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Secondary School Pupils' Perceptions of Physics

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Abstract

This paper describes the analysis of data collected by Durham University's YELLIS project, over the period of 1999 to 2004. Included in this data was the degree to which pupils in England at the end of their secondary education 'liked' or 'disliked' different subjects, and their expected examination grades in these subjects. Our study focused on the perceptions of pupils in the science subjects of biology, chemistry and physics. Using the available data, we were able to analyse the perceptions of a large number of pupils (e.g. 9,827 pupils in 2004) who took examinations in the separate sciences. The study found that physics was perceived as the least popular science, particularly by female pupils. Using regression analysis, we found that the expected grade in a particular science subject correlated quite strongly (Spearman's rho of around 0.5) with the liking of that subject. These expected grades were found to be the lowest in physics, again particularly for female pupils. We therefore concluded that in order to redress the gender imbalance in physics, we need to tackle this problem that physics is perceived as difficult by female pupils.

Introduction

The declining number of students choosing to take physics during their further studies continues to be a cause for concern for scientific and educational communities around the world. In England and Wales, whilst the numbers taking Advanced Level physics fell by 38% between 1985 and 2004 (AQA, 2004a), the numbers taking chemistry and biology rose by 8% and 30% respectively. In Scotland, the number of students taking physics in the Scottish Higher Grade examinations fell by 30% between 1985 and 2003, although comparable falls in numbers also took place in chemistry (38%) and biology (27%) (SQA, 1986-2004). In the United States, the number of students completing bachelor degrees in physics fell by 16% during the period 1985 to 2001, compared to a decrease of 8% for chemistry and an increase of 58% in the biological sciences (National Science Foundation/Division of Science Resources Statistics, 2004). Organisation for Economic Co-operation and Development (OECD) data over the period 1998 to 2003 (OECD, 2005) showed that in Germany, Ireland, South Korea, Mexico, Netherlands and Spain, there was a fall in the number of graduates from degree and advanced research programmes in physical sciences (including physics and chemistry). Over the same period, there was a rise in the number of graduates from biological sciences in these countries. One of the concerns is that this decline in student numbers may lead to a lack of suitably qualified persons for industry, and specialist physics teachers for schools and colleges (Institute of Physics, 2004).

Another important concern is the lack of female students going on to study physics. In England and Wales, of those studying Advanced Level chemistry, the proportion of female students has risen from around 40% to 50% between 1986 and 2004, and the proportion studying biology has remained at around 60%. In physics however, the proportion of female students has remained largely unchanged at around 23% (**Figure 1**).

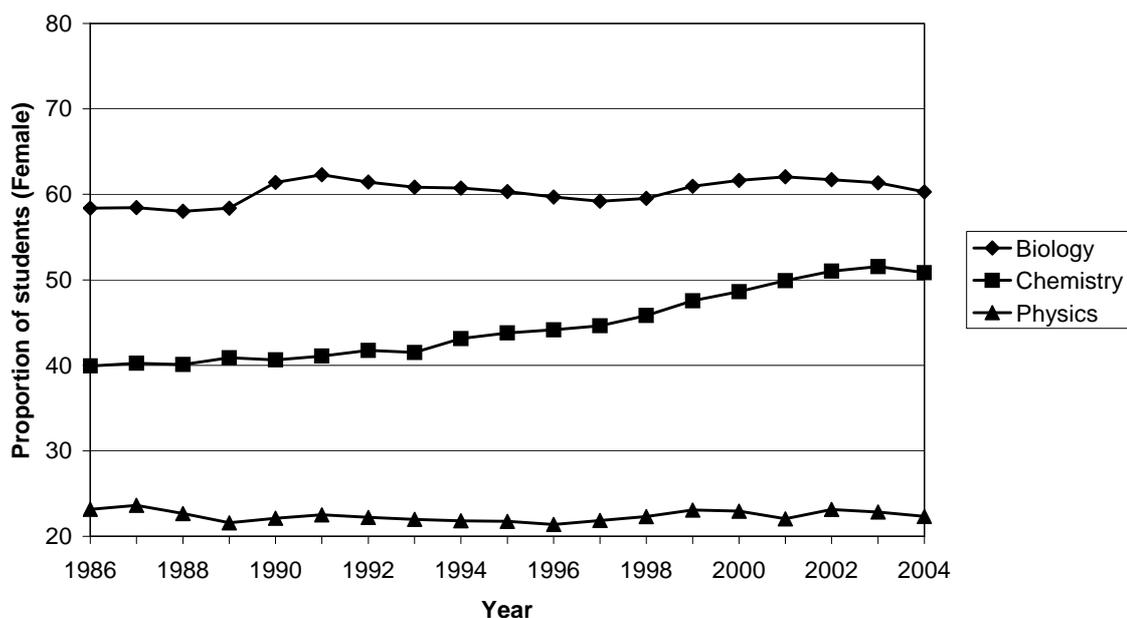


Figure 1: Proportion of female students studying A-level sciences (AQA, 2004b)

Similarly, the proportion of female physics students in Scottish Higher examinations (**Figure 2**) and in bachelor degrees in the United States (**Figure 3**) has remained far below the percentages in biology and chemistry. Concern for the fact that far fewer girls were choosing to study physics compared to boys was expressed in the meeting of the European Physics Colloquium in 2000 (Coughlan, 2000). In the recent 14-19 Education and Skills White Paper (DfES, 2005a), the UK Government specifically highlighted the gender gap in physics with a call to “address the particular problem of poor uptake of physics among girls”.

