

THE RELEVANCE OF
SCIENCE EDUCATION
IN IRELAND

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This publication was supported by Discover Science and Engineering

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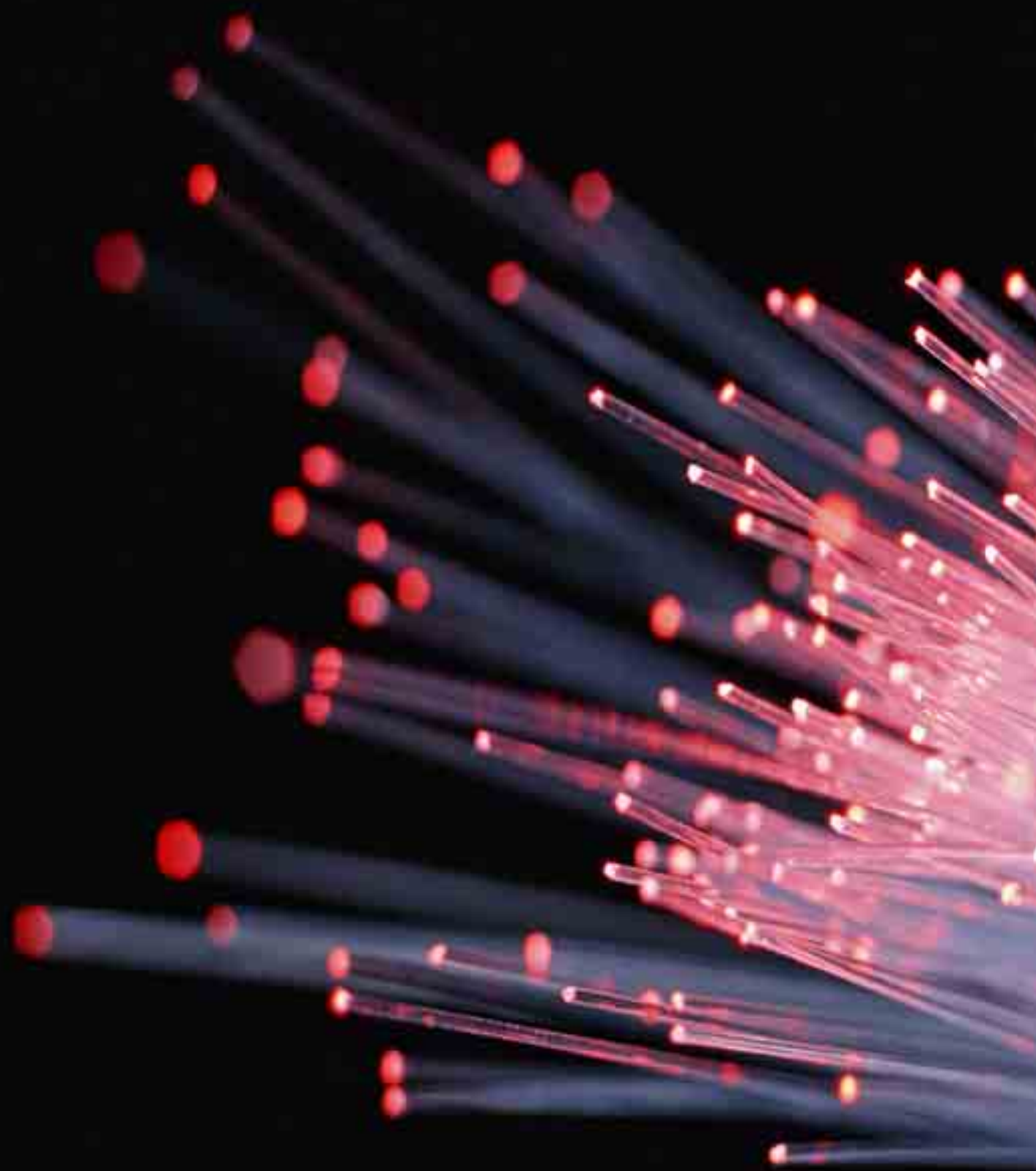
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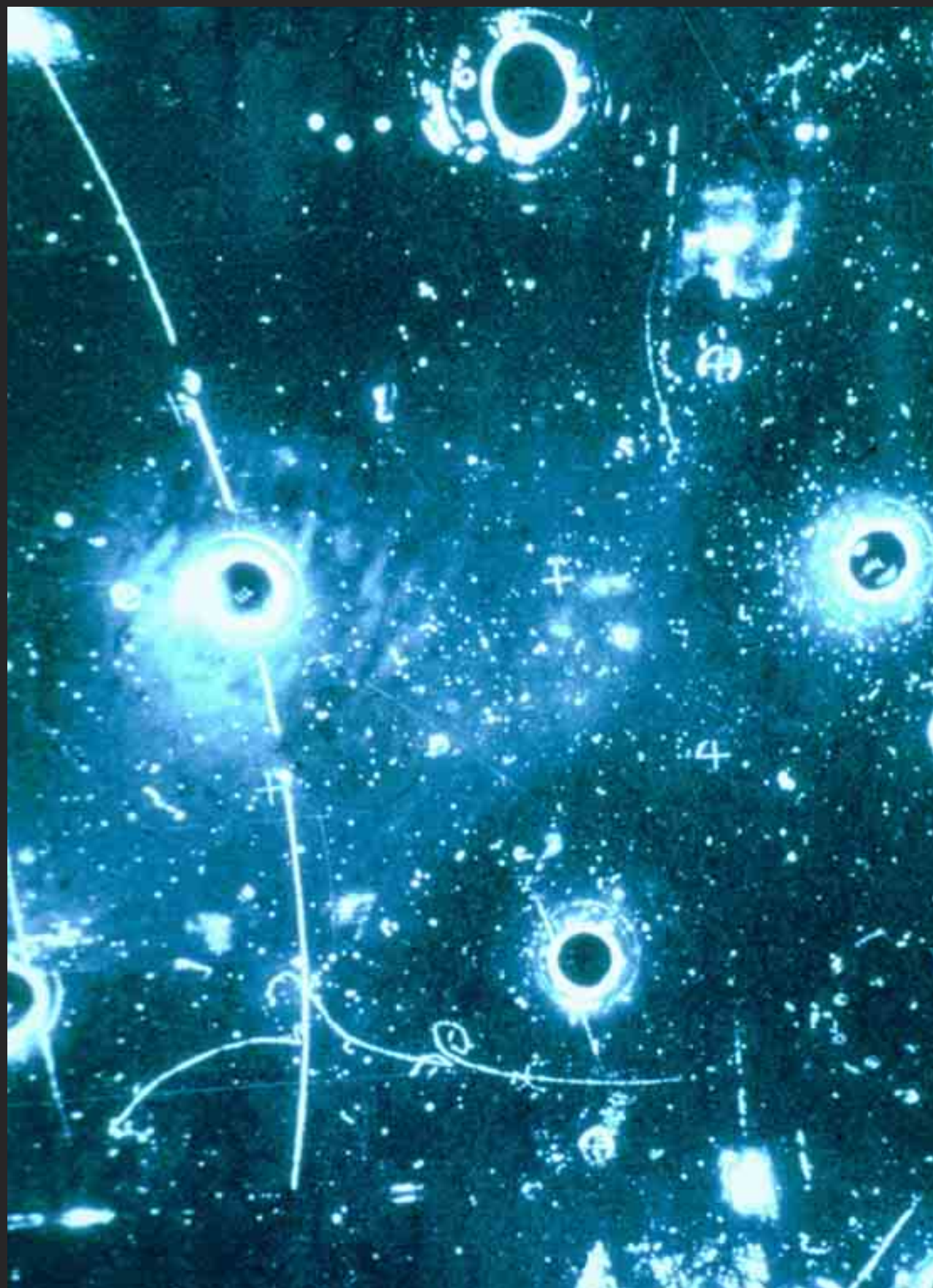
FOREWORD



