There has been more than a decade of declining recruitment of students to physics A-level courses together with the closure of a significant number of physics departments in higher education institutions. In addition, the participation rate of girls in physics has remained fixed at around 20%. Over the same period, recruitment to biology has increased for both boys and girls, while equal proportions of boys and girls continue with their study of chemistry. If girls were more proportionally represented, recruitment to physics A-level could be improved substantially.

This review was commissioned to consider the literature dealing with the participation of girls in physics. It examines the factors that influence their choice and the impact of the various strategies employed to enhance girls' achievement in, and recruitment to, the subject. In particular, it considers the degree to which the issues are currently understood and what the published research can tell us about directions for effective future action. This review draws on 177 sources, the majority comprising UK-based research between 1990 and 2005, covering ages 11–16. There is also some post-16 work that is specific to physics. This material was supplemented by a few important, earlier sources and by research from other countries with similar education systems to those of the UK.

Findings

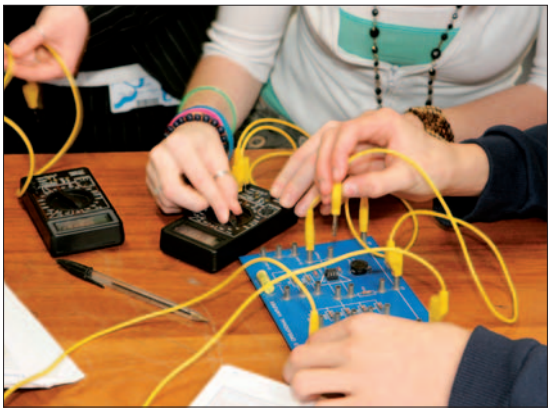
More boys than girls show a preference for physics and subsequently choose to study the subject. The analysis of these gender differences is complex and indicates a number of interacting influences. There is no simple solution and many longstanding beliefs about the reasons for girls' alienation from physics have been contested in the literature. Efforts to improve the situation have had some success but, frequently, the results have not been clear cut. The problem is deep rooted, multifaceted and thus difficult to solve. However, as society changes, so do the possibilities and constraints, so it is crucial to understand the current experience of students in the physics classroom. A significant finding of this review is the absence of recent research into gender and physics, particularly in the UK.

Students

There is emerging evidence from international studies, supported in part by research in the UK, that key determinants of students' attitudes to physics are:[1]

- how students see themselves in relation to the subject, both now and in the future: their "physics self-concept";
- their experience of school physics;
- a personally supportive physics teacher.

Survey evidence shows that more boys than girls report that they like the subject. Both in terms of interest and course choices, more girls than boys report a preference for the biological sciences, with the reverse true for the physical sciences. Surveys tend to report on the differences



rather than similarities between boys' and girls' interests but, where they do consider the overlap, it is found that boys and girls share interests in aspects of Key Stage 4 physics.

There is considerable evidence from studies in several countries that both boys' and girls' interest in science declines as they progress through school. For some, the decline in interest begins in primary school and may accelerate post-14, particularly among girls and in physics. Studies at Key Stages 4 and 5 have found, however, that while interest and enjoyment are important influences, they are not the only factors that determine whether students continue with physics. Evidence suggests that negative experiences are much more influential than positive ones in impacting on students' choice of course.

Detailed large- and small-scale studies have discovered gender differences in what students consider personally relevant.[2] These perceptions influence subject choice and how students engage with learning and assessment situations. In the latter, not only the content of an activity is important. Girls are more likely than boys to value the social context in which tasks are placed in defining a problem; boys are more likely not to notice the context. Typical secondary physics activities tend not to be concerned with the social context at all, although, in practice, they rely on content and contexts more familiar to boys than girls, who are likely, therefore, to feel less competent. Consequently, some girls experience physics as increasingly difficult as they struggle to engage with it; for others, it is increasingly seen as involving learning goals that are at odds with their concerns.

