Institute of Physics Report

Girls in the Physics Classroom

A Teachers' Guide for Action

December 2006

Institute of Physics

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Introduction

In 2005 physics was the 12th most-popular A-level in the UK, with 28 119 candidates. Of these, 21 922 were male, making physics the sixth most-popular A-level subject for boys behind maths (32 719), general studies (28 083), English (26 332), history (22 342) and biology (22 046).

For girls, physics was the 19th most-common A-level choice. Of those who took physics A-level, 34% achieved an A grade. In 2005 only 14% of girls who were awarded an A* or A for GCSE Double Award Science or Physics sat A-level physics. In other words there is a very substantial number of girls who have the ability to do well at physics but who are choosing not to study the subject post-16.

The low uptake is not a new problem; figure 1 shows the proportions of girls and boys studying physics between 1995 and 2005. For physics teachers this decrease is disheartening. For the UK it is a very serious problem because A-level physics is a gateway qualification to a variety of careers that make a substantial contribution to the financial and intellectual wealth of the country.

In 2004 the Institute of Physics commissioned two pieces of work about girls' engagement with physics:

- *Yes She Can*[1] is an investigation by Bob Ponchaud (ex-HMI for science) into schools that are successful at attracting girls to study A-level physics and how this might inform other schools.
- *Girls in the Physics Classroom: a Review of the Research on the Participation of Girls in Physics*[2] by Patricia Murphy and Elizabeth Whitelegg of the Open University aims to consolidate current understanding of the problem and to identify from existing research the reasons why girls choose not to continue studying physics. It also identifies the strategies that have succeeeded in increasing the number of girls studying physics post-16.

The reports reveal some of the important issues that underlie the statistics for examination entries:

- It cannot be assumed that, in the current National Curriculum provision, all students, in particular girls, are gaining meaningful access to physics.
- Students' interest in science declines as they progress through school and the decline appears to become steeper after age 14, particularly for girls and particularly in physics.
- Girls, more than boys, experience a difference between their personal goals for learning and the learning objectives of the physics curriculum. As a consequence they are less inclined to opt for physics, even if they achieve high grades and enjoy the subject.
- As they go through secondary schooling, students experience physics to be increasingly difficult. This perception is partly due to the mathematical demands of the subject but also to girls' developing feeling of "not being able to do physics". The feeling is not borne out by the reality of girls' performance.

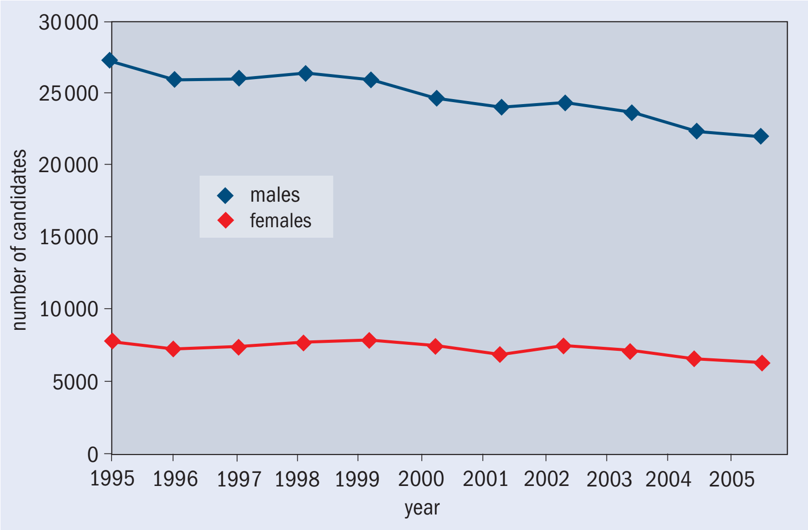

Fig. 1: Number of A-level physics candidates.

The two reports have found that key influences on students' attitudes to physics are:

- self-concept (i.e. students' sense of themselves in relation to the subject : the value they place on the subject and their willingness to engage in it);
- views of physics (i.e. how students experience physics at school);
- teacher-student relationships (i.e. how personally supportive students find their physics teacher).

This guide draws on the work done by Ponchaud, and by Murphy and Whitelegg, to identify some of the strategies that schools could use to try to increase the participation of girls in post-16 physics:

- Section 1 is written by Ponchaud. It explores the lessons that he learned from schools that are successfully recruiting girls to AS physics, retaining them into A2 and gaining good examination results. It also suggests how this good practice can be developed in other schools.
- Section 2 is written by Murphy and Whitelegg. It summarises the research findings and suggests practical ways that you can examine these issues in the context of your school, department or classroom.
- Section 3 is written by Martin Hollins. It is based on two videos: *Saving Nellie* and *Key Stage 3/4 Science: Girls*

1. *Yes She Can* has not previously been published but it forms the basis for section 1 of this report.

2. Murphy P and Whitelegg E 2006 *Girls in the Physics Classroom: a Review of the Research on the Participation of Girls in Physics*, Institute of Physics.

in Physics. It suggests how the videos might be used to stimulate discussion among teachers about their own practices and encourage school departments to review their teaching and learning strategies.

The intention of this guide is to inform teachers about how girls experience physics and what influences their motivation for, and learning of, the subject. The practical advice is grounded in work carried out in classrooms and the methods suggested have been used successfully by other teachers and their students. The aim is to promote informed debate about this important issue.

The work of Ponchaud, Murphy and Whitelegg explored the problem from two different perspectives but they reached a similar conclusion: the issue is not insoluble and teachers have a key role to play. In particular, girls are more likely to continue with physics after the age of 16 if:

- physics is taught in a way that engages with the interests of young people;
- there is an expectation that anyone can do physics;
- classrooms are managed to ensure active participation by students;
- the focus of learning is ideas rather than unconnected facts;
- students feel supported in their learning;
- young people understand the contribution that physics makes to society and can make to their lives.

Many of the changes suggested in this report simply represent good classroom practice and are likely to support both boys and girls in their learning.

You don't have to read this report in its entirety for it to be useful; you can dip into sections that are of particular interest in your school context. For example, you may just want to try those classroom strategies that relate to an issue that affects your school.

1: Lessons from effective classroom practice

The author of this section, Bob Ponchaud, was an HMI for 13 years and a specialist adviser for science to OFSTED for eight years.

The evidence that this section is based on comes from visits to schools in England where the take-up of physics by girls is relatively high. Key Stage 4 (KS4) and post-16 lessons were observed to gain an insight into the context in which decisions about further studies are made and into the reality of classroom experience thereafter. The resulting evidence is necessarily anecdotal but draws on his long experience of classroom observation.

The research confirms that the best single-sex schools are much more successful than mixed schools at getting girls to study physics post-16. Different levels of resource and type of intake are a factor. Nevertheless, features of the ethos, organisation and pedagogy of these top single-sex schools that lead to their success can be transferred to mixed schools. The adoption of these features is already contributing to improved engagement and take-up in the schools that were visited for Ponchaud's research.

Some schools are much more successful than others at recruiting girls into physics, as is revealed by information held on the OFSTED database.[3] Only 80 schools from a sample of 1500 recruited 10% or more of their post-16 girl cohort to take physics in 2003. Of these schools, 44 were girls' schools and 36 of them selected by attainment. A further 10 out of the 80 had more than 20% of their cohort taking physics. These 44 schools contributed almost one-quarter of the total A-level physics entries for the sample. Research suggests that, once socioeconomic factors and prior attainment have been allowed for, the situation is much less stark. However, many lessons can be learned from those schools that are highly successful.

The schools that were visited as part of this project had all succeeded in recruiting girls into AS-level physics, retaining them into A2 and gaining good examination results.[4] The aim was to identify, by observation and interview, features of the organisation and its teaching of physics that might account for this relative success and that could be replicated elsewhere. Observation and interview protocols were used but it is not suggested that this project constitutes rigorous research or that causal connections can be supported by anything other than the author's professional judgement.

1.1 The school culture and ethos

What is it about some schools that makes them so successful at recruiting girls into physics and is this quality transferable?

The schools visited during the survey had a number of common features that were reflected in the classroom and in students' responses during interview. The most successful girls' schools had a strong "can-do" culture, which stimulated student self-belief. No teachers or students in these schools made any mention of the commonly perceived difficulty of physics as a subject. Conversely, in mixed schools difficulty was often cited as a reason why students, particularly girls, did not choose physics. Teachers in the successful schools were not unrealistic about the demands of some topics but they viewed these as a challenge to be met by staff and students. Some students regarded this challenge as part of the appeal of physics. One said:

> "You have to work at it but you get a buzz when you feel you understand a new idea. I don't get that in other subjects."

It is unlikely that this can-do culture can be established quickly or that it is peculiar to physics, but it has a powerful effect on student choice.

The successful schools had also reduced students' and teachers' subjection to gender stereotyping. Discussions with students showed that many of them were either unaware that physics was often regarded as a boys' subject or discounted this view as out of date or irrelevant. Girls in one single-sex school commented:

> "No one has ever told us we can't do physics or any other subject. People these days can choose what they want to do."

Some girls indicated that they had not much liked physics in the early years of secondary education and probably saw it as being more for boys. However, this view had changed as a result of a consistently good experience of the subject. Another major factor was career aspiration, particularly in the medical or paramedical fields. Physics was viewed as a highly desirable, if not strictly necessary, subject for entering these professions, which students commonly regarded as fields in which women could excel.

One of the strong similarities that emerged between girls and mixed groups visited during the survey was girls' preference for a collaborative rather than a competitive approach. Even the most able and confident female students would often preface their response to a question with an expression of uncertainty, reflecting not their own doubt but the recognition that other members of the group might have an equally valid point of view. Girls-only classes were far less often dominated by an individual or a minority than in the case of mixed groups. Group activities, such as discussion or presentations, were also well liked by them.

The number of students taking A-level physics in mixed schools often fluctuates more than the take-up in girls' schools. Teachers, particularly those in mixed schools,

3. Data provided by OFSTED Research and Analysis Division (appendix 4.1).
4. Some had experienced recent decline consistent with the overall reduction in AS entries.

reported that it was common for female friendship groups to opt for physics. Many of the girls interviewed said that they had discussed subject choice in some detail with friends, whereas boys mostly decided independently. This difference was perceived by teachers as reflecting the girls' reluctance to be isolated in a boy-dominated class. However, girls indicated that they simply arrived at a consensus about subject options and would, if necessary, be willing to join a largely male group.

In a girls' selective school for 11–18-year-olds, with 800 pupils on role, there are 60 pupils studying physics at AS-level and 50 at A-level. Teachers have established a can-do culture and teaching takes account of the needs and interests of girls, giving them the confidence to continue the subject. Teaching is enthusiastic but very well planned and organised.

The culture and ethos in the successful girls' schools cannot easily be replicated elsewhere. In any case the culture cannot be attributed to a single subject department. Nevertheless, there may be some useful messages to be gleaned about how physics should be represented and organised in all schools.

Messages for practice

- Accentuate the positive wherever possible and avoid portraying physics as an essentially hard subject. Girls in a mixed school are more likely to be deterred than boys.
- Take positive steps to reduce the impact of stereotyping. All staff, not just physics teachers, need to be well informed about the issues. In particular, teachers must avoid reinforcing stereotypes, endeavouring not to use mostly male examples when talking about occupations or interests.
- Make sure that physics is viewed as a valuable subject in its own right, not just regarded as a qualification for careers in science and engineering.
- Encourage collaborative approaches to the teaching and learning of physics and avoid domination by individuals (see also section 1.3).
- Invite staff to be proactive in discussing study options. They should not just give information; they should give an insight into what studying physics will be like. Involve A-level students and encourage them to give an honest appraisal of their experience.