This publication presents the results of an empirical study in Ireland that formed part of the Relevance of Science Education (ROSE) project. ROSE puts special emphasis on investigating second-level school students' perceptions of the science that they are taught in school and aspects of science that they come across in their everyday lives. As such, ROSE differs from other surveys and publications on science education in Ireland that have appeared in recent years in that it listens to the 'student voice'. Finally, I should emphasise that the views expressed in this document are solely my own and do not represent those of the Royal Irish Academy.

To accompany this document, a website <http://www.ria.ie/publications/rose.html> has been made available. The site contains details of the results of the ROSE survey in Ireland and links to the main ROSE site, as well as other relevant sites.

ROSE differs from other surveys and publications on science education in Ireland in that it listens to the 'student voice'



S U M M A R Y



This report discusses the results of the Relevance of Science Education (ROSE) survey completed by 688 students from 29 second-level schools in Ireland in November 2003. All the students were in Transition Year or in the first year of their Leaving Certificate programme and had completed a course of study in Junior Certificate Science in the previous June.

The ROSE survey has been completed by students in 37 countries. It was designed to gather information about students' opinions of school science and science-related issues in general under the headings 'What I want to learn about', 'My future job', 'Me and the environmental challenges', 'My opinions about science and technology', 'My out-of-school experiences' and 'Myself as a scientist'. The Irish students' views are discussed in relation to current issues in Irish science education and placed in a wider context by comparing the results with those from other countries taking part in the ROSE project.

