences or differences in

opportunities to learn. If, however, learners are understood to be active constructors of meaning then all assessment tasks, like learning tasks, have to be interpreted by the students and their interpretations will depend on their experiences and expectations. Therefore differences in performance may reflect differences in achievement and opportunities to learn but may also indicate that students are responding to different tasks to those intended and what is being assessed is not stable across students and groups of students. This latter view is consistent with how learning is understood in social constructivist and socio-cultural perspectives that increasingly dominate science education. Such views therefore require research to pay attention to aspects of science assessment tasks that might influence students' understanding of what constitutes an appropriate answer and their beliefs about their ability to supply it. Techniques of assessment and their impact on performance have been researched since the 1980s with the introduction of changes in examinations to meet the demands of new curricula, particularly in science. The first assessment technique examined was item format, when patterns of performance in terms of who achieved what in science shifted with the introduction of multiple-choice questions into public examinations.

Item format

Early research into changes in performance patterns in science examinations at age 16 found that, on three out of four multiple-choice papers, boys outperformed girls. Girls were found to outperform boys on the essay questions (Harding 1979). Murphy's (1982) research into all of the subject papers for one examination board found that the performance of boys was improved relative to that of girls when multiple-choice formats replaced written tests. Further research into biology examination performance substantiated these gender differences in relation to multiple-choice and essay-response formats and, in addition, found that girls outperformed boys on structured questions, i.e. those requiring short free-written responses (Gipps and Murphy 1994).

Gipps and Murphy's review of the literature pointed to several explanations for the difference in performance of boys and girls as groups on multiple-choice items. The first was that boys more than girls were prepared to guess and this was seen to advantage them with this form of response. Girls more than boys were also found to tick more than one response or use the "don't know" option, which lowered their overall performance relative to boys. Qualitative data indicated that this arose because more girls than boys saw ambiguity in the distractors so that more than one answer was considered appropriate. This perception of ambiguity was linked to the tendency of girls relative to boys to pay attention to the circumstances in which tasks were set ([section 3](#)). Another explanation was that girls' significantly lower level of confidence relative to boys caused them to opt for the "don't know" option. Powney (1996), reporting on a number of studies, concluded that boys tended to be

advantaged by multiple-choice format and girls by extended writing.

Results from a review of assessment (Gender Working Party Report 1994) of the History trips at Cambridge, where males dominated females in the class 1 results, led to innovations in the assessment process. These included a compulsory extended essay as part of the continuous assessment, guidance to supervisors on the criteria to assess the essay, and anonymising scripts throughout the classification process. The evaluation of these changes found that in the following year females in part 1 achieved the same percentage of firsts as males and in part 2 closed the gap considerably. However, the essay did not advantage females unfairly, rather it was argued that it was the increased awareness of supervisors of the issues and their improved understanding of the marking criteria, as well as girls' enhanced self-confidence, that were influential (Murphy 1994).

Murphy reported on a small-scale study that compared multiple-choice format with structured-response format for the same items, that is controlling for all other factors and attempting to keep the construct (i.e. what was being assessed) the same. Structured format was defined as a short two- to three-sentence free response. She noted that the gender difference in performance tended to disappear in these circumstances and concluded that the issue was that the format influenced the construct (i.e. what was being assessed). If the construct was kept stable across formats, there tended to be no difference in performance between the groups (Gipps and Murphy 1994).

Willingham and Cole's (1997) review compared the performance of populations of year-12 students (aged 16–17) on the US NAEP science items for 1990 that were categorised as multiple choice or free response. Free-response items were usually very short. They found no gender difference in performance across the two types of format. Willingham and Cole in their discussion of format effects also related gender differences in performance to an interaction between response formats and construct (i.e. the change in format appeared to influence what was assessed). They argued that there was a need for more systematic research to develop a better understanding, particularly of written response formats, on the fairness of assessment practices.

More recent follow-up research into format effects is limited but there is some evidence that gender differences in performance in relation to item format continue. It was noted that international surveys of science achievement that continued to show an advantage for boys in science in England in contrast to national tests and examinations depended heavily on multiple-choice items (Arnot *et al.* 1998). Analysis of the TIMSS results for England for year-8 (age 12–13) students found that girls tended to do better on constructed or structured free-response items compared with multiple-choice items, but boys outperformed girls on both types of items (Ruddock *et al.* 2003). Reporting on examples of practice that enhanced boys' achievement in science, a government report for schools in England

noted that boys performed well when multiple-choice items were used (Ofsted 2003).