1. 2 The curriculum and its organisation

What can schools do to make the science curriculum more gender inclusive?

Since the National Curriculum was introduced in 1989, the content of GCSE science courses has been closely prescribed. Nevertheless, schools still have the freedom to organise the curriculum in ways that best meet the needs of their pupils within the constraints imposed by staffing. The development of new GCSE courses, such as 21st Century Science and Applied Science, will encourage a fresh look at the nature and organisation of the curriculum, so it is timely to reflect on possible gender issues.

Double Award "Balanced" Science was originally introduced to ensure that all pupils experienced each of the mainstream science disciplines up to the age of 16. It was hoped that this would increase the proportion of girls taking physical sciences beyond this age. There is little evidence to suggest that it has been successful in this respect, although all pupils now receive a grounding in physics. Like most schools, those visited as part of this survey offered Double Award Science. Most of them also taught separate Triple Award GCSEs in biology, chemistry and physics.

The science curriculum has become increasingly fragmented. The Key Stage 3 (KS3) scheme of work provided by the Qualifications and Curriculum Authority (QCA) divides the science curriculum into 37 units and most KS4 specifications are similarly divided into short modules. Many of the girls spoken to during the survey complained that they could not see where "everything fits together"; they perceived science as a series of unrelated facts and wanted to see the big picture. As one girl not intending to continue with physics said:

> "I can understand the individual bits but I don't see how they fit together so don't really understand why we are studying it or what use it is to me."

This was viewed as less of a problem in biology, for which the students considered the unifying themes to be clear. At GCSE, physics was seen as the most disparate subject.

The schools that were most effective at recruiting girls all taught physics as a separately timetabled and staffed subject, even where it was part of a Double Award Science programme. Continuity of staffing appeared to be a major factor influencing girls' study choices. They were keen to know who would teach them if they chose to continue the subject. Staffing can be more of a problem for some types of schools in some areas. However, it is worth noting that girls' preferences were not strongly associated with the individual personalities of teachers but with a teaching style that was understandable and regarded as effective.

> "I don't particularly mind who will teach me next year [year 12] but I do want to know – it's part of the package really."

In the schools that were visited there was little to suggest that teacher role models were a major influence on attitudes to the subject of physics or post-16 decisions about studying it. Some teachers in mixed schools attributed a decline in the take-up of physics post-16 to the loss of a particular teacher but pupils seldom cited this as a reason. The effectiveness of teaching and the ability "to make it interesting" were regarded as much more important than the personality or gender of a teacher.

In a mixed comprehensive school for 11–18-year-olds has moved away from modular Double Award Science to improve continuity. It now has specialist teaching for the biology, chemistry and physics components of a Double Award course. Teachers commented: "We felt that we were making pupils jump through hoops at regular intervals rather than developing key ideas in the disciplines over time." School-developed resources and links to websites are available for each topic on the school website and pupils are encouraged to review certain areas before starting a new unit. So far pupils have done just as well at GCSE as previously and take-up of sciences in general and physics in particular has improved. More girls are taking physics.

Messages for practice

- Avoid fragmenting the pre-16 science curriculum more than absolutely necessary; plan to make explicit links between related areas. The use of "mind/concept maps" or group preparation of displays summarising a topic may be a useful approach.
- Give weight to continuity of specialist teaching when timetabling. If possible, enable pupils to experience the teaching style that is likely to be used post-16.

1.3 Classroom organisation and management

How can teachers vary their classroom organisation to encourage full participation by girls in physics?

The recently published guide *In a class of their own*[5] describes how some coeducational schools have created single-gender groups for the teaching of science. None of the mixed schools visited as part of this survey had formed such groups but many of them employed a variety of grouping strategies for different classroom activities.

Some schools often organised pupils into single-gender groups for practical work. Teachers found that, in mixed groups, boys tended to rush into practical activity while girls often wanted to draw up tables for results or carry out other preparatory work before starting an experiment. This led to a polarisation of roles, with boys becoming the "doers" and girls becoming the "scribes". A typical comment was:

> "We like to think things through and know what we've got to do. Boys just jump in and don't seem to worry if they get it wrong."

Single-sex practical groups in schools that projected a can-do approach helped to improve involvement by girls in "hands-on" practical activities. However, even in the single-sex groups, students rapidly adopted narrow roles. One school overcame this problem by assigning tasks to different students in a group on rotation.

Some of the most successful lessons observed included small-group activities, such as the discussion of an issue or the preparation of a presentation or some display materials. These approaches were generally popular with girls, particularly when they were working in single-sex groups. In these situations, girls often displayed superior organisational skills to boys and divided up tasks in a systematic way. Tangible outcomes, such as display materials, were of high quality in content as well as presentation, and these often helped girls to articulate their understanding.

Several teachers distinguished between social and working groups. Pupils were usually allowed to sit with other students of their own choosing but they were expected to work in different combinations depending on the activity. Once established, this approach was not questioned by pupils and it ensured that each of them adopted a variety of roles over time. Girls, in particular, were pleased to be freed from the role of recording and note-taking. Varying the groupings in which students worked also enabled the teachers to emphasise the co-operative nature of physics, debunking the view that physics is always a solitary activity.

Pupils are grouped differently depending on the activity. Discussion groups are single gender but followed by whole-class plenary. Practical groups change and individuals are nominated to report back findings. In this way there are no passengers –all pupils play an active part yet none can dominate. Girls hold their own and are not overshadowed by a small number of vocal boys.

Messages for practice

- Distinguish between social (seating) groups and working groups and change the latter periodically.
- Try out different groupings for most practical work and discussion, perhaps including single-sex groups as part of an overall strategy for improving the participation of girls.
- Ensure that all girls play an active part in activities and do not just act as note-takers.
- Group students according to their learning needs and aptitudes not for classroom control.

1.4 Questions and answers

How can teachers frame and address questions in ways that will encourage girls to respond and to articulate their understanding and concerns?

The questioning technique that teachers use is a crucial factor in engaging girls in physics. In a mixed class, boys will almost always be the first to respond to a request for "hands up" to answer a question directed at the whole class. Very few of the teachers who participated in this project used this approach because they were well aware that girls would be less likely to contribute. By allowing thinking time, most of the teachers also avoided instant responses, which typically came from boys and denied other students the opportunity to reach an answer.

> "A hand up means that someone wants to ask a question. I use other ways – such as whiteboards – to find out who can remember something. I ask fewer questions and allow

5. *In a Class of Their Own?* Teaching science in single-sex classes in co-educational schools – a guide to good practice (2004) WISE.

more time for thinking. This stops boys jumping in and encourages girls to contribute."

A large proportion of questions in physics are closed (i.e. they require brief factual responses). Many of them are used to check whether the class has taken specific information on board, such as instructions for practical work or the definition of a physical quantity. Such questions do have a part to play but they do little to engage students or to elicit real depth of understanding. Many of the girls spoken to for this project regarded them as pointless:

"Why ask us things when they are on the sheet or in the book anyway? It's just a question of who can find it or remember it first; it doesn't mean you understand it. I don't bother to put up my hand any more."

The girls perceived questions in biology as more likely to be linked to a mechanism or life process and in chemistry to be linked to an observation. Despite this, even the most able and otherwise confident girls responded in an apparently diffident way to more extended questions in physics. Answers were often prefaced by expressions of uncertainty:

"I'm not really sure about this but I think..." and "This probably isn't right but..."

Discussion revealed that they believed that physics was always precise and unambiguous and that they felt unable to give the "right answer" in its totality. They also wanted to leave the way open for other students who might have a better or fuller response. Teachers sometimes interpreted female students' tentative replies as showing a lack of deep understanding, yet often the reverse was true.

The teachers who were most successful in engaging and inspiring girls used a variety of questioning techniques to counter all of these concerns. Avoidance of the hands-up approach and allowance of more time to respond were used by almost all of them. Closed questions were used sparingly and it was assumed that worksheet and textbook instructions would be read and followed. Emphasis on the use of questions to regulate and control was replaced with questions designed to engage and stimulate thought.

Several specific techniques were also used to encourage greater participation by girls in question-and-answer sessions and to utilise their strengths.

Individual whiteboards

"Show me" boards were used at all levels to encourage all pupils to think about a topic and to produce a brief written response to a question. The written response was then displayed just to the teacher. This activity enabled teachers to gain an overview of the class as well as an understanding of individuals. Pupils were able to respond without the worry that an incorrect or partial answer would be exposed. Girls particularly liked this approach and sometimes used the boards to communicate their concerns as well as answers.

Group response

Tables or small groups of pupils were asked to discuss a question briefly or to apply a principle and come up with a joint response. This lowered the stakes for individuals and encouraged the more diffident pupils to contribute or respond on behalf of others.

Articulation games

Many learning games are now available in published form or on the Internet. Some of them, called articulation games, require pupils to explain terms, processes or principles to others who must then guess what is being described. These games appeared to be particularly successful in mixed groups, with boys often having to be more thoughtful and girls more confident in their articulation.

Good questioning techniques are effective for all pupils, but the current shift away from rapid-fire closed questions towards those that require a more open and extended response is likely to benefit girls in particular. The research findings and guidance given in King's College London "Black Box" publications[6] are universally applicable but may be very relevant in the context of girls and physics.

Individual whiteboards are available and frequently used during lessons. Sometimes they are used to provide the teacher with an overview of pupils' recall of information or for quick calculations. On other occasions pupils are asked to respond to more open questions, such as "What do you think will happen if..." All pupils seem to enjoy using the boards but girls do particularly. "I always have a go because I know if I get it wrong nobody else knows and I can wipe the board clean anyway." Sometimes the teacher asks groups to discuss their response and nominates individuals to explain the group answer.

Messages for practice

- Decrease the use of hands-up, closed, rapid-response questions.
- Encourage the view that there is not always a unique correct answer.
- Give pupils the privacy and confidence to take risks when answering questions.
- Try whiteboards for quick, individual responses.
- Invite group discussion with a spokesperson as a way of lowering the stakes and encouraging collaborative learning.

1.5 The use of language

Is there an unwitting gender bias in the use of language in physics and, if so, how can this be diminished?

Physics makes greater use of precise technical language and symbolic representation than the other science disci-

6. For example, *Working Inside the Black Box* King's College London 2002.

plines – probably than all other school subjects apart from mathematics. Most physics teachers are steeped in the use of, and sometimes the abuse of, this type of language. For example, it is not uncommon to hear "$V = IR$" used to denote Ohm's law. For many pupils – boys and girls – this use of language and symbols is mystifying and it reinforces the impression that the subject does not connect with their world. Teachers who "talk equations" at an early stage in physics education risk alienating many students – girls in particular – from the subject.

Pupils' responses to questionnaires as part of Ponchaud's investigation showed that they closely linked physics with mathematics from the start of KS4. Discussion with students revealed that they made this link not because of the use of numbers but because of the algebraic symbols and words used to represent concepts that they had not fully grasped.

> "It's all about remembering equations. I can work out the resistance of a wire but I don't know what it means."

Girls especially found that this was a problem because they felt unable to "ask questions about a word or equation" and so felt that their understanding was stalled. Teachers who only introduced equations once the underlying concepts were well established were able to keep girls' interest for longer. The use of technical language and equations out of context was greater in most of the mixed classes that were observed than in the girls-only groups. On the whole, boys appeared happy with the technical language and algebraic shorthand because their use conferred status. The boys responded to questions that were terse and often used similar language in reply. Many girls appeared uncomfortable with this form of communication and held back from responding, even when it was evident that their understanding was as good as that of many of the boys.