Irish students' views are discussed in relation to current issues in Irish science education and compared with the results from other countries taking part in the ROSE project

KEY FINDINGS

ABOUT SCHOOL SCIENCE

1. A slight majority of students have more positive than negative responses to Junior Certificate Science. In the main they enjoy the subject.
2. Students' highest degree of interest is in themes involving health, sex, genetics, natural disasters and the origin of life, space and the universe.
3. Students' lowest degree of interest is in topics that have a technical aspect (e.g. how nuclear power plants, rockets, satellites and petrol and diesel engines function).
4. Some of the lowest ratings given by both by both girls and boys were for topics that form major parts of the Junior Certificate Science Syllabus (e.g. 'atoms and molecules', 'how plants grow and reproduce' and 'electricity').
5. Students' responses often show typical gender-related differences, e.g. girls are more interested than boys in eating disorders, babies and cosmetics; boys are more interested than girls in explosive chemicals and nuclear weapons. However, there are exceptions, e.g. both girls and boys are interested in how mobile phones, CDs and DVDs work.
6. Girls tend to show a higher degree of interest in most topics than do boys.
7. About 50% of students regard Junior Certificate Science as a demanding, difficult subject.
8. The majority of students express moderate agreement with statements such as 'school science is interesting' and 'the things I learn in science at school will be helpful in my everyday life'. However, less than 30% of students express strong agreement with such statements.

ABOUT THE ENVIRONMENT, SCIENCE, SCIENTISTS AND TECHNOLOGY

9. Students are optimistic about the ability of science/technology to find solutions to environmental problems and find cures for diseases.

10. They are strongly of the opinion that care for the environment is their personal responsibility.

11. Students are convinced of the importance of science and technology for society.

12. They disagree that 'we should always believe what scientists have to say', and that 'scientists are neutral and objective'.

13. They do not believe science is 'helping the poor' or that it will 'eradicate poverty and famine in the world'.

ABOUT CAREERS

14. Girls and boys want to make use of their individual talents and seek personal involvement and some degree of autonomy in their future careers.

15. Responses to several questions indicate that it is not just financial rewards or some other extrinsic reward that students hope to obtain from employment: students value personal and social relations as much, perhaps more, than material rewards.

16. The great majority of students do not want 'to become a scientist' or 'to get a job in technology' (55% of students chose the extreme 'disagree' option for the former statement and 44% for the latter statement.)

17. Girls' and boys' preferences for careers related to science were dominated by activities that had a biological/medical/health theme.



THE RELEVANCE OF SCIENCE EDUCATION (ROSE) PROJECT



ROSE is the acronym for the *Relevance of Science Education*, an international project directed by Professor Svein Sjøberg at the University of Oslo. The project has been funded by the Research Council of Norway, the Norwegian Ministry of Education, the University of Oslo and the Norwegian Centre for Science Education. Its purpose is to investigate students' opinions of their experience of school science and of science in general. The instrument used to gather data was a questionnaire consisting of 217 short questions, the majority of which could be answered by choosing options on a four-point Likert scale. The questions were designed to cover six main themes: 'What I want to learn about', 'My future job', 'Me and the environmental challenges', 'My opinions about science and technology', 'My out-of-school experiences' and 'Myself as a scientist'. A copy of the questionnaire is to be found on <http://www.ria.ie/publications/rose.html>

To date, 37 countries have taken part in the project. The target population was students in the age range fourteen to sixteen who had completed a course of study in the first stage of their second-level education. In Ireland

The ROSE survey deliberately casts its net wide: it asks students for their views on science in general, not just on school science—a vital distinction