There is evidence that the format of response can influence achievement outcome particularly where it affects what is being assessed, i.e. the construct. Hence item format can be a source of assessment invalidity.

Item content

Item content was described by Murphy (2000 a) to mean what a question is about rather than what has to be done. So the task might be to interpret a graph and the content can vary both in terms of the type of graph and the type of data. A number of content effects have been noted in large-scale analyses of science survey data. However, most of these findings come from early research that has not been replicated in recent years.

In national surveys in the UK and the US of the use of apparatus and equipment, overall 13- and 15-year-old boys outperformed girls but their advantage was restricted to the apparatus and equipment they reported having more experience of outside school. Typically this included apparatus associated with physics. What the assessments measured was therefore differences in opportunity to learn as opposed to achievement differences (Murphy 1995).

Another content effect reported in the literature related to the use of spatial patterns. A study of this effect was included in the national APU surveys at age 13 for England, Wales and Northern Ireland. The results did not reveal a general weakness of girls in the manipulation of spatial data but showed that on items concerned with the equal angle law of reflection at a plane, girls as a group tended to perform at a lower level to boys as a group. One such item was based on content about playing snooker and this was an out-of-school activity that at the time 59% of 11-year-old and 64% of 13-year-old boys reported that they very often or quite often engaged with. It is likely that these out-of-school differences in leisure activities may continue and again points to the likelihood that in some assessments of physics what is being assessed is differences in opportunities to learn rather than differences in achievement.

In a further study of national APU findings for physics it was found that two questions that showed the greatest gender gap in performance in terms of the mean scores achieved by girls and boys were on questions concerned with the concept of atmospheric pressure. Both questions were described as requiring a graphical response and required students to imagine where liquid levels would be in two changing situations – inside a straw in a drink and inside a watering can – and they had to draw these in their response (Bransky and Qualter 1993). Willingham and Cole's (1997) comparison of the performance of year-12 students on the NAEP science items also found a gender effect that arose on items that involved graphical content. On free-response items that required interpretation of graphical data and a graphical response boys outperformed girls. This content effect also dominated response format as in

these cases boys also had relatively more correct responses on free-response items compared with multiple-choice items. This performance effect is therefore an outcome of a combined content and format effect. Items that involve graphical data and a graphical response are more common in physics assessments than in chemistry or biology assessments, both in national tests at Key Stage 3 and examinations at Key Stage 4. However, there is no reported analysis comparing performance of populations of girls and boys on these item types.

The Elwood and Comber (1996) research into gender differences in physics examinations at 18+ did consider item characteristics but found no one characteristic of the questions that might have been advantaging either boys or girls. They noted several problems with the study. First, the sample taking A-level examinations in physics is not representative and this is particularly the case with the small self-selected sample of girls who typically take this examination. Second, the study used a small number of papers and there were therefore insufficient numbers of questions of each type to allow any patterns of subeffects due to gender to emerge. This would not be the case with national assessments and examinations at age 16, particularly if the analyses considered performance for different cohorts over time.

There is evidence from national and international assessments that some gender differences in performance on physics items could arise because of differences in the experiences of students outside school that advantage boys relative to girls. Two questions arise from this. First, is the value given to this content warranted? Second, is there evidence that for some girls differences in experiences are restricting their access to physics in ways that are not recognised by teachers or students but that impact negatively on students' achievements and self-concept?

Across the full range of science achievements assessed in the APU surveys it was found that items that involved content related to health, reproduction, nutrition and domestic situations were generally found to show girls performing at a higher level as a group than boys across the ages. In items where the content was “masculine” the converse occurred. Typical “masculine” contents included cars, building sites, submarines, machinery, etc. (Murphy 1991). These findings were reinforced by Bransky and Qualter's (1993) re-analysis of the APU items that assessed physics concepts and by Chilisa's (1997) separate study. Murphy (2000a) noted that the performance effect arose when the content was considered by students to be outside their domain of competence – more girls or more boys failed to respond to these items. On the other hand if the content was seen to be within their domain of competence students responded with enhanced confidence. This effect can be related to the divergence in students' interests that was discussed in [section 2](#). Willingham and Cole (1997) noted

similarly that in a range of assessment measures in the US, gendered patterns in interest and value differences were generally consistent with gendered patterns of performance difference. Their concern was whether interest differences could affect test scores in inappropriate ways, and they argued that this would be the case if test content related to interests that “went beyond connections required by the construct” (p179). They concluded that content that is not relevant to the construct but could affect gender differences should be avoided.