Teachers, both male and female, in the most successful schools made more sparing use of technical language, used terminology in context and avoided algebraic shorthand. They used everyday language wherever possible and, where terminology was needed, it was carefully defined and pupils' understanding was checked. Wherever possible, pupils were encouraged to use their own words to describe observations or properties, such as using "squeezability" instead of compression. The guiding principle was to establish ideas and concepts before the use of terminology or equations. Pupils were then encouraged to use the essential terms correctly and in context. This did not reduce the demand of the work. In fact, the more careful use of language was often more rigorous.

At the start of the lesson, electricity was introduced in an entirely non-technical way. Groups of pupils discuss questions such as "What is it about electricity that makes it so useful to us?"; "What happens when we turn a light switch off?"; "Why do we have to have a system of pylons and cables around the country?"; and "Why can't we store electricity?" The introduction of terms such as "current" and "voltage" were then viewed as useful and the link with energy transfer was clear. Boys wanted to "get on with making circuits" but the girls appreciated having a rationale for these activities.

In classes where the use of technical vocabulary was minimised there was often more discussion between girls about the work in hand. The removal of the perceived need to use jargon liberated the pupils and encouraged mutual support in learning. This led to questions being asked on behalf of a group in order to check the consensual view arrived at through discussion. Postponing the use of terminology until the ideas represented were well established encouraged girls to talk more about the work and to ask questions to aid their understanding.One girl put it:

> "If physics is relevant then we ought to be able to talk about it using normal language. I used not to ask questions because I didn't know how to put them – I didn't have the right words. [Teacher X] doesn't mind this and encourages us to have a go. If we use the wrong words [Teacher X] doesn't correct us or make us feel embarrassed."

Messages for practice

- Don't use non-essential technical language or formulae as a shorthand for the physical laws during the early stages of learning.
- Use pupils' own everyday language as far as possible and encourage them to do the same until concepts are well established.
- Ensure that essential terminology is clearly defined and used in context and that understanding is checked.
- Reinforce underlying physical principles first rather than starting with formulae.

1.6 The use of analogy and illustration

How can teachers help pupils – girls in particular – to have appropriate mental pictures of ideas in physics and how these relate to the observable world?

Given the abstract nature of physics, analogies and illustrations can frequently play a vital part in giving structure to pupils' learning. However, many teachers are cautious about using analogies, being aware that they have the potential to reinforce misconceptions. Illustrations are helpful only if they connect with pupils' experience and interests. Most teachers naturally use the analogies and illustrations that they found helpful and relevant during their own studies, but there is a danger that these are not appropriate for today's learners. Many of these depictions also have a gender bias, such as mechanical- or football-related illustrations. Some girls may be interested in football just as some boys may not, but it is important to use a range of illustrations to maximise the level of interest provoked.

> "I'm not interested in how Beckham bends a ball or what the acceleration of a Ferrari is – why should I be?"

Discussions with groups of girls showed that they were very keen to have mental pictures of concepts in physics and found it difficult when they were unable to. Electricity, gravity, momentum and heat were common examples of topics where mental images helped. When analogies were suggested or, better still, students were encouraged to think up their own, there seemed to be little danger that they would be taken too literally. 'It's a bit like...' was a phrase that was often used and found helpful.

> "I've got to have a picture of what things are like. I know that electricity in a wire isn't really like people passing sweets around a circle or a switchback ride but it helps me think about it."

Teachers in those schools that were most successful at recruiting girls made good use of illustration and were generally less worried than the others about the use of analogy. The initial use of analogies was seen as less hazardous than presenting girls in particular with a barrier to learning. Similarly, the use of people-related analogies and illustrations, as well as mechanical ones, was regarded as beneficial. Mr (or Ms) Coulomb going up a ski lift and down a slope appeared to help many pupils to understand the significance of energy in electric circuits.

Boys often experience a range of early, concrete preparations for physics, stemming from the use of toys and pursuits that remain very different from those used by girls. Discussion about textbooks and other learning materials revealed that many girls found resources for physics unhelpful. Typical complaints were: "They don't tell us what we need to know" and "You have to be interested in how things work to understand them." This factor may contribute to the success of some girls' schools because they make fewer assumptions about past absorption of physics concepts and instead recreate those experiences in the classroom through demonstration and practical work.

Messages for practice

- Make sure illustrations draw on the experience and interest of girls as well as boys. (A shower curtain that seems to "cling" in the shower does count as a common experience; bending the path of a football does not.)
- Be careful not to make excessive use of mechanistic illustrations, which may be outside the experience of girls.
- Avoid being overcautious about the use of analogies; some mental picture is usually better than none.
- Don't assume that the basics do not need demonstrating through practical work.

1.7 Relevance

What can teachers do to ensure that girls view physics as relevant to their lives?

There is a commonly held belief that subjects must be viewed as relevant by students in order to capture their interest. However, discussion with students both pre- and post-16 suggested that both girls' and boys' views of what constitutes relevance differ significantly, and often their ideas about relevance are not the same as their teachers' either. The term "relevant" was used by students in a variety of ways, including:

- linked to applications of science outside school;
- required for the fulfilment of career ambitions;
- overtly connected with the big issues of life;
- needed to support learning and develop understanding.

The boys' first response when asked about the relevance of physics was often to refer to applications or career ambitions. The girls were just as likely to respond in ways that showed that they were interested in big issues or in achieving mastery.

> "It is a logical subject and I like to try to see how all of it fits together – like a jigsaw. I used not to be able to see the point of it but our teachers are good at reminding about earlier topics and explaining how they can help us with what we are doing now."

At post-16 the girls usually only referred to career ambitions when implying that they were studying physics out of necessity rather than interest; utility was very seldom mentioned at all. Attempts to make physics relevant must take account of these different uses of language and the associated interests. From an early stage in formal education, physics is portrayed as objective and therefore often impersonal and dispassionate. By contrast, the essence of biology is the living world, so it is regarded as relating directly to individual lives and life issues. These perceptions are heightened by educational materials: illustrations in physics texts almost all show artefacts or laboratory equipment in diagrams. Similarly, the frequent use of graphs, numbers and rules confirms the view that physics is definitive rather than exploratory.

> "I like physics but don't like the books – they are dull. It's just information, charts, graphs and pictures of machines. They don't show anything of interest to me."

None of the departments that was visited attempted to obscure the essential differences between disciplines. Even the most successful girls' schools had not created "girly" physics. The approach was to show that physics operates as it does so it can be useful and make sense of the physical world. Physics was then more likely to be viewed as personally relevant and not sterile. The key appeared to be providing a rationale for the content rather than adjusting it to meet the perceived interests of girls.

At the start of a new topic on waves, pupils, in groups, are asked to think of as many different kinds of waves as they can. They are then asked to discuss what these have in common that makes them all waves and then what properties make the different types useful to us. Pupils are then able to see the reason for studying waves and how this could be useful.

Messages for practice

- Try to give pupils a glimpse of the "big picture" by reinforcing links between topics, key ideas and applications wherever possible.
- Try tackling first applications and then principles so that the rationale for studying a topic is clear throughout.
- Supplement standard texts with other reading material, such as articles or newspaper cuttings, to introduce the social relevance of physics.
- Use the Internet to introduce contemporary applications of physics.

2: Lessons from research

The authors of this section, Patricia Murphy and Elizabeth Whitelegg of the Open University, have more than 20 years' experience of carrying out research into gender and science and/or physics in primary and secondary schools. They have reviewed the available research literature to give an overview of current understanding about the issue and to establish the possible reasons why girls choose not to continue to study physics. Their review also aimed to identify what strategies have succeeded in increasing the number of girls studying physics post-16.

The two academics reviewed a variety of research literature, mainly published in 1990–2005 and UK-based. Research pre-dating 1990 was included in cases where there was little useful literature after this time or where earlier studies had important messages that were not replicated more recently. Research based outside the UK was included to compensate for the limitations of UK-based research but only if it was applicable in a UK context. The original brief for the review was to cover secondary, compulsory education. This remit was extended to include studies of post-16 physics because many of the pre-16 studies are concerned with science rather than physics.

This section presents the main findings that emerged, from the four different perspectives of the students, the curriculum, the teacher and assessment. In each case the findings are followed by advice about how they might apply in your context, and by practical suggestions for activities to help you to gather information and to take action using the evidence that you collect.

2.1 The student perspective[7]

Did you know?

Views of physics

- Many studies have found that students' interest in science is less at the beginning of secondary school than it is for other subjects. The decline in their interest in this subject becomes relatively greater by the end of secondary schooling.
- Recent surveys of students at the end of KS4 found that both boys and girls report negative comments about the relevance and appeal of chemistry and physics. Students report that they choose to study biology at A-level for interest and tend not to choose chemistry and physics for this reason.
- Girls in girls' schools show a stronger preference for science than girls in mixed schools, but only at the younger ages (KS3).
- Girls at KS4, including those who intended to continue to study science at A-level, reported more negative comments about physics than did boys and they also identified more topics that they considered not to be useful in the context of everyday life.
- Students vary in their goals for learning physics. Girls predominate in the group that studies physics to do good and to help people, preferring physics content that is related to social and human concerns.
- It is likely that the social contexts and human dilemmas that girls, more than boys, consider relevant and of value are underrepresented in the teaching of physics.

Influences on course choices

- Studies at KS4 and KS5 have found that enjoyment is important but is not a sufficient reason for students to decide to continue with their study of physics.
- Teachers and students rate career intentions as an important influence on students' choice of courses. However, students are not well informed about science-related careers.
- Prior achievement is another significant influence on students' course choices and may be more significant for girls than for boys.
- More girls than boys report a decline in their view of themselves as competent in physics as they go through secondary school. Boys are also more likely than girls to consider studying physics irrespective of their achievements in the subject.
- In the UK and elsewhere, gender is a significant factor in predicting students' take-up of physics. Boys are much more likely to study physics post-16 than girls.

Could this be happening in your school?

Some questions to consider:

- Do fewer girls than boys choose to study physics after the age of 16?
- Do fewer girls choose to study physics post-16 compared with other subjects?
- Is there a decline in the interest and enjoyment of physics for girls as they go through KS3 and KS4 in your school?
- Are girls more likely than boys to consider that they are not "good" at physics?
- If you are teaching girls only, do the girls rate physics as difficult compared with other science subjects?
- Do girls consider that physics lacks relevance to their current and future lives?

Why do you think this is the case? Do you base your views on:

- research?
- common sense?

7. The findings reported here are from sections 2 and 3 of Murphy and Whitelegg's report.

Table 2.1: Student questionnaire (extracted from appendix 4.2)

2. Please circle a number on the scales below to indicate your views about science

	Strongly agree				strongly disagree
I like science because it's interesting	1	2	3	4	5
I like science because I get to discuss issues that are important to me	1	2	3	4	5
I like science because it helps me to understand myself and the world	1	2	3	4	5

- analysis of performance?
- the experience of you and your colleagues?
- observation?

Has any action been taken to change the situation?

2.1a Finding out what is happening in your school

The strategies for finding out what is happening can be used in both mixed and single-sex school settings.

Student questionnaires

Simple but carefully designed questionnaires can help you to find out about students' views about physics. A rating questionnaire (e.g. appendix 4.2) provides useful data. It is also easy for students to respond to and for you to analyse. Table 2.1 shows how the scale is used.

The first questionnaire in appendix 4.2 is an example of a comparative questionnaire. Students are asked to rate:

- how much they are interested in different topics;
- how much they understand about different topics;
- how well they are doing in science;
- how well their teachers think they are doing in science.