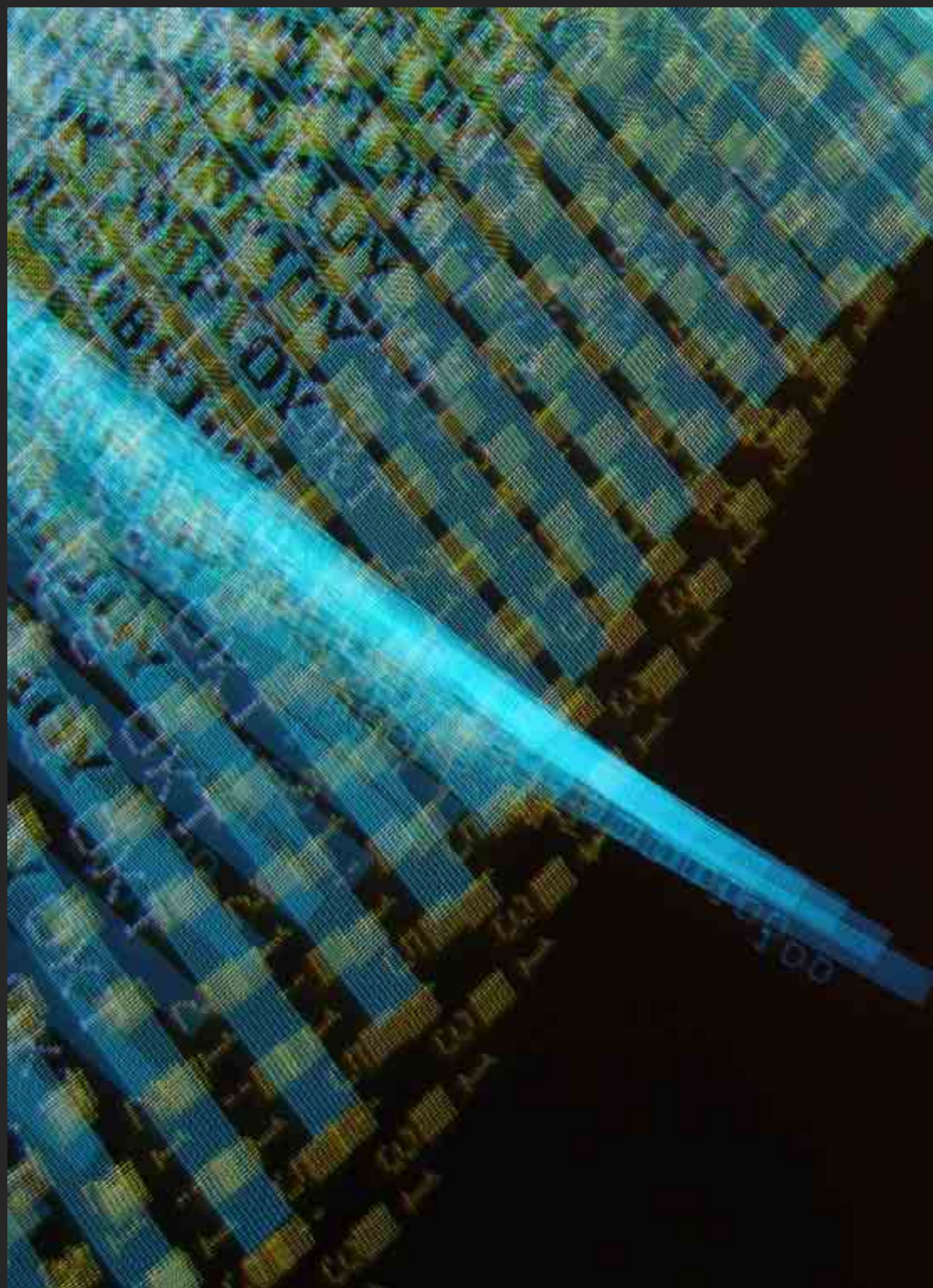


the ROSE questionnaire was completed in October/November 2003 by 688 Transition Year or Fifth Year students (330 girls, 358 boys; mean age 15.5 years). The samples of students and schools were selected following criteria established by the central ROSE team. Twenty nine schools took part, with approximately equal numbers of girls and boys. Each of the main types of second-level schools in Ireland was included (vocational, secondary, community/comprehensive). Schools in counties Carlow, Dublin, Kildare, Limerick, Meath and Wexford took part.

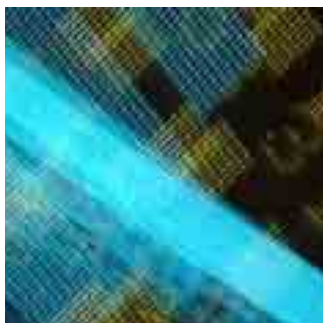
The ROSE survey deliberately casts its net wide. It seeks students' views on a large number of topics, many of which are not part of the formal science curriculum. It also asks students for their views on science in general, not just on school science—a vital distinction. Some questions are also used in other large-scale surveys, such as the Eurobarometer.

Full information about ROSE, including its rationale, and details of the questionnaire, can be found on the project website www.ils.uio.no/english/rose/. The reports by Schreiner and Sjøberg (2005) and Schreiner (2006) are particularly valuable.¹

The primary purpose of this report is to present major features of the Irish data and draw out the implications for science education in Ireland.



THE CONTEXT OF ROSE



The ROSE project was initiated in response to the widespread concern in many countries² about the reasons why students' interest in science, or at least in school science, seems to have been in decline. It is worth emphasising the qualification 'seems' here because the underlying issues relating to students' interests and science are extremely complex. In

Ireland, for example, it is certainly the case that prior to 2003, there had been a downward trend in the numbers of students choosing to study Leaving Certificate Physics or Chemistry courses. It may have been the evidence of the decline that provoked the then Minister for Education into commissioning the *Report of the Task Force on the Physical Sciences* in 2002.³ More recently the rate of decline has decreased, although numbers of students taking Leaving Certificate Chemistry have again fallen slightly. The contrast with the numbers of students taking Leaving Certificate Biology is marked (see Figure 1).

However, declining numbers of students opting for any subject do not *necessarily* indicate a declining interest in that subject. Students choose examination

There is widespread concern in many countries about the reasons why students' interest in science, or at least in school science, seems to have been in decline. However, declining numbers of students do not necessarily indicate a declining interest in science.

subjects for many reasons. For example, it is known that students perceive chemistry and physics as subjects for which it is hard to achieve high grades. It is also clear that these perceptions are, at least in some respects, well-founded.⁴

A further complication is that, difficulty of examinations apart, one cannot be sure if students turn away from studying a science subject because they are becoming disenchanted with the science they are taught in school (with regard to syllabus content, the way the syllabus is taught, etc.) or if they are showing a dislike of science in a wider context (for example, the way that aspects of biology, chemistry and physics are displayed in the media).