There is evidence that the content that is more likely to arise in tests and examinations in physics reflects the interests and values of boys more than girls. Performance differences on physics items in favour of boys are evident within science tests and examinations at Key Stages 3 and 4.

Item context

In [section 3](#) we noted that context is understood as the “problem situation” (Hodson 1998, p116) and therefore its role is as an organiser for science content (Aikenhead 1994). From these definitions it follows that students' perceptions of the context of an assessment task or item will determine what subject knowledge they consider is likely to be needed and therefore what construct is being assessed. In the same section we concluded that evidence from in-depth studies revealed that differences between what girls and boys have learned is relevant and of personal value, influence the problems they perceive. Girls more than boys give value to the social context in which tasks are posed in defining a problem, and boys more than girls do not “notice” the context.

Murphy (1991) reported on context effects in the APU science investigations, which resulted in differences in the problems perceived and the solutions sought by students. Where investigations were defined in relatively general terms (i.e. where the independent variable was specified but not the dependent variable) there was a tendency for girls to consider a number of dependent variables in making judgements about what was “better” in a particular context: for example, an insulating material to protect a person stranded up a mountainside or a type of kitchen towel or flooring for everyday use in domestic settings. This meant that for some girls the problems were more complex than intended by the assessor and their achievements were affected negatively. In later research Murphy noted similar effects in classrooms where science investigations were related to everyday dilemmas and both the independent and dependent variables were specified. Girls' attention to the everyday situation tended to limit their scientific response particularly in the range of data considered necessary, but this did not reflect their understanding of the type and range of data required in problems they recognised as scientific (Murphy 2000 b). This had a negative impact on teachers' judgements of girls' achievements.

Bransky's and Qualter's (1993) study found that the con-

text of items dominated content effects, and this would be expected if the context determines the problem situation for students. For example, cars have been noted as a masculine content that in certain assessments can impact negatively on girls' performance in science and maths assessments. However, if the focus of the item and the application of physics understanding is concerned with safety and social issues, then girls were found to achieve higher scores than boys as a group on these items (Bransky and Qualter 1993). This research also found that on physics items where contexts were technological there was a consistently negative reaction of girls compared with boys. Research into the importance of item context in the assessment of physics has found that contexts that prioritise the human, social and environmental concerns appeal to males as well as females. The use of context created interest for students and enabled them to make sense of the problem, whereas students considered abstract problems hard to visualise (Rennie and Parker 1993; Rennie and Parker 1996). There is evidence that the contexts of physics items are less likely to reflect female perceptions of relevance and their learning goals to "help people" noted in [section 2](#) of the review. Hazel *et al.* (1997) examined assessment practices in first-year physics at an Australian university and noted that female experience and interests were almost totally absent.

Murphy (2000 a) noted that "real-life" contexts are treated superficially in assessment and are used as devices to enhance authenticity without noting the effect it can have on the students' perception of the constructs being assessed. This can disadvantage girls relative to boys in physics and maths assessments (Boaler 1994) and there is evidence that it can disadvantage working-class girls and boys in national tests of mathematics (Cooper and McIntyre 1996). According to Cooper, such effects can systematically underestimate the capabilities of children from certain social backgrounds.

It is likely that the contexts that girls more than boys consider relevant and of value are under-represented in assessments of physics and maths but there is very little recent research into this. Students' perceptions of the context of an assessment item determine what knowledge they draw on and this varies between students and groups of students. There is therefore an important relationship between the context and the construct, which should be reflected in marking schemes.

Forms of assessment

Internal assessment and course work

Hildebrand (1996), reporting on the changes to the assessment of the VCE in physics at age 18, which saw a reversal in the performance of males relative to females on some aspects of the assessment, attributed girls' enhanced performance to changes in the type of assessment used. The original examination relied on multiple choice and numerical answers and boys gained more pass rates than girls.