Questions 4, 5 and 7 need not be complete as they stand; you can add topics to them. You can choose to list the main topics in the science curriculum for KS3 or KS4 so that you can find out students' comparative views of science topics (e.g. rocks and metals, waves in action, etc). It's a good idea to mix topics from the different subjects rather than to group, say, all biology topics. You could use a similar questionnaire to probe views about physics topics only. You need to decide what level of detail to describe the topics in. In deciding this, remember that a questionnaire such as this should take at most 20 minutes.

Students are also asked to comment specifically about physics in the questionnaire. (Note: when asked, many students do not know what physics is. They cannot differentiate between the subjects taught in Double Award Science, possibly because the distinctions are not made explicit.) The questionnaire asks students to:

- rate their agreement with other students' views about physics (you can change these statements to reflect your concerns and your students' comments);
- describe their experience of physics;
- rate their experience of physics.

You will have to decide when is a good time to use the questionnaire (i.e. at the beginning and end of a Key Stage or at the end of a year?). It will depend on the information that you want and what actions you hope it will inform. The introduction to the questionnaire can be altered to suit your students and your context but it is always good practice to set the scene for students so that they know your purpose in seeking their views.

You can use the answers that you receive to the questionnaires to identify some students to interview, either individually or in groups.

Probing students' perceptions of relevance

Research shows that students respond to topics that they believe are relevant to their interests. If you are using group interviews you might want to mix students with different interests to encourage a dialogue. This also helps them to appreciate that they might have different personal goals that influence what they see as relevant. In this way, students can learn about each other while you are finding out about how to plan better for their learning. To begin, choose a topic that was popular:

> "Lots of people rated 'X' as very interesting.
> What makes that topic interesting in your view?"

You will need to follow up the different reasons students give for why topics are relevant. You can get them to come to a consensus that you can record or, if they choose to disagree, be sure you know why.

You can continue to probe, selecting unpopular topics, etc until you feel that you have gained some useful insights into common views.

> "Lots of people rated 'Y' as very boring. What makes that topic boring in your view?"

Exploring students' self-concept

If you want to look at the self-concept that successful students have with regard to studying physics, you might want to group students who feel less confident. For example, it might help to put girls together. You must make clear to them that you want to improve their experience of science (physics especially) and that their responses are confidential.

To start the interview, perhaps use a questionnaire response from another student who has similar feelings about physics but who is not in the interview group. Make sure that you put the onus on the subject rather than the students when asking the questions (e.g. What is it about physics that would make this student feel like this do you think?). Again, try to get some consensus or agreed differences that you can record. Other good questions could include "What could we change about physics to make it more interesting and enjoyable?"; "What could we change about how it is taught that would support a student who feels like this?"; "Do you have any ideas?"

If you found a difference between girls and boys, or within groups of girls or boys, about the relevance of physics to their future careers, you could consider asking them why this is. For example:

- The questionnaire results showed that some boys thought physics was very relevant to their future careers but others did not. Why do you think this is?
- More girls than boys said that physics was not relevant to their careers. Why do you think they feel like this?

Student writing

Some students, particularly boys, will find it difficult to discuss how they feel about their learning in front of each other. Interviews also take time. You might want to set a simple writing task or to organise a group brainstorm session where the students develop a mind/concept map about their experience and views. Alternatively, you could explore what students consider to be their needs in physics and how to meet them or their wants (table 2.2). Their needs will stem from their ideas of what makes learning physics difficult and their wants from what could be done to make it easier, more enjoyable and more interesting. Often the ways that students' needs in physics are met reflects school structures and approach, and students' views may challenge these.

2.1b Taking action

Data from the questionnaires, interviews and students' writing will help you and your department to establish what, if any, differences exist between students in their interests and how these differences relate to their views of what is relevant to them. Relevance is a prerequisite for learning because it informs what we pay attention to, the value we give to things and the connections that we make between new learning and prior learning. Often we assume relevance rather than plan to teach it. If we do attempt to make physics relevant it is often from the perspective of the subject rather than of the students.

2.1c Planning for students' different interests

Analysing topics and their common examples

Topics in physics often start with the knowledge and applications come later. Consequently, when students first meet a topic they tend not to know why it is useful knowledge. Some students, particularly girls, lack the out-of-school experiences to appreciate the relevance of this new knowledge. As part of your planning for a topic, you could consider how students ranked its interest. If this is problematic, plan in advance how to connect the topic to contexts and situations that are common to all students.

Involving students

It is useful to explore students' initial understanding of a physics topic – not the abstract scientific knowledge but their views about what it relates to in the real world and what the point of it is. For example, why do they think that they are learning about the properties of radioactive materials? To understand how to manage radioactive waste and be able to take an informed view about power production costs? So that they can be informed about how radioactive materials are used in medical treatments? Or is the purpose not explicit beyond the need to answer examination questions? You could use the task below, or a version of it, to explore students' understanding of the purpose of learning physics.

Table 2.2: Designing a better learning experience

Needs	Wants
e.g. more time to get into a topic	e.g. project-based work

Task

Write a short paragraph for a student in this class explaining the point of learning about "X". Think about how the topic will help them:

- in school;
- outside school;
- in the future.

These paragraphs could be discussed in a group followed by a short plenary in which you can help students to see the connections between their planned physics learning, their concerns and world concerns. The more connections you can make, the more students will be able to engage with the topic and the richer their learning will be. Record the plenary discussion in a mind/concept map to make it explicit for students and so that you can refer back to it as you work through the different parts of the topic. This activity fits well with the recommendations for starter activities in the National Secondary Strategy for School Improvement. It makes explicit the planned learning objectives and allows students to link their current objectives to their past learning.

Consolidating learning

The mind/concept map from the earlier activity can be revisited at the end of a topic as part of formative assessment in which students consider what they have and have not learned. Remember that the focus is on understanding the function of the knowledge and its value rather than the knowledge itself. You could use the traffic-light technique to get a sense of how students experienced the topic and what purposes they felt were emphasised and supported. This requires students to highlight each aspect of the topics using the traffic-light colours. Red indicates no understanding of the function and purpose of the knowledge; green means that the function and purpose was understood well; and amber denotes partial understanding.

Table 2.3: Teachers' preconceptions about students' achievements

Topic	Girls					Boys				
How difficult do students find, e.g.	very			not at all		very			not at all	
electric circuits and symbols	1	2	3	4	5	1	2	3	4	5

2.1d Reviewing action taken

A questionnaire with a five point scale, (e.g. appendix 4.2) can be used to monitor the impact of intervening to change girls' experience of physics. If you have attempted change, you could re-administer the questionnaire to find out if students' views have shifted.

2.2 The curriculum perspective[8]

Did you know?

Curriculum relevance

- Gender-determined notions about the personal relevance of physics lessons also influence feelings of competence. Perceptions about relevance cause students to choose to, or to feel able to, engage with learning and they therefore influence what they are able to learn. For example, some boys will avoid activities about health and domestic situations while others will approach them tentatively. Some girls will avoid activities featuring machinery if the emphasis is on mechanics and the purpose is not socially relevant (e.g. health and safety).
- What boys, more than girls, pay attention to and feel competent in is generally valued and judged to be relevant in physics.
- Differences in perceptions of relevance also affect the problems that students identify. Girls are more likely than boys to give value to the social context in which activities are set; boys are more likely than girls not to focus on the context.
- A UK study of A-level physics teachers reported that girls found electrical circuits, electromagnetism and mechanics more difficult than boys did. Mathematics teachers agreed about mechanics being more difficult for girls. Boys and girls in the study considered that they were equally successful across all topics.

Curriculum interventions

- Curriculum changes that increase girls' engagement and achievement in physics have no detrimental effect on boys' overall achievement and in some cases they have improved all students' performance.
- Some students, particularly some boys, reject these curriculum changes because they have learned not to pay attention to social contextual issues and feel disadvantaged when required to do so.

8. The findings reported here come from the section 3 of Murphy and Whitelegg's report.

Could this be happening in your school?

Some questions to consider:

- Do you think that there are physics topics or aspects of physics that are more difficult for girls than boys?
- Do students differ in what they believe they are good at in physics?
- Is this affecting how they engage with topics in physics?
- Are there gender differences in test results for these topics; for which girls and which boys?

2.2a Finding out what is happening in your school

Student questionnaires

If you used question 4 in the first questionnaire in appendix 4.2, you will have information at topic level about students' views of how well they understand topics.

Teacher questionnaire

You might want to examine other teachers' as well as your own preconceptions about the achievement of students in physics. To do this, you could list the topics in your student questionnaire on a single side of A4 paper and then ask colleagues to rate how well they consider that girls overall, and boys overall, do in relation to them. Use two columns side by side (table 2.3). If you are working in a single-sex school, you can still use such a questionnaire but use only one column. You could use the following open-ended question after the list to find out colleagues' reasons for their views. What do you base your views on?

- research
- analysis of performance
- experience
- observation

You could follow up this questionnaire with interviews to probe colleagues' views and the basis for them.

Observations

You can use an observation schedule to consider:

- how girls and boys approach tasks and if there is a gender effect;
- how well students understand the physics tasks through their engagement with the tasks.

What you plan to observe will vary, depending on the type of school that you are in and what questions you want to explore. It is useful to set yourself a specific period of the lesson for observing. You might want to observe overall behaviours:

- If you allow students to choose their groups, what groupings do they prefer?
- If you select groups, which arrangements are the most successful?
- If it is practical work, which students collect equipment? How was this decided?
- If there is a planning element to the activity, are the

Table 2.4: Record of observations

Time	Activity	Name	Comment	Teacher intervention
10.15 a.m.	Planning the investigation, what to measure.	Group A Student X	Help needed about how to start.	Asked them to think first about what they were trying to find out and what kind of measurements they would need.
10.20 a.m.			Lauren recording...group still not in agreement about what they are trying to find out. Adam dictating to Lauren, Siobhan intervenes.	Ask them what the problem is – what they can't agree about? Seems to be a disagreement between the girls and Adam.

students engaging together in making plans? Are there any students not engaged in this? Which students? Which student is responsible for recording decisions?

- As you continue with your observations, which students do you judge to be doing well and what are your reasons for this judgement? Is it borne out in the final outcomes?

You might want to look at a few groups, in particular where you plan to interact with students to understand better what you observe.

- How quickly does the group make sense of the task?
- Which groups take longer to get started and is there a gender effect?
- Which groups seek help and for what reasons?
- Which students do not seek help but remain unclear about the task?
- If you interact with groups at this point, find out if students feel they don't understand or can't do this activity and ask their reasons for thinking this.

If you are in a mixed school you can set up a simple recording sheet to track and record your observations (table 2.4), using separate sheets for girls and boys.

2.2b Taking action

Comparing perceptions of difficulty and performance

You can use the findings from the student and teacher questionnaires to compare perceptions. If you used a teacher questionnaire, what overlaps are there between colleagues, what differences are there and what informs these differences? If you have used both student and teacher questionnaires you could compare:

- Boys' and girls' expressed interests with their views about difficulty.
  — Is there any pattern to girls' responses?
- Students' views with teachers' views.
- Teachers' views with test results from end-of-topic tests, homework marks, etc.
- Teachers' views with SAT physics question scores.
  — Are there any gender differences in views of difficulty by topic and does this correspond to actual performance?
  — Is there anything about the test questions or homework that might help to explain any gender differences in performance?

Involving colleagues

If you had data from colleagues, you might want to discuss your results with them. You could also talk about the implications for students and for their teaching, including reasons for students' and teachers' assumptions about areas of difficulty. If there is evidence of a match between perceived difficulty – from either teachers or students – and lower performance you might want to consider the reasons. For example, consider the questions and homework tasks used in terms of their content, context and purposes.

Organising groups

If you have varied your grouping practice:

- Which grouping policy was the most successful in terms of students' task activity, and amount and quality of work done?
- Was the same grouping policy as successful for all girls and all boys?