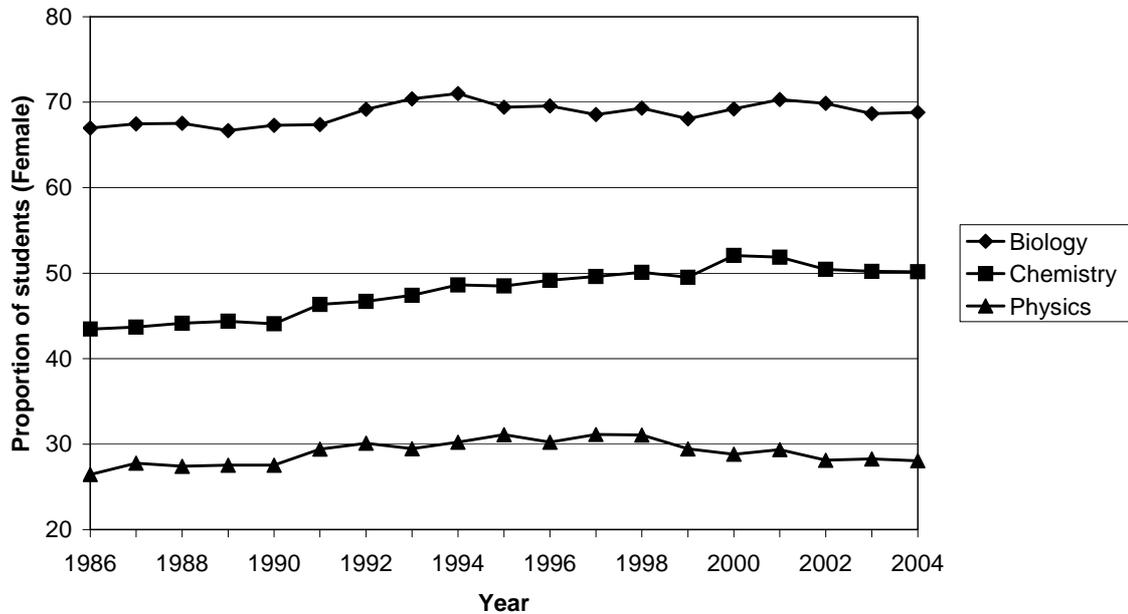


Figure 2: Proportion of female students studying Scottish Higher sciences (SQA, 1986-2004)

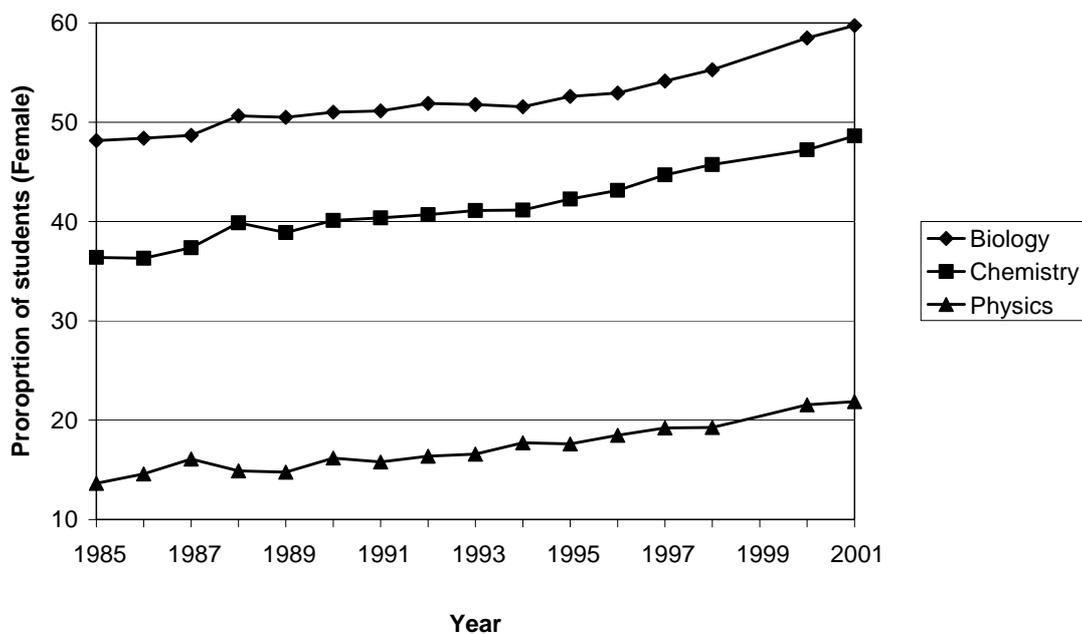


Figure 3: Proportion of female students attaining science bachelor degrees in the U.S. (National Science Foundation/Division of Science Resources Statistics, 2004)

The subject of this paper

In this paper, we examine the issue of the popularity of physics amongst pupils in England, specifically those in their penultimate year of secondary education. In England and Wales, pupils attend secondary school from the ages of 11 to 16, referred to as Years 7 to 11. In Year 10, pupils choose the subjects in which they subsequently sit the General Certificate of Secondary Education (GCSE) examinations at the end of Year 11. Pupils are awarded different grades of A*, A, B and so on down to a grade of G, and then finally a grade of U for an unclassified grade.

It is compulsory that pupils study science for their GCSE examinations. However, they do have a choice of different GCSE science examinations that they can sit. At the present time, students usually choose one of three options for studying science. First of all, students can take GCSE qualifications in the separate sciences of biology, chemistry and physics. However, it is more likely that students choose to study for the Double Award Science qualification, which combines the study of biology, chemistry and physics-related topics, but in less depth than in the separate sciences. This option leads to the awarding of two GCSE qualifications. Finally, students can opt to study for the Single Award Science qualification. This is worth one GCSE qualification, and again combines biology, chemistry and physics-related topics, but which has a reduced curriculum content compared to the Double Award Science.

In order to examine the views of pupils in these final years of secondary education, this paper draws on data obtained by the YELLIS project, run by the CEM Centre at Durham University. In a typical year, the YELLIS project (YELLIS stands for Year 11 Information System) involves around 1,200 schools, with roughly 200,000 pupils. Schools involved in the YELLIS project register voluntarily to take part in the data collection exercise. YELLIS provides secondary schools in England with feedback on how their pupils perform in GCSE examinations. In order to do this, YELLIS uses a test booklet to collect data on pupils' prior-achievement (via a vocabulary and mathematics test), the attitudes of pupils to their studies, and some information on their social background. This data collection is carried out with the schools involved at the start of Year 10. At the end of Year 11, the GCSE examination results for the pupils in these schools are collected, and a comparison can be made between the schools involved of pupils' achievement in each subject.

As part of the data collection process, the YELLIS questionnaire examines the degree to which Year 10 students 'like' or 'dislike' different science subjects (along with other subjects) that are taken at GCSE level; Double Award Science, Single Award Science and also the separate sciences of physics, chemistry and biology. This is done through a single questionnaire item for each subject, with a choice of one of the responses from 'Dislike very much', 'Dislike', 'Not sure', 'Like' and 'Like very much'. In addition, the questionnaire asks pupils for the GCSE grades (A* through to U) which they expect to achieve in the different science subjects. As the YELLIS data is collected in the first term of Year 10, this data provides an indication of how pupils perceive the sciences at the start of their GCSE studies, both in terms of their expected attainment and their liking for different subjects.

One of the advantages of examining such a large dataset is that data has been obtained from a large number of pupils doing the separate sciences, rather than the more commonly taken Double Award Science. Therefore, we can use YELLIS data to specifically examine the attitudes of pupils towards these separate science subjects. This paper therefore describes the analysis of this YELLIS data, and what the data tells us about how Year 10 pupils perceive the different science subjects.