From the late 1980s some extended-response formats and social context questions were included, and girls overall outperformed boys. The use of internal assessments introduced in 1992, which included an extended investigation and a research project, was seen to extend which physics achievements were being assessed, allowing girls to better demonstrate what they knew. The research project was set in a social context. These changes led to a 10% increase in pass rates for both boys and girls, and the gender gap in favour of girls was maintained. On the new forms of internal assessment girls achieved significantly more A grades than boys did and their performance on the examinations was equivalent. Typically this form of assessment relies on extended writing, and as reported above it is this that is seen to advantage girls. There is therefore a perceived tension between choosing assessments that are fit for their purpose (i.e. extend the range of achievements assessed) and concerns about bias in assessment practices. Another tension relates to the costs of different forms of assessments. Multiple-choice formats are seen to be efficient whereas extended assessments are seen to be costly in terms of the teachers' and students' time relative to the range of achievements assessed.

Elwood and Comber (1996) in their research into gender differences in examination at 18+ considered the achieved versus the intended weightings of the four different components of the A-level physics examination. The four components included a multiple-choice paper (25%), a short and long item response paper (35%), a passage analysis and selected topics paper (20%), and a practical paper (20%). The multiple choice and the short and long item response papers contributed more to overall scores than intended for both males and females. The other two papers contributed less than intended, slightly more so in the case of males compared with females.

The introduction of the GCSE in 1988 introduced coursework into national examinations, which is a set of tasks administered and assessed by teachers against national criteria and moderated by exam boards. The amount of coursework varied considerably between subjects and depended on teachers' views of what was appropriate to be assessed and the best form of assessment for achieving this. Quinlan (1990) found a direct relationship between the improvement of girls' grades between 1985 and 1988 and the type and weighting of coursework. Stobart *et al.* (1992), however, showed that coursework did not contribute disproportionately to final grades at GCSE. This was because the coursework marks for both boys and girls were more bunched, i.e. less variable, than their examination marks, hence it was the examination score that played the greater role in determining students' rank order. Furthermore, coursework marks were more influential on the grade distributions of boys than on those of girls.

The intended weighting of an assessment form is usually specified by the examination board in the allocation of marks and suggests the contribution that a form or component of assessment will make to the overall grade. The

achieved weighting is the actual contribution made and depends not only on the marks allocated but on the spread of marks on the component with respect to others and the intercorrelation between the components or forms of assessment that make up the total score.

Elwood (1999) analysed the comparison between intended and achieved weights for the different forms of assessment in the 1997 science GCSE results. She found that coursework seemed to have less influence for girls in modular science and in the intermediate and higher tiers of combined Double Award Science, with the achieved weights in coursework being less for girls than for the boys in those cases. There is some evidence that this might reflect the nature of science coursework, which teachers do not treat as integral to the assessment and prescribe in quite narrow ways (Elwood 2001). The analysis of the achieved and intended weights for the examination papers revealed that the biology paper in Double Award had the most influence, particularly for boys. In the intermediate and higher tiers the chemistry papers had more influence and more so for girls than boys.

Arnot *et al.* (1998) report some evidence that more boys than girls consider that coursework advantages girls. Only a small proportion of girls reported a perceived advantage for themselves. This was in marked contrast to teachers' views, where over a half considered that there was a difference in boys' and girls' ability to do coursework, and the overwhelming majority of these teachers believed this form of assessment favoured girls. Beliefs of this kind might influence teachers' views of the validity of girls' final achieved grades in science and physics and influence their interactions with them about their future study.

There is evidence that girls as a group achieve higher coursework scores but that does not mean that girls are advantaged by this mode of assessment relative to boys. The achieved weighting of the different forms show that coursework scores in science have more influence on the final grades of boys compared with girls. There is evidence that teachers continue to believe that coursework advantages girls relative to boys, and this might influence their judgements of students' future potential in the subject irrespective of their achieved grades.

Computer-based assessments

We found little research into gender and computer-based assessment in science or physics, which reflects the current extent of its use in an English context. Nevertheless there are strong indications that this form of assessment will increasingly feature in the assessment of students' science achievements. Cheek and Agruso (1995), reporting on gender and equity issues in computer-based science assessment, conclude that based on Shavelson *et al.*'s (1993) work in the US it can be predicted that certain students:

“will fare better when tested on identical content/process via a computer-based medium, others

will test worse in this particular medium”. (p78)

Willingham and Cole (1997) also found little evidence to enable comment on this form of assessment. They did caution that as the medium was exploited further to address different formats and content in assessment it would be necessary to revisit the possibility of gender differences with this form of assessment.