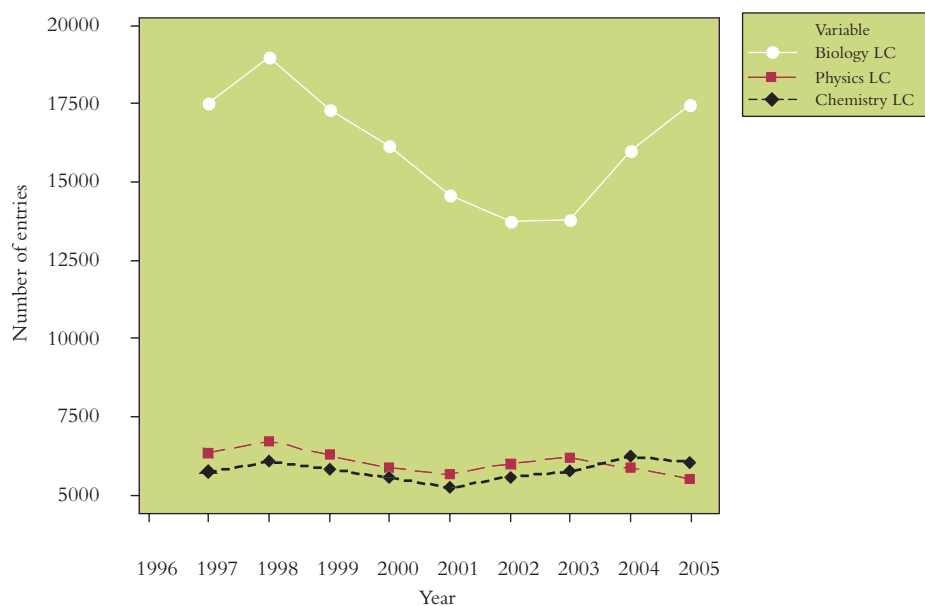


Figure 1 Number of entries in Leaving Certificate Biology, Physics and Chemistry, 1996–2005.

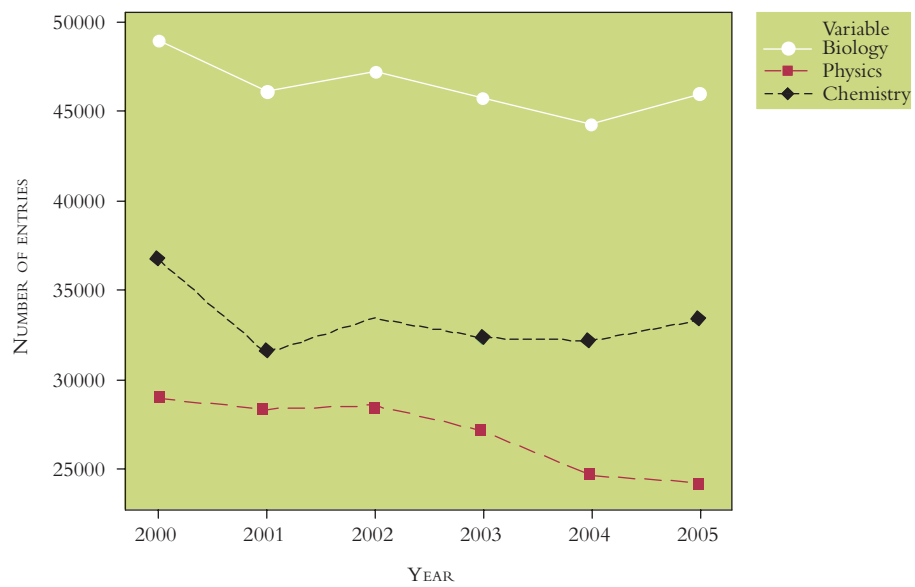


Figure 2 Number of entries for A Level Physics, Chemistry and Biology in England and Wales, 2000–2005.