Analysis of the data

Liking or disliking the science subjects

In analysing the YELLIS data, we first of all examined the extent to which pupils ‘liked’ or ‘disliked’ the different sciences. **Table 1** shows the responses for the cohort of pupils completing their GCSE examinations in 2004. In this paper, the year that is given for any particular cohort will refer to when they sat their examinations, rather than when they filled in the YELLIS questionnaire.

Table 1: Percentage of pupils giving each response for the three science subjects (2004 data)

Subject	N	Dislike very much (%)	Dislike a little (%)	Not sure (%)	Like a little (%)	Like a lot (%)
Biology	9827	1.7	6.4	15.5	44.5	31.9
Chemistry	9827	2.4	7.4	15.7	43.4	31.1
Physics	9827	4.1	12.5	20.4	39.6	23.3

For this part of the analysis, only those pupils who took the GCSE examination in each of the separate science subjects were included. Also, only those pupils that provided a response for how much they liked *each* of the sciences were included (not all pupils provided a rating for each subject). This ensured that the same cohort of pupils was being compared across the different subjects. Data from the Department for Education and Skills (DfES) in the UK (DfES, 2005b) showed that around 42,500 pupils were entered for the GCSE physics examination in 2004. Our figures therefore accounted for around 23% of all the pupils doing the separate GCSE physics examination in that year.

The 2004 data showed that pupils were less likely to rate themselves as liking physics a little or a lot (62.9%) compared to biology (76.4%) or chemistry (74.5%). Since the pupils’ responses were in the form of ordinal data, using Friedman’s ANOVA test for non-parametric data showed that the variation over the three science subjects was statistically significant at the 0.1% level ($\chi^2 = 931.0, p < 0.001$).

Plotting the pupil ratings of the science subjects for different cohorts in different years (**Figure 4**), we saw that this pattern of physics being the least popular of the science subjects has remained the same over recent years.

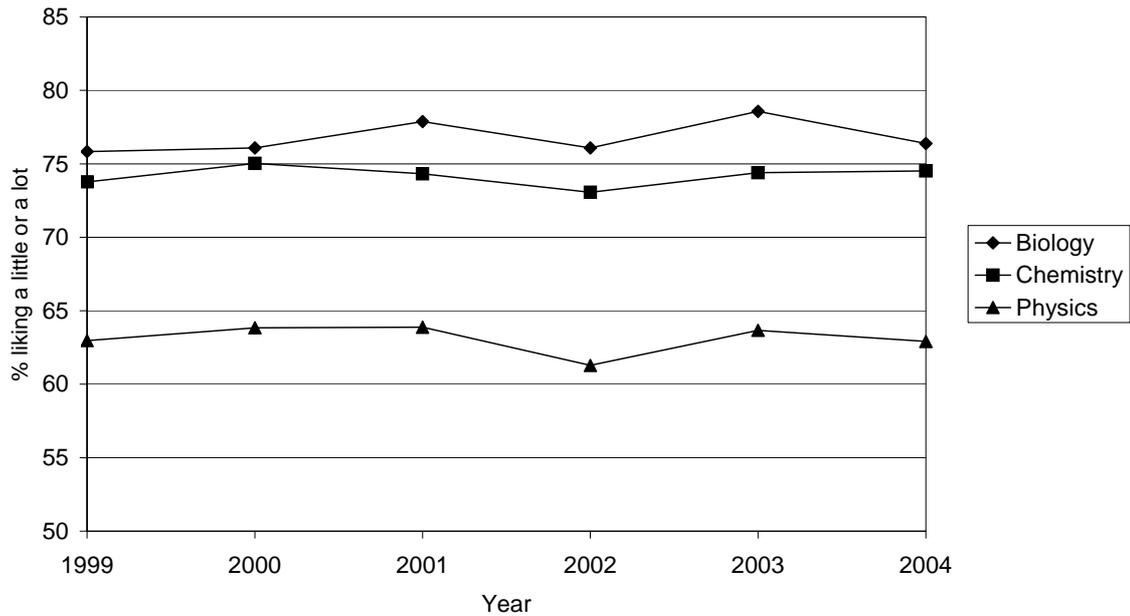


Figure 4: Percentage of pupils liking each subject 'a little' or 'a lot' over recent years

We also analysed these ratings for the different sciences in terms of gender (**Figure 5**). We found that whereas biology was perceived as being more liked by female pupils compared to male pupils, the reverse was true for physics and chemistry. Physics was the least popular science subject for both male and female pupils, and physics was far less popular for female pupils compared to male pupils.

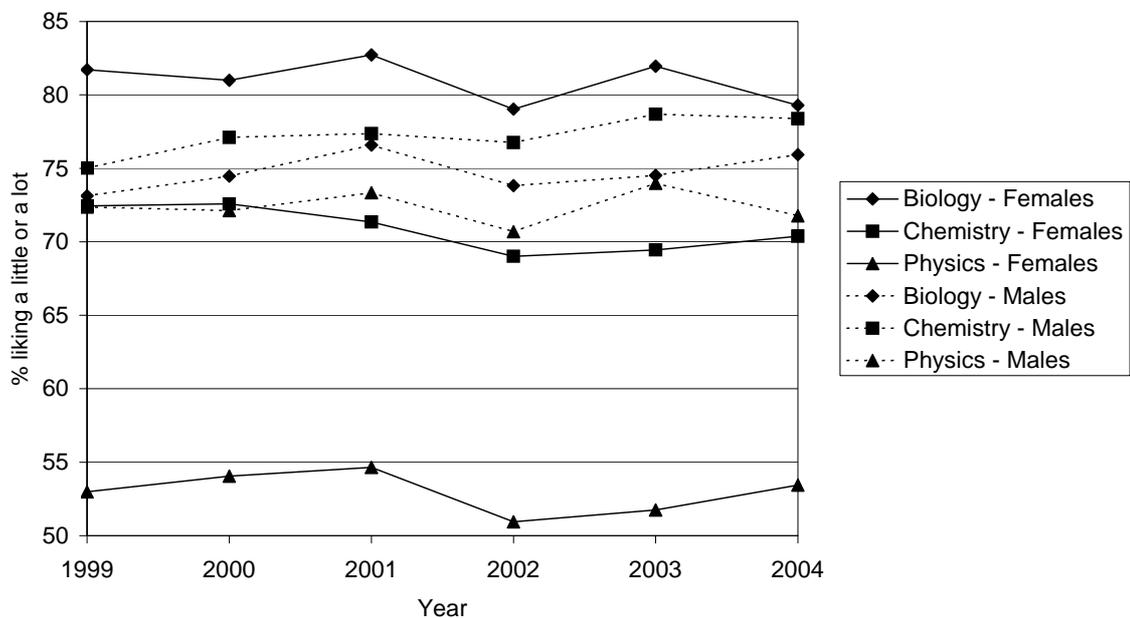


Figure 5: Percentage of female and male pupils liking each subject 'a little' or 'a lot' over recent years