Evidence from technology studies highlights that girls continue to feel marginalised in relation to computer use compared with boys, and there is evidence that in teachers' definitions of success, technological expertise is attributed to boys more than girls, which impacts on students' self-concept in relation to computers. This suggests that using a computer medium for the assessment of physics could have a compounding effect that would further disadvantage girls relative to boys.

Modular examinations

The Ofsted report on boys' achievement (Ofsted 2003) noted that in one school that was successfully raising boys' achievement in science, boys whose English was weak performed well on modular science tests used in Key Stage 4. Modular examinations are very prevalent at A-level examinations in Key Stage 5 and are increasingly available in Key Stage 4, where they allow students to take an examination that counts towards part of the Double Award Science at the end of year 10. The modular approach disrupts a hierarchical and linear structure of a subject like physics, and therefore it would be expected to affect students' views of their science experience. The grade achieved at the end of year 10 could either serve to motivate and enhance students' self-concept or, in contrast, lead to disaffection. Modularity is therefore a significant issue in assessment.

We could find no research on gender and the effect of modular staged science assessment at Key Stage 4 in science. There was some small-scale research into modular A-levels in physics. McClune (2001) compared year-12 and year-13 students' performance on linear and modular physics examinations using the same exam questions on topics both groups had studied. The students were selected at random from across the examination centres in Northern Ireland. The sample of students was sufficiently large but the sample of items was small, consequently the results can only suggest some possible issues for research. Year-13 students outperformed year-12 students on the same short response examination questions; however, for the girls the differences were only significant on the question that was on a topic not previously covered in the GCSE course. On the selected questions, which were free response and structured essay type, there was a similar pattern, with year-13 students gaining a higher proportion of the available marks compared with year-12 students. This was disrupted for one question where year-12 boys significantly outperformed year-13 boys. A question raised by the research was whether learning across topics about

7: Entry and performance patterns in physics

the subject deepens student understanding of any one topic, so year-13 students' superior performance reflected their consolidated understanding in contrast to year-12 students. Alternatively it was argued that the effect could be due to increased maturity and test wiseness of the students. In which case opting to defer assessment or to resit modules may advantage students by up to a grade difference, based on the results of this study.

The author speculated about the possibility that students were disadvantaged by end-of-year modular examinations, which cut them off from their study of early modules without the benefit of an overview of the subject, which traditional linear approaches allow. On the other hand if the modular assessment followed straight after the period of study this might advantage students, in comparison to traditional assessment. Research into modular maths courses (Taverner and Wright 1997) reported improvements in grade results from modular courses but did suggest that modular assessment might lead some students to expect a poor grade or a fail grade overall and hence to drop out of their A-level study.

There is little research evidence about the benefits of modular assessments in physics at Key Stage 5 and an absence of research at Key Stage 4. It is possible that poor grades achieved on staged assessment in year 10 could lead students to give up on their study of science prematurely. Obtaining a good grade might be personally motivating for students and alter teachers' expectations and interactions with these students.

Subgroup differences: gender/race and class interactions

There is an absence of research into subgroup effects within girls and boys in relation to assessment techniques and processes generally, or specifically in relation to physics. Hildebrand (1996) noted that the changes to the VCE in physics only enhanced the performance of some girls and not those from lower socio-economic backgrounds.

Supovitz (1998) compared gender and racial/ethnic group performance on two alternative science assessments – an open-ended paper and pencil test and a hands-on performance assessment for grade-4 students aged 8–9 in six schools. He found significant differences in the performance between white students and both black and Hispanic students, and concluded that group achievement was sensitive to both the item content and form of assessment in science subjects.

Gillborn and Youdell's (1998) ethnographic research in two schools in England considered teachers' tiering practices and identified an important interaction between gender, race and assessment processes that limited black students' access to the higher grades in GCSE.

What evidence there is about interactions within groups indicates that much more research is needed and that disadvantage for some subgroups may be considerably greater than indicated by an analysis of assessment

techniques and processes by gender alone.