Prior achievement is an important influence on school students' course choice. Even if they are interested in the subject, students need to feel that they can be successful at physics if they are to continue their studies. Recent, non-UK research reinforces the impression that males are more likely than females to rate themselves as successful learners in maths and science. There is also evidence of a greater decline in girls' physics self-concept (i.e. their sense of themselves in relation to the subject), relative to that of the boys, as they go through secondary school. Girls' perceptions of their current and future possibilities influence their choice of subject greatly.

Both teachers and students consider career intentions

"There has been more than a decade of declining recruitment of students to physics A-level courses together with the closure of a significant number of physics departments in higher education institutions."

1. See section 3 (pp2–12) in *Girls in the Physics Classroom: Review of Research on Girls' Participation in Physics* (Murphy and Whitelegg 2005).
2. See section 3 (pp13–22) in *Girls in the Physics Classroom: Review of Research on Girls' Participation in Physics* (Murphy and Whitelegg 2005).

"In physics, where some girls have a less positive self concept, it is much more important for them to receive support."

to be important in determining course choices. However, in-depth studies show that students lack knowledge of the range of science-related careers. Some evidence from studies outside the UK suggests that the traditional image of "masculine" science may be shifting, or is at least becoming less significant in accounting for gender differences in science at secondary school. However, there is also evidence that, as they progress from secondary to higher education, young women increasingly see no future in a career in the sciences.

Curriculum interventions[3]

Early attempts to remedy the imbalance between girls and boys tried to "compensate" for the difficulties experienced by girls. There was no attempt to change the curriculum or approaches to teaching science. Instead, interventions concentrated on developing additional scientific skills and experience; providing a safe, single-sex environment in which to build confidence; and offering girls female role models in science. Overall the long-term impact of such initiatives appears to be limited.

Other girl-friendly interventions identified the lack of personal relevance of science for girls as the key problem. They selected curriculum topics (e.g. health, diet) that they assumed would seem relevant to girls. Again, in general, these interventions had limited long-term impact and did not develop girls' understanding of the relevance of science to them.

A range of international studies indicate the need to change the curriculum, and the teaching and assessment methods, so as to increase girls' engagement with science. The proposal is for a curriculum described as "context based" or "humanistic". Key aspects include:

- using a variety of social situations and contexts to organise and determine the scientific content of the course;
- representing science as something that people do, influenced by historical, political, cultural and personal factors, not just as "a body of knowledge";
- using the values inherent in science as topics for discussion and critique.

This curriculum approach relies on more use of discussion, debate and student collaboration in learning. Such methods require a change in the teacher–student relationship, with the teacher acting as a knowledgeable guide.[4] The Secondary Strategy includes pedagogic strategies that are complementary to these ideas but that need to be focused on the gender issue. For example, questioning and feedback strategies developed for assessment for learning need to be informed by the findings about gender differences in this area. Similarly, peer-assessment and self-assessment strategies have to recognise how girls' self-concept in physics differs from that of boys. Teachers also need to understand what makes a good teacher–student relationship and how it can be developed. Some teachers find these changes difficult to make and will require support and specific professional development.

There is evidence, mainly from research outside the UK, that this type of curriculum experience leads to increased enjoyment, achievement and participation levels, and higher motivation, particularly for girls. Trials in other subjects, in the UK and elsewhere, report similar findings. However, some students – more commonly boys – do not enjoy this approach, seeing little value in the focus on social contexts and problems.

School and teacher effects[5]

All students require support from teachers but, in physics, where some girls have a less positive self concept, it is much more important for them to receive support. Boys tend to find male teachers more helpful and understanding than girls find teachers of either sex.

Past research has shown that teachers' expectations of physics students have a significant effect on students' self concept. Recent research is limited, but it appears that teachers expect boys to do better than girls in science and physics. One England-based study found that teachers' lower expectations of girls in physics persists after Key Stage 4. Teachers of A-level physics – predominantly males in the sample – did not consider that girls and boys performed differently. However, they did believe that there were content areas that only girls would find difficult. The teachers' views were not shared by the students or supported by their achievements.