If you have not tried different grouping practices, use your observations and interactions with students to help you to decide on some alternative strategies.

Organising equipment collection

If you did observe that some students, perhaps among the girls, had difficulty getting to equipment, change how you organise equipment collection. You could allocate a colour, number or letter (make sure that they are clearly not related to ability) to groups and then get the students to collect their equipment in order, changing the rota periodically.

Roles in groups

If you noted that students adopt certain roles, you could assign roles that change from topic to topic. Consider the following roles:

- spokesperson
- planning scribe
- discussion chair
- equipment collector

- measurement taker
- data recorder

You may need to consider whether all students will feel confident in the different roles. You could introduce a mentoring scheme, where a student takes responsibility for handing over a role and supporting another student.

Supporting learning in groups
If you noted your own or colleagues' interventions during your observations with students, you could reflect on these to consider the characteristics of effective interactions and the students that they work for. Look at your notes:

- Which interventions were successful?
- What were the characteristics of successful interactions (i.e. what was their purpose and content)?
- What roles did they place the student in, in relation to the teacher (follower of instructions, decision maker)?
- What kind of help did you have to give with planning and executing the activity?
- Did the help differ for boys and girls?
- Were some interventions more effective with boys or girls, or with some girls?

Taking account of students' views of tasks
In your observations you may have noticed that students differed in the sense that they made of the tasks that you set. If you noticed differences, you might begin an investigation or experiment by talking through a planning activity with the whole class. In the discussion:

- encourage students to offer ways of tackling the task rather than settling quickly on the "right" approach;
- ask students first to state their understanding of the task (i.e. what it is they are finding out for what purpose) and then to describe their approach;
- critique the approach in relation to the students' task and purpose;
- explain the task and purpose you have in mind and the reasons for this focus.

In this way, students' different ideas can be expressed and validated at the same time as helping them to see why physics tasks have particular purposes and approaches. Students' perceptions about tasks might offer you some ideas for alternative tasks and approaches that broaden their experience of physics and extend their access to it.

2.3 The teacher perspective[9]

Did you know?

Teacher–student relationships

- A major influence on students' attitudes to physics is the teacher-student relationship, particularly for girls. A positive attitude is associated with a supportive personal relationship.
- Students value strong leadership, friendliness and understanding in their teachers but they are more likely to experience these qualities in subjects other than science and maths. Large classes are not conducive to positive teacher–student relationships.
- Evidence from research shows that girls still receive less teacher attention in science classes than boys. Teachers are more likely to allow boys to dominate discussion as a means of controlling their behaviour.
- Girls are more likely than boys to receive feedback on the quality of their work rather than on their behaviour. Boys receive more than girls – positive and negative. Negative feedback is typically about boys' behaviour.
- This difference in feedback has been associated with girls' tendency to underestimate their achievements in physics and science relative to boys. Teachers reported that they were not aware of differences in their treatment of girls and boys.
- Teachers' beliefs about student abilities have a significant affect on how students view their own abilities. There is evidence that teachers have lower expectations of girls in physics, even those girls who continue to study physics post-16.

Teaching strategies

- Students, particularly girls, value teaching approaches that give them responsibility for their learning, and the chance to make decisions and think for themselves.
- Teaching strategies associated with increased motivation and achievement for girls and that also maintain and enhance boys' achievements include investigative practical work; problem solving and project-based activities; and group and class discussion that gives value to alternative views and approaches to tasks.
- Girls are particularly responsive to collaborative group work when the teacher manages the roles carefully.
- Single-sex groups can have a positive effect on students' views about their ability in physics and their take-up of physics courses. However, if single-sex teaching is to be effective, research shows that teachers need to be aware of gender issues and committed to gender-inclusive teaching. Otherwise, it is possible that single-sex groupings will have little, or even a detrimental, effect.

Could this be happening in your school?
Some questions to consider:

- Do you consider that physics classrooms in your

9. The findings referred to here come from sections 4 and 5 of Murphy and Whitelegg's report.

school are less supportive of students than other subject classrooms?
- Do you think that girls in physics classrooms receive less attention than the boys? What are the reasons for this?
- Are there differences in the type of attention that girls and boys receive? Why might this be the case?
- Do teachers have lower expectations of girls relative to boys in physics?
- In your opinion, do girls and boys learn differently? Does this affect the type of feedback that you give to students and how you interact with them?
- Do you allow opportunities for collaborative learning between students?
- Do students get opportunities to research their own ideas and take responsibility for their learning?
- Do you think that there might be advantages to students learning physics in single-sex groupings?

2.3a Finding out what is happening in your school

The following activities are suggested mainly for use in mixed settings but some, such as the first one and the activity with colleagues, would be informative for all school contexts.

Student questionnaire

Questions 7 and 8 in the questionnaire in appendix 4.2 will help you to get information about how students experience physics. In section 2.1 we also recommended using simple writing tasks, with students brainstorming in groups about what they felt their needs were and how these could be met. If you did these activities, check what the students said about the teacher and what makes them feel supported. If you didn't, you could try them now.

Another simple questionnaire is shown in table 2.5. It can be completed by individuals and should only take minutes. You could use a five-point rating scale, such as that in appendix 4.2. The phrases can be supplemented or changed by using statements made by your own students about the activities mentioned in section 2.1. We have referred to "a physics teacher" but in some contexts you might replace this with "a science teacher", because research shows that many secondary-school students have only a vague notion about what physics is.

Teacher questionnaire

This activity is intended for use in mixed-school settings but understanding teachers' beliefs about girls in relation to boys is useful for everyone who teaches physics to girls. You might want to find out whether colleagues' expectations of girls are lower than their expectations of boys, and their reasons for thinking this. If you used the teacher questionnaire in table 2.3 you will know what topics colleagues think are more difficult for girls, and for girls relative to boys. If you didn't use the questionnaire you might like to use it now. To determine teacher expectations, think about adding to this information using another simple questionnaire. You might want to involve just physics teachers, including colleagues from biology, chemistry and maths. The behaviours listed are just suggestions; you may wish to add to or amend them.

Let colleagues know that you are interested in their views about how girls and boys get on in physics. A possible introduction is given in table 2.6. You could follow up this questionnaire with interviews to probe colleagues' views and the basis for them.

Table 2.5: Student questionnaire

We are interested in what you think makes a good physics teacher.

1. The statements below are things that other students have said. Look at the statements below and underline those that you agree with:

A good physics teacher:
knows lots about physics
allows us to talk through our ideas
keeps good control of the class
makes physics interesting
gives us regular tests
gives us time to think about ideas before moving on
keeps the pressure up so we do well in exams
has a good sense of humour
doesn't allow talking
helps us understand the importance of physics
doesn't allow people to muck about
expects us to know the right answers quickly
lets us work in groups we choose
doesn't shout
helps you when you don't understand
lets us do practical work
is fair and gives us all a chance to answer

2. What, in your view, is the most important thing a teacher needs to be like to help you learn physics?
....
....
....
....
....
....

Observations

To investigate whether there is a difference in the amount and type of feedback that students receive and whether this affects their engagement in physics, you need to observe what goes on in classrooms. You might observe a colleague or video one of your own lessons. Whatever you decide, you or a colleague can use field notes or an observation schedule, such as in table 2.4, to make a record.

Teacher questioning

Think about what part of a lesson you want observed. For

Table 2.6: Teacher questionnaire

The questions ask you (i) whether you believe some behaviours are more typical of girls than boys, and vice versa; and (ii) whether girls and boys differ in how well they do in physics. Circle the extent to which you agree with the following statements. If you feel that girls and boys are equally good or poor in a particular respect, circle the positive or negative end of the scale for both; differences in behaviours should show up in the difference between the scores.

Behaviour			**Girls**					**Boys**		
Which students:	*very*				*not at all*	*very*				*not at all*
answer questions in whole class sessions?	1	2	3	4	5	1	2	3	4	5
find physics interesting?	1	2	3	4	5	1	2	3	4	5
do the best coursework?	1	2	3	4	5	1	2	3	4	5
are the most confident in discussion?	1	2	3	4	5	1	2	3	4	5
are the most diligent in doing homework?	1	2	3	4	5	1	2	3	4	5
enjoy physics?	1	2	3	4	5	1	2	3	4	5
tend to do the writing up carefully?	1	2	3	4	5	1	2	3	4	5
find physics easy?	1	2	3	4	5	1	2	3	4	5
ask for help in practical work?	1	2	3	4	5	1	2	3	4	5
are likely to want to continue with physics?	1	2	3	4	5	1	2	3	4	5

example, you might select the introduction and starter activity and the plenary if you are interested in feedback in a whole-class situation. You might in one observation session focus mainly on the questioning technique:

- Are students selected to answer questions?
- Who has their hands up?
- Which students are asked questions by selection or because their hands are up? Check if it is a girl or a boy and how many times any individual student is asked.
- Are there students who had their hands up but gave up?
- Which students are not involved in the question-and-answer sessions?

Teacher feedback

In another session you might want to consider the type of feedback given. This could involve observing whole-class question-and-answer sessions where you consider:

- What types of question are asked of which students?
- How long are students given to respond?
- What kinds of feedback are students receiving – think of the length of the interaction, content and purpose.

To extend this exercise, you could observe a few groups of students as they continue with their work. Focus on the teacher–student interactions. Consider:

- which students seek help;
- which students don't;
- what kind of help they seek;
- what kind of interaction follows – note the content and purpose of the interaction;
- which students are challenged to reflect on their thinking and take responsibility for the next step;
- which students are told what to do – note whether girls or boys are involved in each type of interaction;
- which students the teacher chooses to interact with – is this about their work or their behaviour?

Collaboration between students

You could use observation as a way of investigating students' approaches to learning. Feedback from the questionnaire about what makes a good physics teacher may provide insights into which students valued discussion and collaboration. When students are set individual tasks, leave a tape recorder recording on tables with either mixed or single-sex groups. Record 10–15 minutes of the session.

- Which students tend to talk together?
- Which students discuss their work during their talk?
- Do some students talk out loud about their work as they attempt it? Are they girls and boys or mainly girls?
- Is there more collaboration on tasks in single-sex groups? Is this the case for girls and boys?

2.3b Taking action

The feedback from the activities will provide you with information to reflect on your practice. You might want to try some interventions to change practice.

Encouraging collaboration

Some practices, such as organising more group work, need to pay attention to the roles that different students tend to avoid or embrace. Advice given in sections 2.2 and 2.4 ("Taking action") will help here. Your observations will have indicated which students tend to collaborate and which avoid it. You might usefully discuss with the class, or let groups discuss together, the rules needed to ensure collaboration. These will include:

- listening carefully to one another;

- giving space for people to say what they think;
- together considering the merits and limitations of each suggestion;
- making these explicit so that shared understanding can be achieved.

You have an important role to play too because you must:

- set tasks needing joint discussion and decision making;
- monitor the progress in groups so that students continue on a productive path;
- help students to reflect on their thinking;
- offer possible ways forward but not instructions;
- help to deal with conflicts of views.

Changing questioning techniques and feedback
You will be aware from your observations about any gender differences in your questioning technique. To change these you could use techniques such as:

- limiting hands-up questioning sessions and selecting students yourself, paying attention to ask both boys and girls, and different boys and girls, across a topic.
- introducing "wait time" (i.e. a set time for students to reflect on the question so that they know that they are not under pressure to know the right answer).
- giving challenges to to take their thinking further.
- involving students in generating "good" questions for a specific topic.

You will need to involve students in these changes because they have learned certain ways of behaving in your class and will need to understand the reason for change.