Data for Double Award Science Pupils

The main advantage of using the YELLIS data to examine the attitudes of pupils towards the sciences was the fact that because of the size of the dataset, a large amount of data could be obtained for pupils taking the separate sciences. However, in looking at the pupils who took separate science GCSE examinations, we acknowledge the fact that this sample of pupils was not representative of the overall cohort of pupils studying GCSE science. The vast majority of pupils experience the sciences through the Double Award Science course, rather than through the separate sciences. From DfES figures (DfES, 2005b), 479,500 pupils took the Double Award Science GCSE examination in 2004, compared to around 42,000 students that took GCSE examinations in the separate sciences. Therefore, could we say anything about the perceptions of this larger cohort of Double Award Science pupils regarding the separate strands of biology, chemistry and physics?

In fact, examining the available YELLIS data, it was found that a large number of pupils who subsequently went on to sit the Double Award Science examination still provided a rating of how much they liked physics, chemistry and biology. We found that out of 792,448 students for whom we had Double Award Science results over the period 1999 to 2004, 299,634 students gave ratings for each of biology, chemistry and physics. Therefore, we analysed this additional, conveniently available sample of Double Award Science students, to see how their responses compared with those doing the separate sciences. **Table 2** shows the responses for this sample of Double Award Science pupils in 2004.

Table 2: Percentage of Double Award Science pupils giving each response for the three science subjects (2004 data)

Subject	N	Dislike very much (%)	Dislike a little (%)	Not sure (%)	Like a little (%)	Like a lot (%)
Biology	37747	5.3	13.3	27.5	40.9	13.0
Chemistry	37747	6.8	16.2	29.5	37.2	10.3
Physics	37747	8.0	17.9	31.8	33.7	8.6

Compared to the data for the pupils studying the separate sciences (**Table 1**), Double Award Science pupils were less likely to 'like' each of the sciences. This was not surprising, as we might have expected more able pupils to study the separate sciences with their more in-depth coverage of the subjects. However, once again, physics was the least popular of the three science subjects amongst the Double Award Science pupils. This pattern has been the same, once again, over recent years (**Figure 6**).

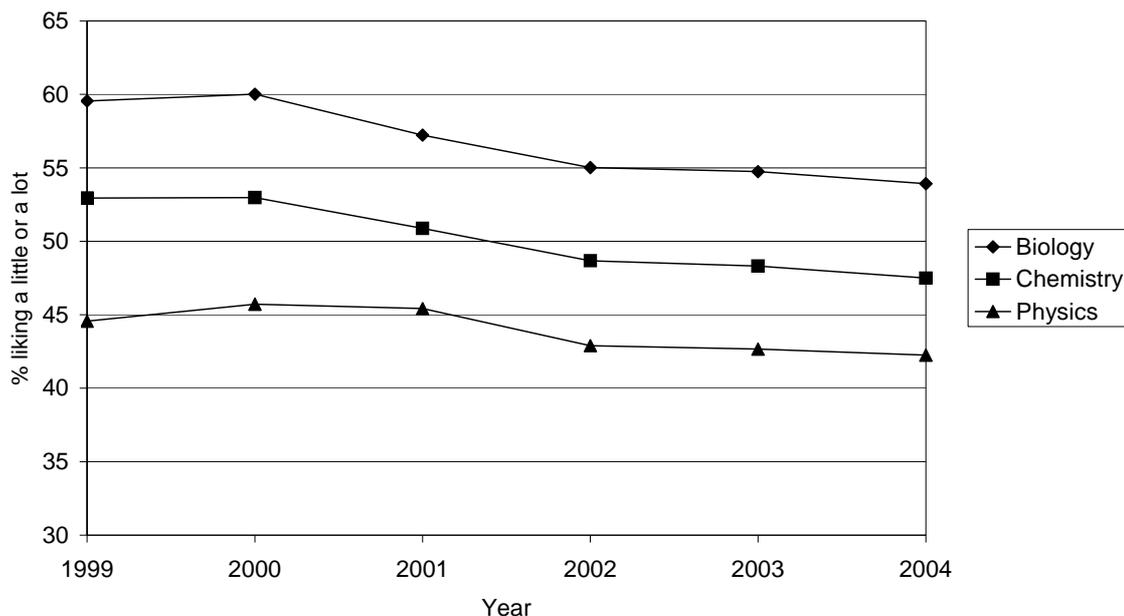


Figure 6: How much Double Award Science pupils liked each subject over recent years

We can also examine the differences in the ratings between female and male pupils doing the Double Award Science examination (**Figure 7**).

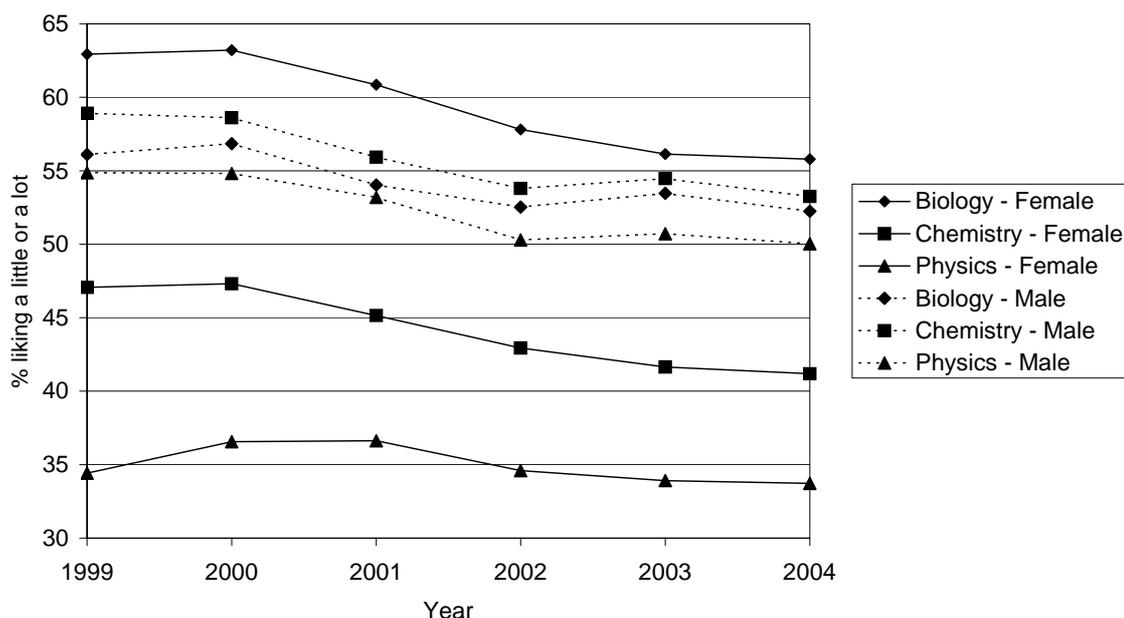


Figure 7: How much female and male Double Award Science pupils liked each subject

As for the separate sciences, physics was the least popular science for female and male pupils, and physics was far less popular amongst the female pupils than amongst the males. Male pupils were also more likely to like chemistry than female pupils, whereas the reverse was true for biology.