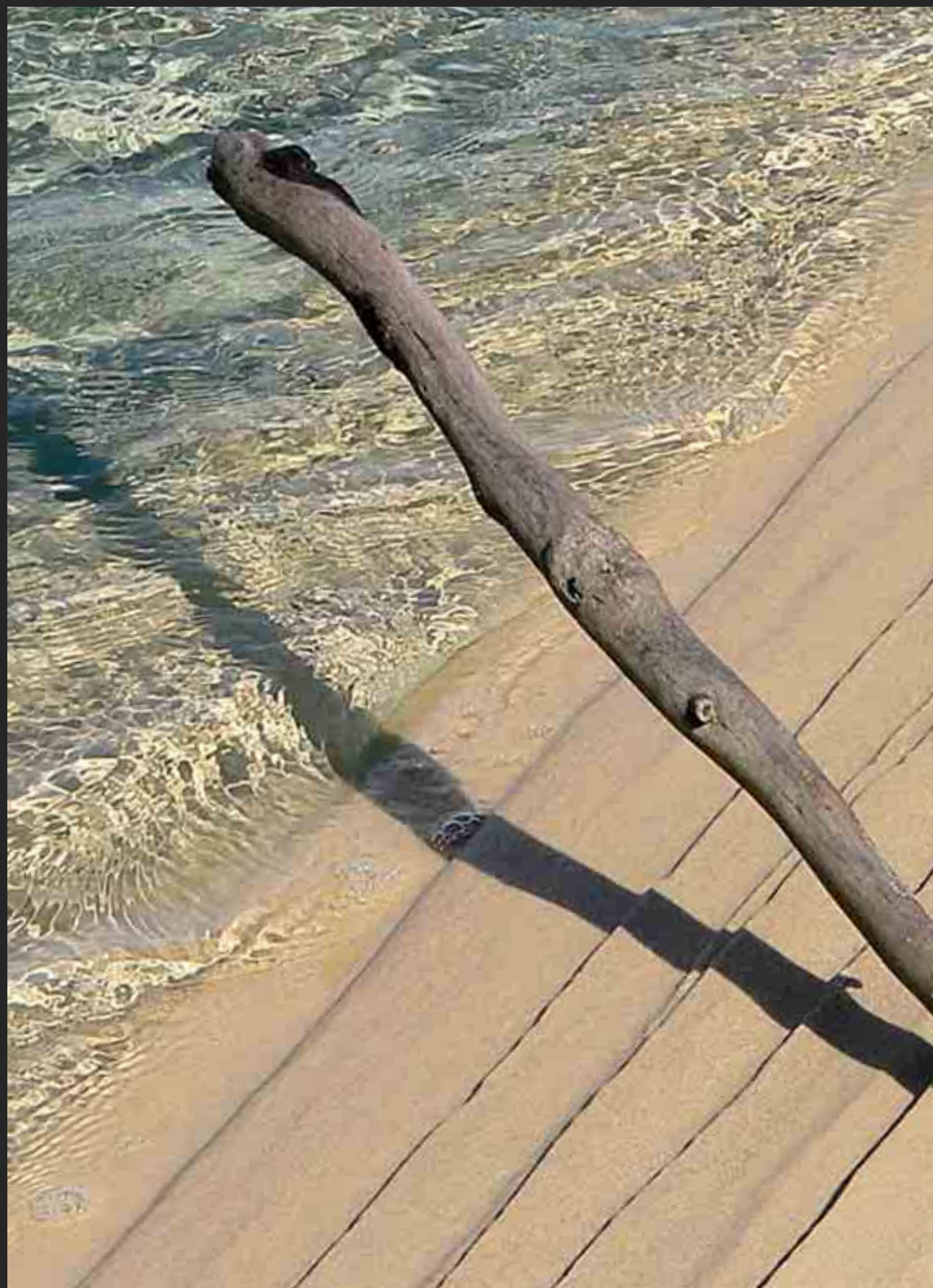
THE RESULTS OF THE ROSE SURVEY



First, it is important to realise that ROSE does not attempt to measure students' knowledge or understanding of scientific principles. Moreover, it does not measure students' ability to think in detail about scientific issues. In this respect ROSE is different from international studies such as PISA or TIMMS.⁵ Instead, ROSE attempts to gather information about students' likes and dislikes in relation to school science and to science in its wider aspects. Not all questions have as much relevance to Irish students as they might have to, say, students in an African country. Indeed, one should be careful in the conclusions one draws from the ROSE data (as one should be with data from any survey). For example, although the sample size in Ireland was not small, we cannot be completely sure that the results would be replicated if the entire population of students had taken part. However, the sample was sufficiently large to give some confidence that the general trends are representative. Students' responses to the questions were scored as follows:

- 1 = 'disagree' or 'not interested'
- 2 = 'low disagree' or 'low not interested'
- 3 = 'low agree' or 'low interested'
- 4 = 'agree' or 'very interested'

Statistically significant gender differences were found in the responses to the great majority of questions, but the size of the differences are not necessarily large