In science classes, teachers tend to give more attention to boys as a group than girls, although teachers are not aware of this. The nature of the feedback given also varies with gender. Girls are more likely to receive feedback on the quality of their work rather than their behaviour; the converse is true for boys. There is no recent, UK-based research to indicate whether these observations also apply to physics teachers.

Generally, teachers in single-sex schools have higher expectations of girls than those in coeducational schools. Girls in single-sex schools are more likely than their peers in coeducational schools to be entered for the higher papers in Key Stage 3 maths and science tests, and for Triple Award Science at GCSE. The impact of single-sex schooling on achievement is less clear. Early studies urged caution about the findings that single-sex organisation was a significant factor associated with girls' enhanced achievement because the studies failed to take into account social, cultural and institutional factors, and the prior achievements of the student populations.

However, recent work in England, which controlled for prior attainment and some social and institutional factors, suggests that achievement and single-sex organisation are related, because girls' exam performance at age 16 was significantly enhanced in single-sex schools. The enhancement was particularly strong in science and for lower-ability girls.

Early research suggested that girls' subject preferences

3. See section 3 (pp13–22) in *Girls in the Physics Classroom: Review of Research on Girls' Participation in Physics* (Murphy and Whitelegg 2005).
4. See section 4 (pp23–28) in *Girls in the Physics Classroom: Review of Research on Girls' Participation in Physics* (Murphy and Whitelegg 2005).
5. See section 4 (pp23–28) in *Girls in the Physics Classroom: Review of Research on Girls' Participation in Physics* (Murphy and Whitelegg 2005).

were less polarised in single-sex schools than in coeducational settings. Girls showed a stronger preference for science than their peers in mixed schools but only in the early years of secondary schooling. More recent research supports these findings and attributes the decline in girls' interest in science to the curriculum experience offered by the school rather than school organisation.

There is little research into the effectiveness of single-sex groupings in physics in coeducational environments. What limited evidence there is suggests that single-sex groupings can enhance girls' achievement, self concept and motivation to continue their study of physics, but only where the pedagogy and curriculum are inclusive.

Assessment issues[6]

Both large-scale analyses and smaller-scale studies report that physics and the other sciences are measured to be up to a whole grade more difficult compared with most other subjects at A-level and GCSE, although there is some debate about the size of the grade difference. More important, the validity of the comparisons has been challenged on both technical and educational grounds.[6] However, the perception of physics as a difficult subject is widespread and is part of the "commonsense" knowledge of teachers and students.

There is significant evidence that teachers consider that the mathematical demands of physics have a major impact on its level of difficulty. Students' perception that physics is difficult strengthens as they progress through the school system, partly due to the increase in mathematical demands and partly to an increased sense of inadequacy in the subject, which is more common for girls. Students, particularly girls, report that the need to cover a lot of content quickly affects their ability to gain depth of understanding, which reinforces their perception that physics is difficult at Key Stage 4.

In England and Wales, far fewer girls than boys are entered for physics in the Triple Award Science GCSE and their performance relative to boys is poorer, both at the pass level and at the top A* and A grades.[7] Entry to physics exams in Scotland and the Republic of Ireland show a similar gender gap in favour of boys. However, in this restricted sample, on average, girls outperform boys in the top grades in contrast to the situation in England and Wales.

Overall, girls outperform boys in Double Award Science, but this is associated with the biology and chemistry components of the exam. For both the higher and the foundation papers, boys' performance relative to girls' is highest for the physics component.

Boys' performance is slightly ahead of that of girls in national science tests at Key Stage 3. However, analysis of a representative sample showed that, in both the higher and lower tests, generally boys did better on physics questions and girls on biology questions. The publication of results aggregated across papers and subject components masks these observations.

Research suggests that girls perform less well in multiple-choice exams compared with short, free-response formats. Boys appear to do equally well in both. However, the evidence that girls prefer extended responses is equivocal.

There is evidence that some gender differences in performance in physics arise from differences in student experience outside school. Analogies used to illustrate physics principles are more likely to reflect the interests and values of boys. For example, the law of reflection at a plane is frequently described with reference to the behaviour of snooker balls. Many girls are more interested in social contexts and the relevance of science to human dilemmas – factors that are underrepresented in the assessment of physics and maths. However, there is little recent research in this area.