We acknowledge the fact that this sample of Double Award Science pupils (amounting to 37,747 pupils in 2004, or around 8% of those taking the Double Award Science examination that year) was not a representative random sample. Rather, this

was simply a convenient sample available to our study. However, assuming that there was no particular reason for some Double Award Science pupils giving ratings for the separate sciences and some not, the pattern of results for Double Award Science pupils were in broad agreement with those that took separate science subjects.

What might influence a pupil's liking for a science subject?

In the above analysis, we found that for the same cohort of pupils, their liking for science subjects varied with the subject itself and also with gender. The question we then asked was, given the data available to us from the YELLIS dataset, was it possible for us to deduce what else might influence the liking for a science subject?

The additional data that we had available to us contained the following variables:

- The GCSE grades that pupils expected to achieve in each subject at the beginning of Year 10.
- The actual GCSE grades achieved by pupils in each subject at the end of Year 11.
- A measure of general ability for each pupil, based on a vocabulary test and a mathematics test.
- The year that the pupil completed their GCSE examinations.
- The gender of the pupil.

By converting the GCSE grades to numerical measures (A* = 8, A = 7, ... F = 2, G = 1, U = 0), and gender to a dichotomous variable for females and males, we calculated the Spearman's rho correlation values between these various measures available to us, and the liking of students for the science subjects. Spearman's rho correlation values were calculated because the liking for the science subjects and the GCSE grades were ordinal measures. The resulting correlations are given below in **Table 3** for the case of physics, calculated only from the data for the pupils who did the separate sciences.

Table 3: Correlations of the different variables with the liking for physics

Variable	Correlation with liking for physics
Year of examination	0.01
Gender	0.22
Expected GCSE grade in physics	0.52
Actual GCSE grade in physics	0.12
General ability measure	0.01

We found that the largest correlation was between the expected grade in physics and the liking for the subject. The actual GCSE grade was not strongly related to the liking for physics. When we repeated the same analysis for biology and chemistry (using the GCSE measures for those subjects), we found each time that the expected grade was similarly correlated to the liking for that subject (**Table 4**).

Table 4: Spearman's rho values for the correlation between expected GCSE grade and the liking for each science subject

Subject	Spearman's rho
Biology	0.46

Chemistry	0.51
Physics	0.52

Of course, the analysis was restricted to the variables that we had available from the YELLIS dataset, and other influences (for example teacher variables) would be important as well. However, based on the available data, we concluded that an important influence on pupils' liking of a science subject was their expectation of success in that subject.

Expected grades in the separate sciences

Based on the above findings, we chose to further examine the expected GCSE grades of pupils in each of the science subjects, to see how expectations changed between one science subject and another. Beginning with the cohort of pupils taking the separate sciences, **Table 5** gives the expected grades of pupils who went on to sit their GCSE examinations in 2004.

Table 5: Percentage of pupils expecting each GCSE grade in the separate sciences (2004 data)

Subject	N	A*	A	B	C	Below C
Biology	9588	18.1	44.8	28.6	7.7	1.0
Chemistry	9591	18.4	41.2	29.7	9.3	1.5
Physics	9582	15.9	38.4	32.0	11.7	1.9

As can be seen from the numbers of pupils (N) in each subject, within the cohort of pupils that provided data on how much they liked each subject (**Table 1**), not all these pupils provided a response for what grade they expected in each science subject. However, this only amounted to about a 2% non-response rate. Amongst those that did provide responses, pupils' expectations were more likely to be highest in biology and lowest in physics. This perception that pupils would do least well in physics has been the same over recent years (**Figure 8**).

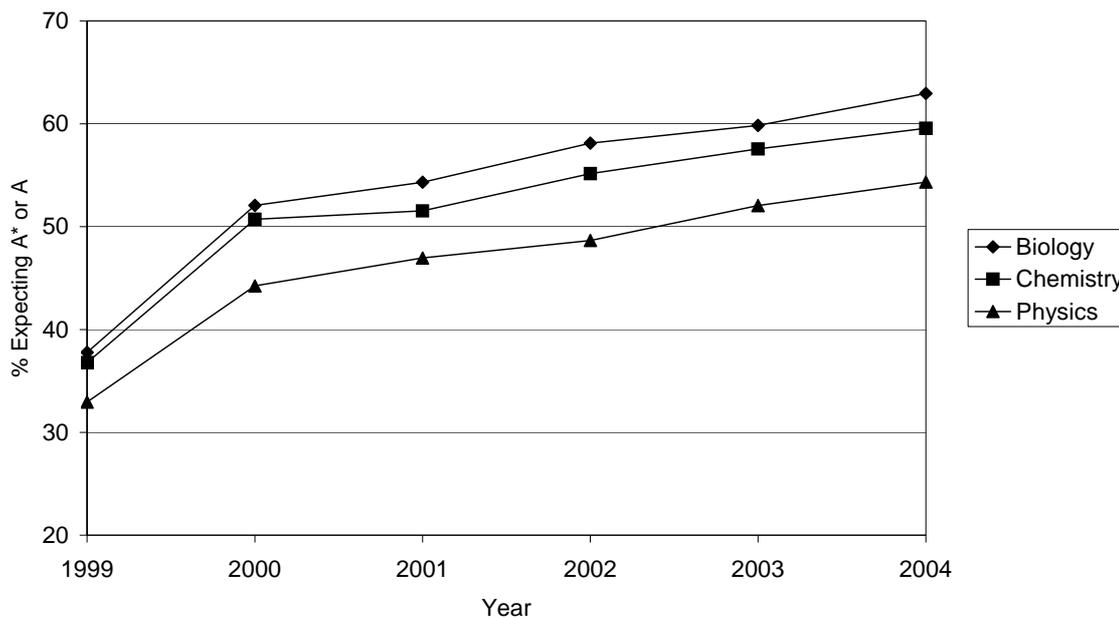


Figure 8: Percentage of pupils expecting A* or A GCSE grades in each of the three separate sciences

An issue to note here is the rise in the expected grades of pupils in the separate sciences over recent years. One explanation for this is that schools with more able pupils have been choosing to join the YELLIS project over this period. In fact, there was a rise in the actual GCSE grades achieved by these pupils (**Figure 9**), which might therefore support this view. Another possibility is that over this time, more pupils have been achieving higher GCSE grades in the separate sciences. In fact, from DfES data on past examination performance of all pupils who sat these separate science examinations, there has only been a slight increase from 43% of pupils achieving A* or A grades in 1999 (DfES, 2000) to 47% in 2004 (DfES, 2005b). Therefore, the former explanation for this rise in expectations is more likely to be the case.