The implications

- How schools organise students to address the differentiation in the science curriculum at Key Stages 3 and 4 is under-researched, particularly how prior achievements influence school organisation and the potential within these organisations for schools to respond flexibly to students' progress in science. These school structures and teachers' entry decisions will impact on students' access to physics, and insights into them are essential to inform action.
- Statistical evidence of the award route and prior grade of students opting for physics post-16 by gender would help illuminate which students are turning away, or being turned away, from physics. Teachers' views need to be researched to establish what grades and routes they consider the best pathway to A-level and their reasons for this.
- Statistics about which schools in the future will continue to offer a specialism in physics at GCSE need to be collected, as part of a wider evaluation of the changes in the specification of science awards, from 2006.
- It would be useful if teachers were directed to monitor the gender dimension of students' entry and results by tier at Key Stages 3 and 4 in both science and maths.
- There is some evidence of a gender dimension to the achievement patterns in national science tests at Key Stage 3 and in Double Award Science in relation to physics. Teachers might consider focusing on items from past papers to establish what if any are the sources of difficulties within groups of girls and boys and the differences and overlap between these relative to boys', to inform their teaching in both key stages.
- Further research to establish if there is a gender difference by subject in national science tests, and in Double Award Science across boards and specifications, would be useful. This subject effect should also be monitored for the new specifications if the new examination structures allow for this.
- The publication of results needs to be reconsidered to provide teachers with the insights they need to evaluate their assessment practice and decision-making from a gender perspective.
- Past evidence about item characteristics suggests that further research and re-analysis of national test and examination data into these effects, in particular format–construct interactions on gender difference in performance, is needed. Item format can be a source of assessment invalidity and any narrowing of the range of formats used or shifts in formats need to be informed by the research evidence.
- Content and contexts that are more likely to arise in physics items reflect the interests and values of boys more than girls. There are no recent analyses of this available at the item level and research is needed to consider if the content and contexts selected reflect

the construct (i.e. what is being assessed) or are a source of invalidity. It would be useful for teachers if examples of performance data by gender were published at item level.

- There is an important relationship between the context and the construct of an item, which should be reflected in marking schemes. There is some evidence that this is happening currently but there is a need for research into this as a potential source of assessment invalidity.
- How gender differences in performance on different forms of assessment are interpreted reveal differences between researchers in their theoretical positions. There is no compelling evidence that any one form advantages one group over another, which is partly explained by the multidimensional nature of any assessment form. Examination of achieved weights

does suggest that forms of assessment vary in their contribution to final grades in ways not intended. There has been no published recent research into this issue and no research specifically into the achieved weighting of components in Triple Award physics.

- There is little research evidence about the benefits of modular assessments in physics at Key Stage 5 and an absence of published research into modular assessment and its impact at Key Stage 4. Tracking the uptake of staged assessment and research into students' and teachers' experience of it would be informative.
- More evidence about subgroup effects is needed to inform teachers' practice and assessment practices nationally.

8: Recommendations

What the review findings reveal is a complex problem that limits students', particularly some girls', access to physics within the normal curriculum provision at Key Stages 3 and 4. This leads to students' increased sense of inadequacy in the subject and the growing belief that physics is a difficult subject. One way therefore of understanding why some girls may not be continuing with physics is that they do not feel able, i.e. sufficiently competent, to continue with it. The review points to many factors in the physics curriculum and its teaching and assessment that undermine or deny girls' sense of competency. Perceptions of competence alone are not sufficient to influence girls' choices, and the review points to the significance for girls in particular of being able to perceive a future in physics that will benefit them and help them achieve their goals. This inability to see a future for themselves in relation to physics has several sources. The first is to do with how careers and physics are understood to relate and whether those careers are seen to be possible and desirable careers by girls. This highlights another source, which is the mismatch between many girls' goals and the goals of physics education as they experience them and as they are represented in the current curriculum at Key Stages 3 and 4. The research available, therefore, has allowed two aspects of the problem of girls' participation in physics to emerge more clearly.