Another useful way of changing your feedback for students is to encourage peer assessment. Organise students to work in groups with a spokesperson elected to report back to the whole class. In the plenary session, allocate responsibility to each group to comment on another group's presentation by identifying two things that were good about it and two that could be improved. In this way you can gradually change the style of feedback while giving students more responsibility for their own learning.

2.3c Changing expectations
You or your colleagues may have particular beliefs about girls and physics, including the belief that girls struggle with physics more than boys. Many of the activities suggested in this report will help you and your colleagues to see that this often has little to do with girls' potential to achieve in physics. Through changing practices, it is likely that views about girls' performance will also change.

2.4 The assessment perspective[10]
Did you know?

Patterns of entry and performance
- Fewer girls are entered for the Higher Tier papers in maths at KS3 and KS4, limiting their access to the top grades relative to boys.
- There is some evidence that teachers in girls' schools have greater expectations of girls than do teachers in mixed schools. Girls in girls' schools are more likely to be entered for the Higher Tiers in KS3 maths and science tests.
- In mixed schools, far fewer girls are entered for Triple Award Science than boys. Girls in girls' schools are equally likely to be entered for Triple Award Physics as boys in mixed schools.
- In England and Wales, girls' performance relative to boys' is lower across the pass grades and in the top A* and A grades. This is not the case in Scotland and Eire.
- Girls slightly outperform boys in Double Award Science GCSE. However, there is evidence that boys achieve at a higher level in the physics components of both the Higher and the Foundation papers.

Question effects
- The type of response formats used in tests and exam questions can alter what is being assessed in physics. Girls' performance may be lower in multiple-choice formats compared with questions that ask for a short, free response. Boys appear to do equally well on both.
- Questions in physics are often set around objects that are less familiar to girls, such as those about the speed of bikes.
- Girls are more likely to notice the context of a question than boys and this can make it less likely that they will give the "correct" answer, such as whether a bike is being ridden in a competition or with friends going to school.
- There is evidence, too, that girls' performance relative to that of boys is poorer on questions involving graphs or figures and requiring the same form of response.
- Teachers report that girls are advantaged by coursework assessment in science compared with boys. Overall, girls achieve higher coursework scores in Double Award Science than boys. However, evidence suggests that coursework scores have a greater effect on the grade distributions of boys than girls.
- Curriculum interventions to enhance girls' access to, and achievements in, physics tend only to be successful if they are accompanied by corresponding changes in the forms of assessments used and the range of achievements assessed.

Could this be happening in your school?
Some questions to consider:

- If you offer Triple Award Science, at GCSE are roughly equal numbers of girls and boys entered for it?
- If you offer Triple Award Science in a girls' school, which girls are entered and which girls aren't?
- Is there a gender difference affecting entries to the Higher Tier of Double Award Science?

10. The findings referred to here come from sections 6 and 7 of Murphy and Whitelegg's report.

- Is there a relationship between the students entered for the Higher Tier paper in GCSE science and GCSE physics and those entered for that in maths?
- Is entry to Higher Tiers in science and maths at KS3 equivalent for girls and boys?
- Which girls tend not to be entered for the Higher paper?
- Is there a gender difference in performance in the components of science in combined science at KS3 and GCSE?
- If girls' performance is poorer in physics questions compared with other science questions, is this related to features of the questions other than what is intended to be assessed?

2.4a Finding out what's happening in your school

Analysing test and examination data

Schools routinely collect examination and test data. To consider the questions above you need to examine entry patterns by tier of paper and by gender in physics, maths and science, as appropriate. There are two important issues to consider:

- actual achievements in relation to predicted achievements;
- achievements over time: KS2 → KS3 →KS4.

Predicted versus actual achievement

Consider first who is being entered for what paper. Is there any difference in entry patterns at KS3 and KS4 for girls and boys? Which students achieved better than expected/ lower than expected? Is there a gender dimension to this? You could ask your colleagues in maths if you can have data about entry patterns to the three papers. You might want to look at individual students to consider if there is any relationship between entry in physics and mathematics. For teachers in mixed schools:

- Are more girls than boys entered for the Intermediate paper and more boys than girls entered for the Higher and Foundation papers in maths?

In girls-only schools:

- Are there subgroups of girls who tend to be allocated to the Intermediate and Foundation papers?
- Is there a relationship across science and maths in entry patterns for particular girls and for girls relative to boys?

Does your department and/or school routinely consider predicted grades versus actual grades at GCSE? How many students achieved the top grade in the Foundation science paper and what are the proportions of girls and boys achieving this grade? Might these students have achieved a similar level or higher if entered for the Higher paper (i.e. was there a ceiling effect on these students?). Which students are achieving lower than a C grade in the Higher paper? Which students – girls or boys – achieved the top grades A*–B and how many of these are continuing with their study of science? Is there a tendency for more boys with lower grades than girls to continue their study of physics?

Achievement over time

You could collect data about individual students from their entry levels at KS2; from their allocated sets at KS3; from the SAT papers that they are entered for and the levels achieved; and from the consequences for their set allocation in KS4. If you already have these data, you could look at a small sample of students across year-10 groups to consider how the school's use of assessment data and school structures, such as the setting, may be channelling some students away from learning physics early on in their secondary education.

Examining performance in physics

There are a number of investigations that you could undertake, as an individual or as a department, involving both students and colleagues.

Question format

An investigation into question formats used in tests could involve students in a formative assessment activity. You could select a small number of physics multiple-choice items from texts and SAT papers. Organise students to work in groups. Choose the spokesperson for the class discussion but make it clear that what is to be agreed is the group's responsibility.

Task

- The purpose of the task is to explore how you go about answering questions, not the answers themselves.
- Read the questions carefully; answer one at a time.
- When everyone has finished, talk through your thinking together (i.e. how you decided to reject certain options and came to choose another).
- If you felt that you couldn't answer a particular question, what did you think the question was about?
- Together agree the main things that group members wanted to say about each question.

You could use a whiteboard to summarise the group presentations. To avoid an overlap in presentations, ask the groups to report back about certain questions but then invite all groups to consider whether they agree with what has been said and if they have any views to add. You need to think about:

- what students pay attention to in questions;
- whether this created barriers for them in understanding what the answer was;
- what differences there were between girls and boys in what features of questions they pay attention to.

You could repeat this activity using a multiple-choice response and short, free response physics questions.

Content and context effects

To explore content effects (i.e. what the question is about, such as balancing a see-saw, rather than the concept intended to be assessed, such as moments), it might be wise to avoid a multiple-choice format. A content effect is usually noted by non-response (i.e. students believe that they can't answer the question). Select a number of questions that assess the same concept/topic but use content that would be familiar more to boys than to girls and vice versa. Also select some questions with content that might be equally familiar to both boys and girls.

This selection of questions could be addressed with colleagues as part of a professional development activity. You could circulate a couple of past SAT and exam papers and ask them to fill in a simple grid (table 2.7a). Use this to select the questions and organise students in groups. Ask students to look at all of the questions carefully and to fill in a simple grid (table 2.7b). Analyse the grids for differences among girls, and differences between girls and boys. Is there a content effect? Does it link to differences in students' views about what topics are of interest and relevant to them (section 2.1). How do the students' responses compare with colleagues' views?

Graphical content and response

Research shows that girls are more likely than boys to have difficulty responding to questions with two-dimensional diagrams, three-dimensional phenomena and graphical data requiring a graphical response. You could select questions with this type of data representation and ask students to fill in a grid like that in table 2.7b. In your analysis, look for differences among girls as a group and between girls and boys.

2.4c Taking action

Teachers' predictions and students' progress

If you have looked at relationships between entry and achievement data you may have insights into your own entry decisions. The next step is to discuss colleagues' decision making and what influences it. You could use the findings reported in this section with your own data to explore whether expectations of colleagues differ for girls relative to boys or for particular girls compared with others. Is this a phenomenon associated with physics or does it occur in other science subjects and maths? Is this backed up by achievement outcomes? You may want to circulate national figures among colleagues to set the departmental results in context.

At this stage you may want to put in place plans to allocate some resources to extend data collection and analysis for annual monitoring so that predicted and actual achievement are routinely examined.

If you have begun to collect data over time for the same student, you may want to follow up your views about whether there are school and departmental organisational structures that limit individual progress. You could take this further by setting a simple questionnaire for colleagues. You might ask physics colleagues the following:

- How satisfactory do you consider the data to be that are used to group students for physics?
- What additional data do you consider necessary?
- How satisfactory do you find the current grouping policy in KS3 in catering for individual progress over time?
- How satisfactory do you find the current grouping policy in KS4 in catering for individual progress?
- What concerns do you have about the current grouping system at KS3 and KS4?
- What would you like to see done differently?

Questions could have a five-point scale, such as that used in appendix 4.2. You could ask the same questions of colleagues teaching chemistry, biology and mathematics, although you may need to establish first what the grouping policies are in their subjects.

Question effects

Do you routinely use a multiple-choice response format in tests? Have you considered trying different formats (e.g. the short structured free response typically used in SATs and GCSEs) for end-of-topic tests to see if there are any differences in girls' scores and in girls' scores relative to boys'?

To explore question characteristics with colleagues, provide them with a grid[11] (e.g. table 2.8), which can be used to analyse existing physics questions. Note that the grid is about the characteristics of questions, not the criteria being assessed. It allows colleagues to discuss what characteristics are most common in physics test and examination questions and which types of question could be developed to extend girls' access and to broaden the experience of physics. You could present some of your findings as part of

Table 2.7a: Teacher grid: question content and context effects

Question number	more familiar to girls than boys	more familiar to boys than girls	equally familiar
1			
2			
3			
etc			

Table 2.7b: Student grid: question content and context effects

Question number	confident can answer	less confident can answer	wouldn't attempt	reasons
1				
2				
3				
etc				

Table 2.8: Analysing existing physics questions

Things to look for	Oriented towards boys	Oriented towards girls	Apparently neutral	Gender inclusive
Content	more relevant to boys' out of school experience	more relevant to girls' out of school experience	abstract, no links to everyday experiences	equally relevant to boys and girls
Format	multiple-choice/short free response/graphical	short free response	short free response/ graphical	no format dominating, balance towards short free response
Context	abstract, decontextualised	human, social problem situations	concrete/human experiences (e.g. boys and girls in tug of war)	covers a range of personal and social and environmental situations

11. Adapted from L Rennie and L Parker (1993 Assessment in Physics: urther exploration of the implications of item context *The Australian Science Teachers Journal* December **39 (4)** 28–32.

a discussion about how to take action in the department, which will overlap with the action planned to extend the relevance and interest of physics (section 2.1). In an assessment context, the issue is to help students to see what the question is assessing (i.e. the physics rather than the specific question characteristic). Helping students to deal with content effects could become part of revision sessions.

Question format
You can use a summary of the key points about what students pay attention to in their responses to questions to initiate a whole-class discussion. It is important to include in this summary the reasons why some students felt unable to respond to certain questions. It may be that the class discussion reveals ambiguity in the question and the multiple-choice options or mark scheme, which can be usefully discussed. The more girls who are helped to learn how to interpret ambiguity, and what they should or shouldn't pay attention to, the less likely it is that the question response format will act as a barrier to their demonstrating their achievements in physics.

Content and context effects
You could involve students by summarising the grid responses and identifying some representative questions. In choosing questions, select some that girls felt confident about answering and some that they didn't. Select the same for boys, as well as some questions that girls and boys felt equally able to tackle. If you are in a girls' school you can select the questions that revealed differences between girls in their perceptions of competence. Organise the students into discussion groups and nominate a spokesperson. Provide the students with the questions, how they were categorised and some of the main reasons given for the categorisation.