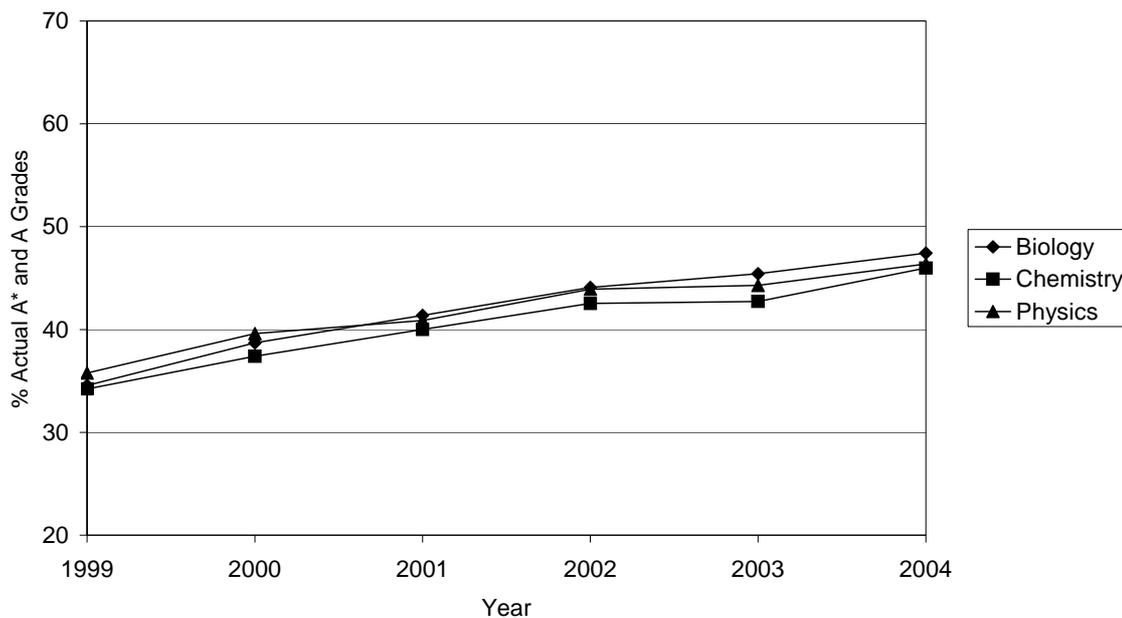


Figure 9: Percentage of pupils actually getting A* and A GCSE grades in the three separate sciences

We also examined the expected grades of male and female pupils separately (**Figure 10**).

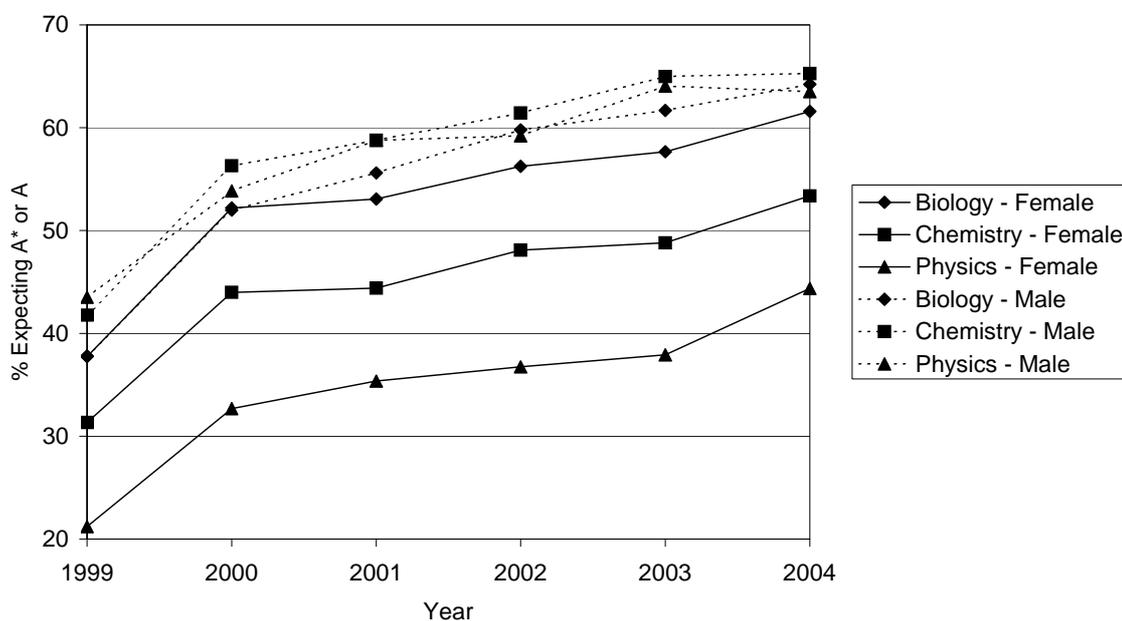


Figure 10: Percentage of female and male pupils expecting A* and A GCSE grades in the separate sciences

In this case, male pupils were more positive about how they would do in all three of the science subjects. For physics however, we saw that the expectations were lowest for both the female and male groups of pupils. The difference between biology and

physics was found to be quite small for the male pupils, and more pronounced for the female pupils.

These findings therefore showed that approximately 20% less female pupils felt that they would achieve top grades in physics compared to biology. We saw previously that pupils' liking of a science subject was quite closely correlated (Spearman's rho of around 0.5) to their expectations in that subject. Although we cannot attribute causation from our results, other studies have shown the influence of previous achievement on students' attitudes towards science, rather than the other way round (Rennie and Punch, 1991). Therefore, it seems likely that one of the factors that contributed to female pupils liking physics less than the other science subjects was the lower expectation of success that they had in physics at GCSE level.