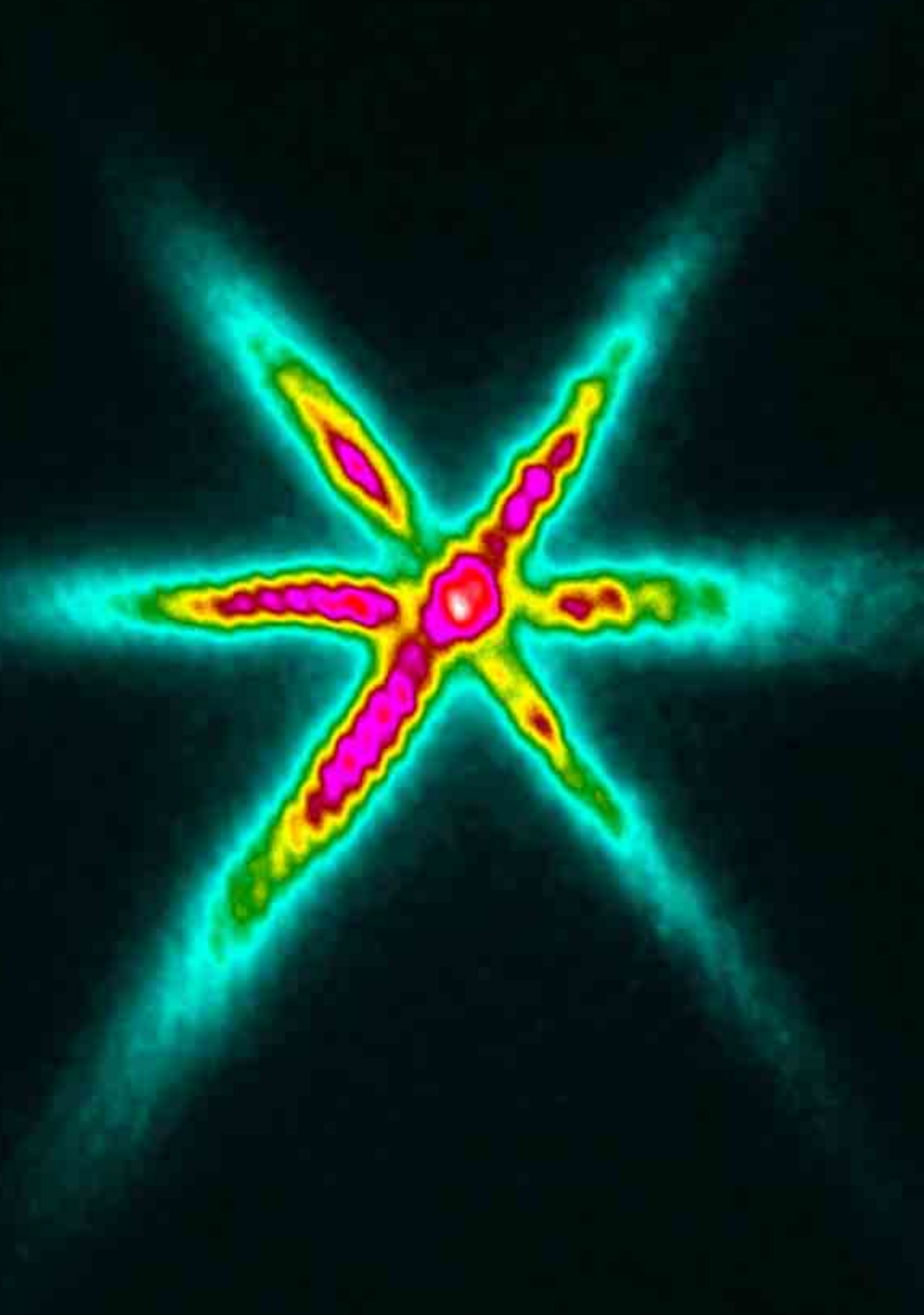




The nature of the individual questions determined which of the sets of choices was used. For example, responses to 'School science is a difficult subject' were scored on the disagree/agree scale, whereas responses to 'I want to learn about how computers work' were scored on the not interested/interested scale.

If students chose the four options in equal proportions, the average score would be 2.5, indicating that, overall, students were equally divided between those that chose the 'negative' responses and those that chose the 'positive' responses. Note that an average of 2.5 does not necessarily mean that equal numbers of students chose each option (1, 2, 3 or 4). They could, for example, have completely ignored the two extreme options and chosen the options scored as 2 and 3 in equal numbers. However, examination of the frequency tables for the choices of the four options shows that such unusual distributions rarely, if ever, occurred. The choice of the four-point scale may also have over-emphasised students' feelings about the many issues that the questionnaire touches on. Some, for example, might have had no particular feeling about a topic but might still have chosen one of the options scored as 2 or 3 because there was no 'neutral' option available.⁶

Gender differences were found in the responses to the great majority of questions, with nearly all of them showing differences between the average scores of girls and boys significant at the 5% level. However, with samples of over 300 people in each category, even numerically small differences in means of the order of 0.2 units will turn out to be significant at the 5% level. That is, even though gender differences in means are often present, their size is not necessarily large.



P R E S E N T A T I O N O F R E S U L T S



Detailed results for all sections in the survey are given on the website. The percentages of students choosing each of the four alternatives on the scales are given, together with the means and medians for the questions. In this document, results are shown as bar charts, with most of the figures showing the means for girls' and boys' responses separately. For many

questions there is a statistically significant difference at the 5% level between the means for the girls and the means for the boys. For this reason it does not make sense to pool the girls' and boys' results. In the illustrations of the results that follow, the girls' and boys' results are presented separately but side-by-side in bar charts. To make the comparisons between questions more obvious, the charts have been given a common format: results are presented in order of decreasing size of mean for the girls. This serves to highlight gender differences, but it will often be seen that the girls' and boys' responses follow a similar order. On a somewhat arbitrary basis I have chosen to regard a mean equal to or greater than (approximately) 3 as 'high', and one less than or equal to (approximately) 2 as 'low'.