Task
In your groups, examine the questions, the categorisation (i.e. whether they were questions that girls or boys felt more confident about answering and the reasons for this). Discuss:

- what the question is assessing
- what you need to know to answer such a question
- the reasons given for the way that students responded to the question

Make notes of your views, including those you agree on and any differences of opinion.

Get the students to report back. Use the approach to handling feedback that was suggested earlier. You can then use whole-class discussion to make explicit what the barriers were for students and how to read beyond the content to the physics being assessed.

As a final part to the activity, you could ask the students to fill in the grids again and this will provide them and you with an indication of what they have learned. Data about the impact of an intervention are always useful if you want to get colleagues involved in taking an intervention further.

3: Lessons from videos

3.1 Introduction
Two videos have been made to illustrate the messages of the previous two chapters. *Saving Nellie* is a scripted drama that shows two teachers struggling to change their teaching to "save" their student Nellie's interest in physics. *Key Stage 3/4 Science: Girls in Physics* is a documentary featuring a real lesson covering similar content, which is rated for its girl-friendliness. The purpose of the programmes is:

- to present the important findings of research in an accessible and entertaining way, so that teachers remember key messages;
- to show teaching approaches that will promote effective learning of physics among all students, and to encourage girls to consider continuing with the subject;
- to stimulate discussion among teachers about their own practices;
- to encourage school departments to review their teaching and learning strategies.

3.2 Getting and using the videos
The programmes are available both through Teachers' TV (http://www.teachers.tv/) and as DVDs. (If you would like a copy of the DVD contact the education department at the Institute of Physics.) They can be watched by teachers, alone or in groups, for interest and hopefully enjoyment. It is suggested, however, that use of a structured discussion or seminar format with the programmes will ensure that the issues raised are more fully considered. Possible contexts for this include:

- a school departmental meeting;
- a local physics teachers meeting;
- a session in an ITE course.

Appendix 4.4 contains some exemplar notes that can be used to structure activities at the meeting and, as a follow-up, in departments and classrooms. Many of the suggestions are about understanding students' motivations and student–teacher relationships. Teachers may feel that some of the outcomes are a bit intangible. For this reason a further follow-up session for the group is recommended to find out how everyone fared.

3.3 Summary of programme content
Saving Nellie
Two "mature" physics teachers, Helen and Eric (Helen Baxindale and James Fleet), are asked to change their teaching to "save" student Nellie's interest in their subject. They devise five strategies or "five fab physics formulae":

- Make it relevant – how to ensure that students see the point of physics in general and the topic to be learned in particular; we see how appropriate language can help and premature use of formulae can be a barrier.
- Crowd buster – how to organise group work in the classroom, for discussion activities as well as for practical work;
- Ideas are king and queen – how to ensure that students' ideas are taken seriously by the teacher, to provide motivation and engagement;
- Know the students – how to assess their interests and confidence, their abilities and their motivation to study physics (or lack of it); all students need to feel that their teacher understands them in relation to their physics learning;
- Passionate physics – how can we expect students to care about the subject if the teachers don't appear to?

Eric and Helen attempt, with varying degrees of success, to implement these strategies during a lesson on mechanics with year-10 students. Nellie comments on the success of their strategies for her and other students.

The lesson opens with Eric writing a derivation of Newton's second law of motion on the whiteboard. At Helen's prompting he changes tack and asks about how his students travelled to school. When he tells Helen his belief that physics is hard and girls can't do it, she takes over the class and organises a group practical on moving cars. Eric now takes to a skateboard to make his physics relevant, but he has to learn how to change his questioning technique to show that he values his students' ideas.

Another lesson for the teachers to learn is that their students bring personal attributes to the lessons, and acknowledging these may make all the difference when trying to generate interest in the subject. As Nellie tells them,

> "We students are interested in those teachers who show they care about us."

Eric's contribution to the lesson reaches a dramatic finale with him showing that he cares for his fellow physicist Helen. He goes on to declare his passion for physics to the class: "It's everywhere!" At the end of this emotional lesson, they meet the real class teacher, Barry, who comments on their five fab physics formulae:

> "Oh! those. They're not new – the trick is remembering and applying them."

Key Stage 3/4 Science: Girls in Physics
This programme shows Barry teaching a similar lesson about mechanics, which illustrates the ways he implements good teaching practice that is inclusive. Barry discusses

his approaches to camera and an adviser from the Institute of Physics comments on the success of the lesson. Barry starts by asking the whole class the "How did you get to school today?" question. He then conducts a lesson in which he is rated by an unseen commentator on his application of the five fab physics formulae.

Step two in the lesson is the question "What happens when a car driver sees the brake lights come on in the car in front?" Barry asks groups (which he has arranged as all-boys and all-girls) to discuss the question and then report back. The concepts of thinking distance and braking distance emerge from the exercise. The former is illustrated with a reaction-time game in which selected students report back to the class on the interactive whiteboard. During the discussion of braking distance, Barry is shown to be open to students' ideas. This time the ideas are written on individual whiteboards so that the teacher can check the response of the whole class.

The class discussion of factors that might affect braking distance leads into a session of group practical work. Barry enjoys the moment when the students realise that he has anticipated where their discussion would lead – he has all of the equipment that they need. He explains his reasons for single-sex groups for this work. The lesson comes to an effective end when the conclusions of the class about how speed relates to stopping distance are found to challenge their initial predictions. Barry and the adviser both express satisfaction at the outcome of this "ambitious" lesson, while Barry acknowledges that there was some room for improvement.

4: Appendices

4.1 Analysis of take-up of physics post-16 by girls in a sample of 1500 schools

The OFSTED database was used to analyse by gender the 2002 AS-level physics entry and the 2003 A-level entry in a random sample of 1500 maintained secondary schools. The schools were ranked according to the proportion of the female cohort that was entered for physics and in mixed schools for the difference between the male and female entry in 2003.

Only 80 schools from this sample recruited 10% or more of their post-16 girl cohort to take A-level physics in 2003. Of these, 44 were girls' schools, 36 of which select by attainment; 10 had more than 20% of their cohort taking physics. Between them these schools accounted for 675 from a total of 3025 girls studying A-level physics; almost one-quarter of the total number of A-level physics entries for the sample.

Inspection judgements for KS4 in the sample of schools most successful at recruiting girls into physics show several distinctive characteristics. These are:

- high quality of teaching;
- teachers with good knowledge and understanding of science;
- effective planning;
- high expectations compared with other schools;
- good use of ongoing assessment;
- good acquisition of skills, as well as knowledge and understanding;
- high levels of pupils' interest, concentration and independence.

Inspection judgements for post-16 work are not significantly different from those made about other schools, although judgements at this level are generally more favourable.[12]

12. It should be noted that the inspection indicators used are for science and not specifically physics.

Reasons given by girls for taking/not taking physics post-16

Reasons for taking physics (ranked according to frequency given) are:

- enjoyment of physics pre-16;
- success in physics pre-16;
- style of teaching during KS4;
- enthusiasm and confidence of teachers of physics;
- physics needed for career.

Reasons for not taking physics (ranked as above):

- not needed for career;
- too mathematical;
- too hard a subject;
- not relevant;
- too much concentration on information (facts).

4.2 Exemplar questionnaires

A number of exemplar questionnaires follow.

Table 4.1: Student questionnaire on science

Science interests

We would like your help in planning the science teaching and learning in the school. This questionnaire asks what topics you find interesting in your science lessons. We would also like to know how well you think you are doing in your science learning. The questionnaire is confidential. We do not need to know your name. Most of the questions ask you to circle a number to show what your opinion is. Remember: it is your opinions we are interested in and your opinions matter, so please try to answer all of the questions.

1. Please complete the following:

female ☐ male ☐ science group: ....

About your views of science

2. Please circle a number on the scales below to indicate your views about science.

	strongly agree				strongly disagree
I like science because it's interesting	1	2	3	4	5
I like science because I get to discuss issues that are important to me	1	2	3	4	5
I like science because it helps me to understand myself and the world	1	2	3	4	5
I like science because it's relevant to my life	1	2	3	4	5
I like science because it's relevant to the kind of work that I want to do	1	2	3	4	5

3. Please circle a number on the scales below to indicate your agreement or disagreement with the statements about why people should study science.

People should study science because:	strongly agree				strongly disagree
it's important for the country's future wealth	1	2	3	4	5
it helps them to make better informed choices in life	1	2	3	4	5
it's important for the future of the environment	1	2	3	4	5

About your experiences of science in school

4. For this question we want you to circle a number to show how interesting you find different science topics and how much you think you understand them.

How interesting do you find, for example:	very much				not at all
how the heart works	1	2	3	4	5
light waves: reflection and refraction	1	2	3	4	5
rocks and metals	1	2	3	4	5
genetics	1	2	3	4	5
magnetic fields and electric motors	1	2	3	4	5
plant structure	1	2	3	4	5
chemical equations	1	2	3	4	5
the lifecycle of stars	1	2	3	4	5
fighting disease	1	2	3	4	5
polymers and plastics	1	2	3	4	5
circuit symbols and devices	1	2	3	4	5
respiration	1	2	3	4	5
the planets	1	2	3	4	5

Table 4.1: Student questionnaire on science (continued)

5. Indicate how much you think you understand about:

How interesting do you find, for example:	very much				not at all
how the heart works	1	2	3	4	5
light waves: reflection and refraction	1	2	3	4	5
rocks and metals	1	2	3	4	5
genetics	1	2	3	4	5
magnetic fields and electric motors	1	2	3	4	5
plant structure	1	2	3	4	5
chemical equations	1	2	3	4	5
the lifecycle of stars	1	2	3	4	5
fighting disease	1	2	3	4	5
polymers and plastics	1	2	3	4	5
circuit symbols and devices	1	2	3	4	5
respiration	1	2	3	4	5
the planets	1	2	3	4	5

6. Indicate how you think you are doing in science and how you think your teachers think you are doing.

	very good				very poor
How do you rate yourself in science	1	2	3	4	5
How does your teacher rate you in science	1	2	3	4	5

7. These are some statements that students say about physics. Please circle how much you agree or disagree with them.

	strongly agree		not sure		strongly disagree
Physics is very relevant to the work I want to do	1	2	3	4	5
I find physics very practical but it is boring	1	2	3	4	5
Physics is important to study because it helps me to understand the world	1	2	3	4	5
The laws and all of the maths makes physics difficult to learn and remember	1	2	3	4	5
Physics is interesting but not enjoyable	1	2	3	4	5
Physics is too difficult for me	1	2	3	4	5
Physics is remote compared with other subjects	1	2	3	4	5
I want to study physics because it's a good subject to have – it means you're clever	1	2	3	4	5
I'm not really sure what physics is	1	2	3	4	5
Physics is fascinating but I won't continue with it. What's the point?	1	2	3	4	5

8. How would you describe your experience of physics?

....

....

....

9. How would you rate your experience of physics?

	strongly agree		not sure		strongly disagree
Physics is interesting	1	2	3	4	5
I don't really know what physics is	1	2	3	4	5
Physics is enjoyable	1	2	3	4	5
Physics is difficult	1	2	3	4	5
Physics is very relevant to my learning	1	2	3	4	5
Physics is relevant to my career	1	2	3	4	5
Physics is a boys' subject	1	2	3	4	5

Table 4.2: Pupils' perceptions of physics teachers

We are interested in what you think makes a good teacher.