- It cannot be assumed that in current National Curriculum provision all students, particularly girls, are gaining meaningful access to the subject. The review findings suggest that this constraint on access emerges in the web of interactions within the physics curriculum and assessment experience. Understandings of gender and its influence on prior learning and students' identities as learners mediate teachers' practice and students' experience of it.
- Changing access to physics within the secondary school experience will of itself not change how girls and boys feel positioned in the future in relation to the subject. This requires a more fundamental reconsideration of the contribution of physics to students' future lives both inside and outside of work.
- The review evidence suggests that rather than specific interventions there is a need for teaching and learning to be continuously informed by, and sensitive to, the influence of representations of gender. The review does point to ways that access can be enhanced by action in schools, and where there is a need for additional or new research to better understand the problem and how to address it. It also highlights what the issues might be if more girls are to see the benefit of continuing with their study of physics post-16. The recommendations that follow are based on this.

Policy

Some boys and girls will share goals for learning but research shows that there are differences between and within them in what they value. This may be associated with the reported greater concern of girls to have social applications and issues covered in their physics lessons. There is evidence from interventions that a context-based or humanistic approach is successful in enhancing student motivation, retention and achievement especially for girls but also for boys. However, to achieve this requires systemic change to the curriculum, its assessment and teaching. A way forward that is feasible and evolutionary rather than revolutionary is to integrate recommendations about how to enhance girls' participation with ongoing curriculum and assessment developments.

Key Stage 3

The review has highlighted the need for pedagogic change and a broadening of teaching strategies and this could be addressed if national initiatives in the Key Stage 3 science curriculum took account of gender issues and evidence explicitly.

- Questioning and feedback strategies developed for assessment for learning would enhance girls' participation if they were informed by the findings about gender differences in teachers' classroom interactions and feedback. Peer assessment and self-assessment strategies need to direct teachers to the importance of students' self-concept in physics and how gender mediates this differently for some girls relative to boys.
- The evidence of the review suggests that more may need to be included in the Key Stage 3 strategy and associated professional development to develop teachers' awareness of the significance and characteristics of positive teacher–student relationships that support different students' learning in physics.
- Often the selection of activities in science and their purposes disallow student autonomy and decision-making even in practical activity. This is a key source of students' alienation from physics. More support for teachers to understand the interaction between types of activities and pedagogic strategies and the consequences for students' roles in learning is needed.
- Group and whole-class discussion is increasingly being recommended at Key Stage 4. The review findings suggest that this needs to be central to the Key Stage 3 science curriculum and extend beyond discussion of science ideas to include students' world-views and values and how these influence what they find interesting, or not, in the topics and activities in physics.

“Review findings reveal [that there] is a complex problem that limits students', particularly some girls', access to physics within the normal curriculum provision at Key Stages 3 and 4.”

- The way national science test results are made available should be reconsidered. Results for boys and girls by tier of entry and on subject components will provide teachers with some of the insights they need to evaluate their assessment practice and decision-making from a gender perspective.

Key Stage 4

The emphasis on scientific literacy in the Key Stage 4 curriculum and assessment specifications is shifting the goals of physics towards social action and concerns, but whether this is the case for the academic route identified for future scientists is unclear.

- New curriculum and assessment specifications should be informed by the evidence about the characteristics of a context-based science curriculum and its assessment and performance.
- Professional development to support teachers in the implementation of the new specifications needs to be informed by, and sensitive to, gender issues.
- Students need greater awareness of the contribution of physics to careers and this should not be dealt with superficially outside the physics curriculum. What students and girls in particular need to understand is how physics contributes to different careers and what the social contribution of different careers are, including scientific and science-related careers. This should begin to be addressed in the Key Stage 3 curriculum and in all routes in the Key Stage 4 science provision.
- National entry data for girls and boys that tracks access to different awards and routes in the science curriculum at Key Stage 4 would be very informative for teachers and help them to evaluate practice in their schools.
- Students' performance on the new curriculum and assessment specifications needs to be monitored in relation to which subgroups of students are successful and which are not, and the findings made available to teachers. Success needs to be considered across grades and papers if differentiation continues.
- The findings about the absolute difficulty of physics and maths are technically questionable. Nevertheless it is common practice to treat these findings as valid and as such they exert considerable influence on teachers. Teachers need guidance about how to treat with this evidence, and more evidence about performance by gender to challenge their beliefs about what girls and boys can and cannot do in physics and maths in Key Stages 4 and 5.
- Teachers' and students' perceptions of the difficulty of physics and the use of league tables that do not discriminate between subjects taken may be two important ways in which students' access to physics post-16 is being curtailed. This may prevent access to students whose potential and interest in the subject and/or career intentions are only emerging at the end of Key Stage 4, and action is needed here.
- Statistics about which schools in the future will continue to offer a specialism in physics at GCSE need to be collected, as part of a wider evaluation of the changes in the specification of science awards, from 2006.