Was this lower expectation of female pupils justified? We could examine this by looking at the percentage of female and male pupils that actually obtained the top grades in the three separate sciences (**Figure 11**).

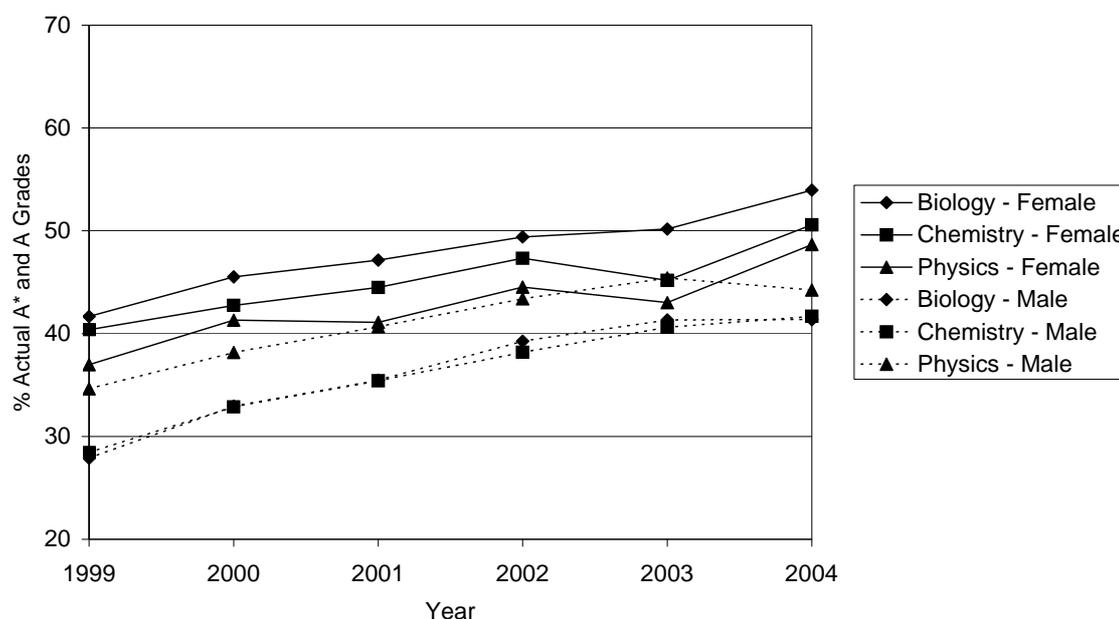


Figure 11: Percentage of female and male pupils actually getting A* and A GCSE grades in the separate sciences

We found that the female pupils on average outperformed the male pupils in biology and chemistry, and males and females were close in actual attainment in physics. Therefore, the more confident expectations of the male pupils were not justified by what they actually obtained. However, the actual GCSE results also told us that female pupils performed least well in physics. In this cohort, approximately 5% less female pupils achieved top grades in physics compared to biology. Therefore, these female pupils did indeed perform the least well in physics. However, the difference between the subjects was smaller than that expected by the female pupils. Therefore, female pupils' low expectations in physics were only partially justified by their results.

Expected grades for Double Award Science pupils

Having examined the differences in expected GCSE grades between the separate science subjects and between female and male pupils, we examined the available data for Double Award Science students. We wanted to find out the expectations of pupils in biology, physics and chemistry for this larger cohort.

Once again, we were able to draw on a convenient sample of pupils who, despite taking Double Award Science, had provided expected grades for each of the separate sciences. Of the 792,448 students that we had results for over the period 1999 to 2004, 286,424 pupils gave expected grades for biology, chemistry and physics. We were therefore able to look at the percentages of these Double Award Science pupils that were expecting A* and A grades in the three science subjects (**Figure 12**).

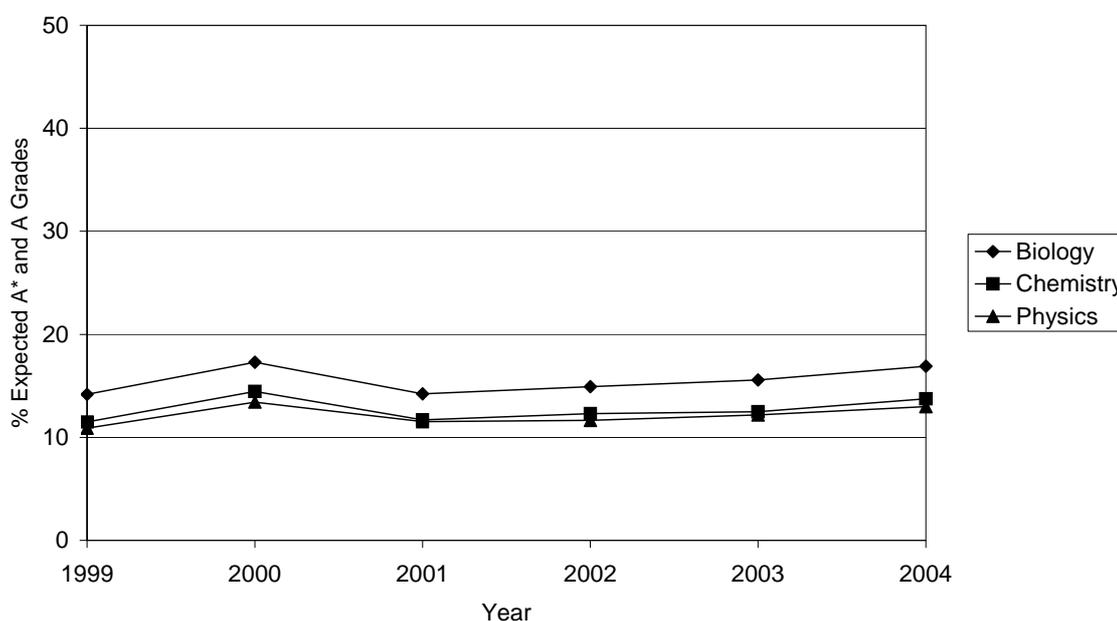


Figure 12: Percentage of Double Award Science pupils expecting A* or A GCSE grades in each of the three separate sciences

We found that for the Double Award Science pupils, the percentages expecting the top grades were lower than for those pupils taking the separate sciences. Assuming that more able pupils were doing the separate sciences, we were not surprised to find this difference between the two different cohorts. In addition, we also found that the percentages of Double Award Science pupils expecting the top grades were lowest in physics. This was similar to the results for the separate science students. However, for the Double Award Science pupils, the percentages for chemistry and physics were closer than for the separate science pupils. Looking at gender differences in these results (**Figure 13**), they once again showed that the differences in the percentages for the different sciences were pronounced for the female pupils only. Approximately 7% less female pupils thought that they would achieve a top grade in physics compared to biology.