1. The statements below are things that other students have said. Look at them and underline those that you agree with:
A good physics teacher:

Knows lots about physics	Allows us to talk through our ideas	Keeps good control of the class
Makes physics interesting	Gives us regular tests	Gives us time to think about ideas before moving on
Keeps the pressure up so we do well in exams	Has a good sense of humour	Doesn't allow talking
Helps us understand the importance of physics	Doesn't allow people to muck about	Expects us to know the right answers quickly
Lets us work in groups we choose	Doesn't shout	Helps you when you don't understand
Lets us do practical work	Is fair and gives us all a chance to answer	

2. What in your view is the most important thing a teacher needs to be like to help you learn physics?

....
....
....
....
....

Table 4.3: Teachers' perspectives of girls' and boys' behaviours in physics

Behaviour			**girls**					**boys**		
Which students:	very				not at all	very				not at all
answer questions in whole-class sessions?	1	2	3	4	5	1	2	3	4	5
find physics interesting?	1	2	3	4	5	1	2	3	4	5
do the best coursework?	1	2	3	4	5	1	2	3	4	5
are the most confident in discussion?	1	2	3	4	5	1	2	3	4	5
are the most diligent in doing homework?	1	2	3	4	5	1	2	3	4	5
enjoy physics?	1	2	3	4	5	1	2	3	4	5
tend to do the writing up carefully?	1	2	3	4	5	1	2	3	4	5
find physics easy?	1	2	3	4	5	1	2	3	4	5
ask for help in practical work?	1	2	3	4	5	1	2	3	4	5
are likely to want to continue with physics?	1	2	3	4	5	1	2	3	4	5

4.3 Checklist: How inclusive is your physics teaching?

The following questions and prompts are intended to help school science departments and individual teachers to reflect on their own practice in relation to the teaching of physics to girls.

Departments

- Do you really believe that girls can do as well as boys in physics? Is this reflected in conversations with female students about their aspirations and choices?
- Have you spoken to careers staff to make sure that they are aware of the full potential of physics qualifications and present a positive view of the subject to girls?
- Does the school website or booklet information about choices give potential physics students of both genders a positive view of the subject, its breadth and the benefits of further study?
- Do you use successful post-16 students of both genders to inform GCSE candidates about their experience?

Individual teachers

Planning

- When planning, do you try to make explicit the links between lessons and topics in order to explain "the big picture"?

Classroom organisation

- Have you tried single-gender groups for discussion and practical work? Have you given students specific roles during these activities to ensure full participation?

Questions and discussion

- Do you use a variety of questioning techniques, including a growing proportion of open questions requiring an extended response?
- Are students given sufficient thinking time and the opportunity to discuss their ideas with peers?
- Do you encourage small group as well as individual responses (after brief "talk time")?
- Have you tried individual whiteboards for quick individual response gathering?

Language

- Do you use technical language only when essential and reinforce it by using it in context?
- Are students encouraged to use their own language to explain their ideas, before being introduced to the specialist vocabulary?
- Do you avoid "talking equations"?

Illustration and analogy

- Are you careful to use a range of illustrations that draw on the interests of girls as well as boys?
- Do you encourage students to use their own analogies (while reminding them of the limitations of analogy)?

Relevance

- So that work has a clear rationale, do you make a point of following the sequence: applications; principles; applications?
- Do you supplement standard texts with other reading materials, such as articles and newspaper cuttings?
- Is the Internet used to introduce contemporary applications of physics?

4.4 Suggested activities to accompany videos

The following activities can be used by individual teachers, departmental and subject-specific groups of teachers, and as a seminar in an education course. It is not essential to view the programmes but they have been designed to provide interesting and entertaining contexts for the work. The activities are described briefly and a reference section follows for those who would like to extend the work or obtain background details.

The films emphasise in particular in addressing the issue of why more girls do not continue with physics. Helen and Eric have to try to understand Nellie. Her motivations will differ from that of other girls. Barry has noted which particular girls in his class enjoy participating in a demonstration, for example. Research tends to present the general; teachers must apply the lessons to the particular. The following suggested activities may help with this problem.

An outline programme for a workshop session and follow-up

- Watch *Saving Nellie* (14 minutes)
- Review one or more of the five fab physics formulae (strategies) using the suggestions below. These draw on other parts of this report.
- During this watch *Key Stage 3/4: Girls in Physics* in whole or in part
- Try a new teaching approach and discuss the outcomes of this with colleagues – and the students!

The five strategies

1 Make it relevant (table 4.4)

Section 1.7 identified the range of criteria that students have for deciding whether physics is relevant, including usefulness in everyday life, for career ambitions and for answering big questions about life. Gender influences these decisions, with girls commonly wanting to learn the subject for social and personal reasons while boys may be more focused on future jobs. Teachers can make use of such generalities, but in the classroom they are faced with the challenge of finding out what makes physics relevant to each of their students.

2 Organising class groups (table 4.5)

There is always some group work in science – laboratory practicals would be unmanageable otherwise. Science investigation skills include planning, doing, recording and concluding. It is important that all students have opportunities to practise each of these skills. Research shows that boys can dominate the "doing", leaving girls to organise

Table 4.4: Make it relevant

Make a note for yourself	Discuss with others	Try out in class
What might inhibit you from trying to make the lesson relevant to your students? Is it lack of time or the feeling that you will never get on their wavelength and so draw a blank when it comes to relevance to them?	What topics have you found popular with classes/girls/boys? What reasons do they give for this? Can lessons be learnt to make other topics more popular?	One aspect of relevance is topicality. Do you use current news items involving physics in your lessons – UPD8 from the Association for Science Education may help here.
Both films start by referring to the everyday relevance of the topic (forces and motion). Can you think of alternative starts for this content using contexts for employment and for a "big issue" in life (see also section 1.7).	A number of changes have been made to GCSE science courses from 2006 (section 2.2). These were made in part to help present the subject as relevant to all, not just future, scientists. How will this change teaching?	In the second film, Barry uses a software programme for students to demonstrate their stopping reflexes. Try using a programme (an approach – practical, IT, role play...) that you think would appeal to students as a demonstration or a group "game".

Table 4.5: Organising class groups

Make a note for yourself	Discuss with others	Try out in class
To what extent do you allow groups to form themselves? Are there disadvantages in this?	What kinds of groups are used in the two films? What are their advantages and limitations?	In section 2.2 a number of roles are identified for group members. Review them and try out your own version of these when doing class practicals.
Barry tends to use single-sex groups for practical work because he believes that boys could "bully" the girls into minor roles. Is this your experience?	Do you make use of the distinction between social groups and working groups? How might this be used to support girls in their physics lessons?	Discuss with students what they think would be the best way to share tasks, and why.

Table 4.6: Valuing students' ideas

Make a note for yourself	Discuss with others	Try out in class
What methods do you use in lessons to find out what your students think?	In section 2.3 there are some suggestions for promoting collaborative work and good questioning techniques. What are colleagues' experiences of using these?	Try a new questioning technique that gives students thinking time before they answer a question.
Are you able to identify some common alternative conceptions that students have (eg that things move when a force acts on them and do not when there is no force). How do you address these?	Can you think of ways to make more space for students to reveal their thinking and reflect on it – for example in how you ask questions or in your expectations about their written work?	Use a buzz group (5 minute-discussion among two or three neighbours) before taking answers to questions.

Table 4.7: Know your students

Make a note for yourself	Discuss with others	Try out in class
Think about one of your least promising students and carry out the task on p13 (section 2.1c). What would it help to know about her as you try to explain the point of your lesson?	What analogies are useful for communicating physics concepts. Think about your students' experiences and discuss your favourite analogies. Why do you think they work well with students?	Section 1.6 discusses the use of analogy and recommends that it is used more freely. Try out some less-than-perfect examples and get feedback on them from your students. Can they see the limitations?
Make a list of the analogies you use in teaching physics – do they rely on experiences that are common for girls and boys?	In the film Nellie confesses that she is a conker champion with a metal-cored conker! How could you use knowledge this in a lesson?	Ask students to describe a physics concept in their own words, without the use of technical language.

and to record. In the films we see groups being used for a wider range of purposes. Groups are an important way of developing student communication skills; the opportunity for communication between student and teacher can be significantly enhanced. Barry uses a number of methods to achieve this in his lesson.

3 Valuing students' ideas (table 4.6)
In *Saving Nellie*, Eric's attempt to be "relevant" by asking questions about skateboard motion falls into the trap of only wanting to hear the "right" answers from his students, which switches them off. Research indicates that physics has a bit of an image as being about right and wrong answers, and also that girls are more likely to reject learning in this mode. Although the truths of physics cannot depend on consensus, there is plenty of scope for consensus about how to search for those truths, both with ideas and with practical procedures. In the classroom, teachers find out about students' ideas that are relevant to the lesson by asking questions. A lot of research has been carried out into better questioning techniques (open not closed, allowing thinking time, etc). The films show some of these.

4 Know your students (table 4.7)
Saving Nellie draws attention to the importance of relationships in teaching. Research referred to in section 2.3 points to the importance of the teacher as a role model. Eric starts the story as a poor role model for girls in physics, in particular because encourages girls to think they cannot do physics. One has sympathy with his and Helen's lament that they teach far too many students to know them all in any detail. The danger is that, as they confess,

> "We concentrate on those we think are good at the subject."

This may result in the exclusion of girls who may lack confidence in physics but not necessarily ability.

5 Be passionate about physics (table 4.8)
As cool, objective presenters of the universe and all of its ways, can we risk showing passion and being considered geeky? Some of the other strategies may give the impression that the teacher should be like one of the class, but strategy number five requires the teacher to be distinctive. Enthusiasm and expertise can bring respect and authority, and also show students where the subject might lead them. The constraints of the curriculum, assessment systems and other accountabilities mean that many teachers don't feel that they are free to teach the subject as they'd wish. That's

Table 4.8: Be passionate about physics

Make a note for yourself	Discuss with others	Try out in class
What is the essence of the subject, for you personally? How have you tried to present this to your students?	What makes you enthusiastic about physics? How are its satisfactions different from other subjects?	In appendix 4.2 there is a questionnaire in which questions 7–9 explore what students think about physics. Use this as the basis for a discussion with them.
When will your students have seen you enjoying your teaching? How could you do more of this?	What opportunities have you taken to spend more time teaching what really turns you on in physics? How could you do more? Does it need to be extracurricular or can you suspend the syllabus for a while?	Take some time to explain to the class the relationship of a particular topic in physics to the subject as a whole.

not something to burden the students with, however.

Please note that no assumptions are being made here about what qualifications are necessary to teach physics. Enthusiasts in the subject have all kinds of backgrounds. When you are teaching physics, whatever your other experiences and expertise, you need to care about physics.

Resources for further activities and advice

Supporting Physics Teaching (11–14) Institute of Physics (2006)
This set of five CD-ROMS is a mine of useful material for teachers. Designed for non-physics teachers it nevertheless has useful ideas relevant to the themes of these programmes. For example, the *Forces* CD-ROM includes a film in which pupils discuss their ideas about forces on objects. The *Electricity* resource explores analogies for electrical quantities, such as ropes, hills and delivery vans.

Pedagogy Pack Science National Strategy (2005)
This is a set of 20 units on a range of teaching, learning and class-management strategies for teachers' self-study. There are units on questioning, group work, active engagement and modelling, each of which contains suggestions that may help in the teaching of girls in physics.

Only Connect Science Year CD ASE (2001)
This compendium of resources includes a useful section about how to get pupils talking about science concepts through analogies.

Looking and Learning in Science and Improving Teaching and Learning in Science
Success for All, DfES (2004/5)
These two CPD packs each include DVDs/CD-ROMs. The target audience is teachers of 16–19-year-old students but there are relevant sections on taking students ideas seriously, getting to know students better and making content relevant. The resources span all of the sciences but there is a physics-specific disc in the latter.

Girls in the Physics Classroom

A Teachers' Guide for Action

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