Recommendations

It cannot be assumed that, in the current national curriculum provision, all students, particularly girls, are gaining meaningful access to physics. However, improving access to physics at secondary school will not change how students see themselves in relation to physics. Such a change would require a more fundamental reconsideration of how students can be made aware of the contribution of physics to their future lives, both in work and more generally. In addition the review's evidence suggests that specific interventions have a very limited usefulness, and that there is a need for teaching and learning to be informed continuously by, and to be sensitive to, gender issues.

Monitoring

It is a matter of considerable concern that, despite the identification of the problem, we still do not have research-based understanding of why gender has such a profound impact on the choice of physics post-16 in England. It is vital that this situation is not allowed to continue. The curriculum at Key Stage 4 is about to undergo a radical change, with Key Stage 3 to follow.

Recommendation 1

It is vital that QCA and Ofsted monitor the impact of the changes at Key Stage 3 and Key Stage 4 on students' engagement with, and performance in, the new curricula, to determine which subgroups of students are successful and which are not. The findings should be made available to teachers.

Access to exam results for boys and girls by tier of entry and by the separate science subject components would provide teachers with the insights that they need to evaluate their assessment practice and decision making from a gender perspective. In addition, differences between the performances of girls and boys in separate science components should be monitored to inform test development and teachers' practice.

Recommendation 2

The way in which national science test results are made available at Key Stage 3 should be reconsidered. The National Assessment Agency should pro-

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6. See section 6 (pp35–39) in *Girls in the Physics Classroom: Review of Research on Girls' Participation in Physics* (Murphy and Whitelegg 2005).
7. See section 7 (pp40–52) in *Girls in the Physics Classroom: Review of Research on Girls' Participation in Physics* (Murphy and Whitelegg 2005).

"There is little information available about girls' experiences of science and physics in schools in England and how this informs their attitudes and future aspirations."

vide more informative feedback on national entry and performance data for the sciences.

Teachers need access to school-based and individual performance data to monitor their decisions on entry to assessments.

Recommendation 3

Schools should be encouraged to compare entry decisions at Key Stage 3 with later progress and achievement in Key Stage 4, and predicted GCSE exam results with actual results.

Continuing professional development

The Secondary Strategy for science recommends a number of measures that should increase girls' engagement and participation in physics. However, implementation is unlikely to happen unless the professional development is informed by an understanding of how gender operates in the classroom.

Recommendation 4

The Secondary Strategy should show how it will contribute to greater engagement and participation by girls in physics.

Recommendation 5

Science learning centres should be encouraged to offer courses to help teachers to improve their understanding of gender issues in relation to girls' access and engagement, and how to implement appropriate change in their schools.

Careers

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 employment sectors is.

Recommendation 6

The QCA should consider the extent to which the National Curriculum portrays an accurate and contemporary picture of the role of physics in the modern world and supports students' understanding of professional and technical careers.

Recommendation 7

In collaboration with the Equal Opportunities Commission, the DfES should investigate the quality of careers guidance in science given to young people, and the awareness of careers advisors and teachers of the gender dimension in relation to STEM.

Research

There is little information available about girls' experiences of science and physics in schools in England and how this informs their attitudes and future aspirations. Longitudinal research that follows girls as they experience Key Stage 3 and Key Stage 4 science in different schools is essential if we are to remedy the situation.

There is a need for qualitative studies that provide evidence and tools for teachers to support an inclusive pedagogy. The pedagogy used in single-sex physics classes should be examined and compared with that employed in mixed classes to establish what, if any, effect single-sex organisation has.

The literature concerned with the impact of context-based science courses and assessment usually involves findings about girls and boys generally and rarely deals with issues such as ethnic or socioeconomic background. There is a need for research into the effects on these subgroups of girls to inform intervention in the future science curriculum.

Recommendation 8

The DfES, working with the research councils and other funders of educational research, should establish an agenda for research to inform and address the girls and physics problem.