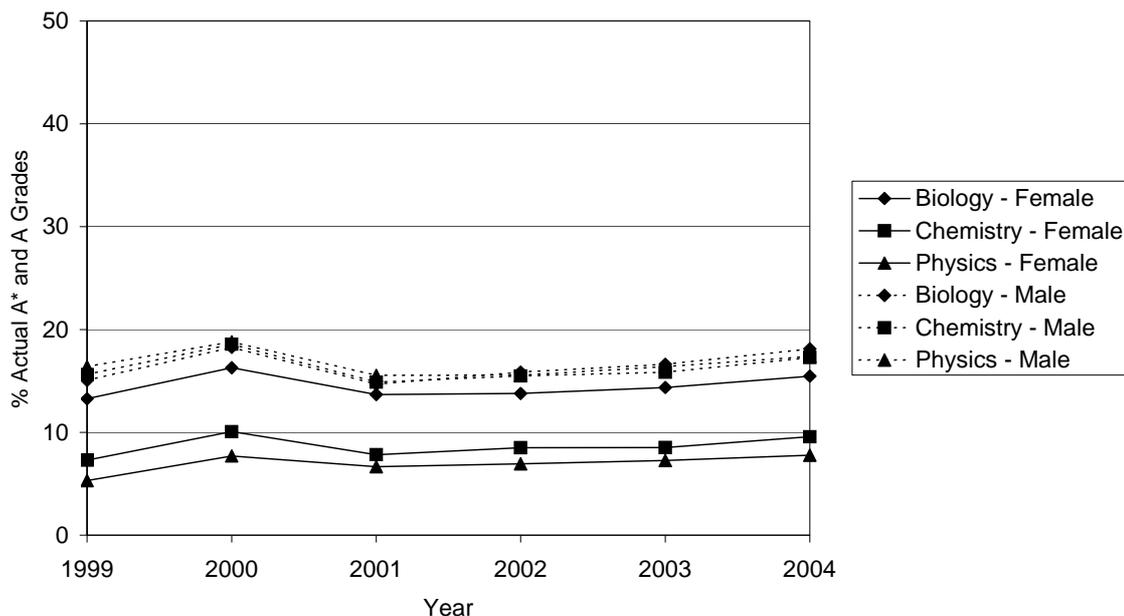


Figure 13: Percentage of female and male Double Award Science pupils expecting A* or A GCSE grades in each of the three separate sciences

The general pattern of expected GCSE grades, provided by the convenient sample of Double Award Science pupils, was found to be similar to that of the separate science pupils. We therefore concluded that female pupils had lower expectations in physics than for the other sciences, for both those studying Double Award Science and those studying the separate sciences.

Discussion

From our analysis, one of the conclusions that we have reached is that physics is perceived less favourably than the other science subjects, the reason being that pupils' expectations of success is less in physics compared to biology or chemistry. We highlighted earlier the study by Rennie and Punch (1991), which discussed the relationship between attitude towards science generally and previous achievement. Looking at physics specifically, the possible relationship between expectations of success, or to put it another way the perceived difficulty of the subject, has also been suggested in a number of other studies.

Duckworth and Entwistle (1974), in a survey of secondary school pupils, found that physics was rated both as less interesting and more difficult than either biology or chemistry. In their study of undergraduate students in physics, biology and English, Spall *et al.* (2003) found that biology was seen as easier than physics by all the groups of students, and seen as more interesting by both the English and biology students. Williams *et al.* (2003) found that secondary school pupils found biology more interesting than physics, the predominant reason being that physics was a more difficult subject. Our study supported this finding, with our findings being based on a far larger cohort of pupils (Williams *et al.* surveyed 317 pupils).

A second conclusion that we reached was that physics was much less likely to be liked by female pupils. Our findings showed that the differences that we observed between liking for physics and liking for the other sciences, in particular for biology, were much more pronounced for female pupils. These findings were in broad agreement with the meta-analysis carried out by Weinburgh (1995). In comparing gender differences in attitude toward a variety of science subjects, Weinburgh found an overall effect size of 0.12 for the difference in attitude between male and female students in physics, compared to an effect size of 0.03 in biology (both differences in favour of male students).

Our analysis also suggested that a possible reason for the gender differences in how physics and biology are perceived might be the different expectations of success in those subjects. Osborne, Simon and Collins (2003), in their review of literature looking at attitudes towards the sciences, highlighted the fact that the perceived difficulty of science subjects seemed to be a major influence on whether pupils took science subjects for their Advanced Level studies in the UK. Therefore, the fact that expectations in physics is lower for female pupils may be one of the contributory factors towards the poor uptake of physics by female students in further education, as highlighted in the introduction to this paper.

Therefore, if we want to improve the uptake of physics in further education courses, particularly amongst female students, then we need to tackle this perception that physics is more difficult than the other science subjects. An important factor that will enable us to do this will be the ability of teachers to explain physics to pupils. Osborne, Simon and Collins (2003) argued that for science subjects generally, “research evidence shows clearly that it is the teacher variables that are the most significant factor determining attitude, not curriculum variables”. Looking at physics specifically, Nielsen and Thomsen (1988), in their study of secondary pupils in Denmark, found that

“What has mostly struck us in the students’ responses during the interviews is the overwhelming consensus that the teacher is the single most decisive factor in forming the students’ attitudes about physics ... A ‘good’ teacher can make an otherwise disliked subject tolerable, maybe even interesting, but a ‘bad’ teacher is able to kill any prior interest in the subject.”

Woolnough (1994) also called for science to be taught by “well qualified teachers ... who were enthusiastic about, and expert in, the subject they were teaching”.

However, this is where we enter a possible vicious circle, a lack of those doing physics leading to a lack of suitably qualified teachers of physics. Dillon *et al.* (2000), in their survey of primary and secondary teachers, found that 47% of those teaching science at primary school had no qualification at all in physics. This was in comparison to 19% that had no qualification in biology. At secondary school, 66% of those teaching GCSE science did not have a degree in physics, compared to 29% that did not have a degree in biology. Therefore, this lack of well-qualified physics teachers tends to suggest that little will change with regards to popularity of physics amongst pupils. Certainly, from our findings in this paper, we see that little has

changed in the past five years in the way that pupils perceive the subject. We can only hope that when return to examine this data source in the future, the situation has not become even worse for physics.

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