Practice

- The importance of eliciting students' prior scientific knowledge is widely recognised in science education and in the Key Stage 3 science strategy; that it is equally important to elicit their world-views and how these influence what they find interesting in topics and activities in physics is not. Simple strategies that make students' views of relevance explicit and available for discussion exist and teachers might think about using these as part of their formative assessment practice.
- Effective teaching and learning relies on teachers sharing with students the goals for their learning and students being able to make sense of them. As part of this, students need opportunities to make explicit their values and goals for their learning in relation to physics. These insights could be used by teachers to promote discussion and reflection about the nature of physics and why it is represented and practised in particular ways.
- To maintain girls' and boys' interest and motivation to study physics it is important that they experience themselves as competent in the subject. Teachers might think about monitoring over time students' evolving views of themselves as learners of physics using self-assessment strategies such as reflective diaries. Examples of students' narratives about their experience of science could be made available as part of professional development resources to help teachers with this.
- Teachers could consider finding out at significant points in students' science education, using a simple questionnaire, how students rate the difficulty of physics, their reasons for this and how this compares with their ratings of other subjects, including other sciences.
- Teachers set activities but it is the students who make sense of what the task is. Students' views of relevance influence this and can alter what is available to learn for girls and boys. Teachers might think of monitoring students' understanding of tasks as they undertake class work or revision. This would enable them to see which students pay attention to what and help them to guide students about what to pay attention to and why, or, in the case of some students, how to take wider account of what might be significant.
- Observations of colleagues' practice is increasingly part of teachers' professional experience. If observations at times focused on student roles in learning and the nature and type of interactions and feedback to students, this would provide teachers with insights into the ways that gender mediates students' learning that could inform their own and departmental practices.

8: Recommendations

- Teachers responsible for assessment in schools might consider tracking girls' and boys' entry to national science tests and tiers of entry to Double Award and Triple Award Science. To inform departmental practice they could compare entry decisions at Key Stage 3 with later progress and achievement in Key Stage 4, and predicted examination results with actual results, bearing in mind which students have had ceilings placed on them by entry to lower and foundation papers.
- To explore whether there is a gender dimension to the achievement patterns in national science tests at Key Stage 3 and in Double Award Science in relation to physics, teachers could use selected items from past papers to establish what if any are the sources of girls' difficulties relative to boys' to inform their teaching in both key stages.

Research

- There is a need for qualitative studies that provide evidence and tools for teachers to use in dealing with gender differences in physics. As part of this research, the pedagogy in physics classrooms where single-sex organisation is applied could be examined and compared with the pedagogy employed in successful mixed classes in order to establish what effect if any the single-sex organisation has.
- Not enough is known about how to support all subgroups of students when adopting humanistic science courses and assessment. There is a need for research into subgroup effects to inform any intervention in the future science curriculum.
- How schools organise students to address the differentiation in the science curriculum at Key Stages 3 and 4 is under-researched, particularly how prior achievements influence school organisation, and the potential within these organisations for schools to respond flexibly to students' progress in science. These school structures and teachers' entry decisions will impact on students' access to physics, and insights into them are essential to inform action.
- More research is needed to find out teachers' views about the characteristics of students they consider are capable of studying physics post-16 and how these views influence their award and tier entry practices at GCSE.
- Further research to establish if there is a gender difference by subject in national science tests, and in Double Award Science across boards and specifications, would be useful. If this evidence were available it would be beneficial if teachers could access it. Subject effects could also be monitored for the new specifications if the examination structures allow for this.
- Prior research has shown that item characteristics such as the response format, the content in the item and the context of the item can be sources of assessment invalidity if they alter what is intended to be assessed. The national test item banks and performance data are valuable sources that warrant further analysis to establish whether item characteristics are related to gender differences in performance.
- The examination of achieved weights does suggest that forms of assessment vary in their contribution to final grades in ways not intended. There has been no published recent research into this issue and no research specifically into the achieved weighting of components in Triple Award physics. Research evidence may be helpful in challenging teachers' beliefs about gender and assessment.
- With the increased emphasis on modular courses and assessment there is a need for research that tracks the uptake of staged assessment and students' and teachers' experience of it.

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