‘WHAT I WANT TO LEARN ABOUT’ — SECTIONS A, C AND E



These three sections all had a common purpose, as stated in the common title. In total the sections contain over 100 questions, and it is not possible to discuss each of them individually in this document. As a result, attention is focused on a relatively small number of selected examples. Those discussed are chosen to highlight particularly important aspects of

the generality of questions in the sections, to reflect interesting gender differences, or to signal themes that recur elsewhere in this document. On looking at the questions it is clear that they cover a very wide range of aspects of science/technology. The rationale for choosing the questions is described in detail in the ROSE publications (see note 1) and will not be repeated here. However, it will be seen that many of the questions are related to the broad categories of physics, chemistry and biology. Others refer to wider themes such as health, the universe and the paranormal. Analysis of the Irish students' responses shows that they are similar to those of other ROSE countries, with almost no pattern at all discernable.⁷

For example, where the ROSE team chose questions that they regarded as being about themes in physics, it seems impossible to find a systematic pattern in the way that the students answered those questions, with

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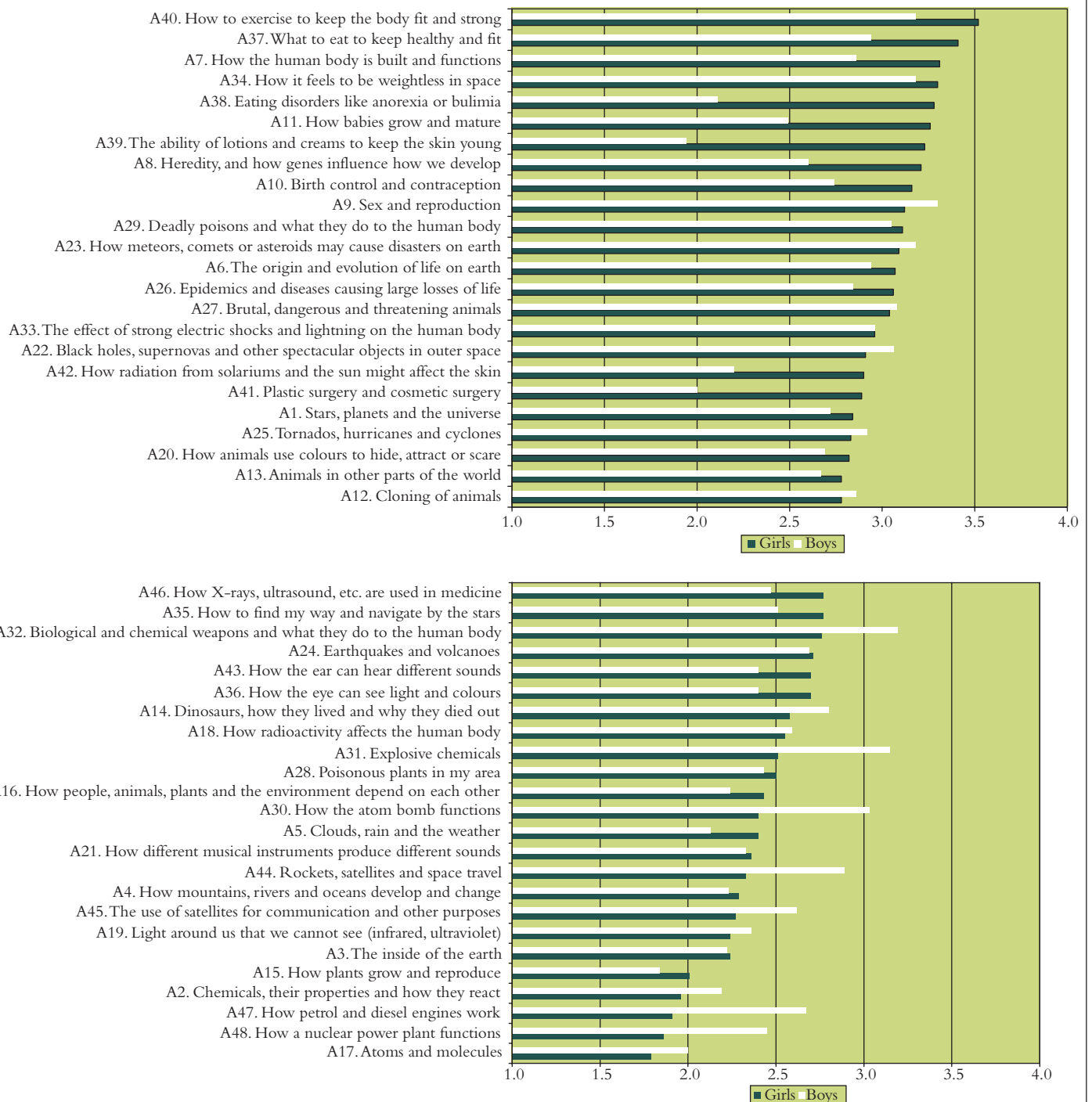


Figure 3 Responses to questions in Section A. Differences in means for questions A2, A5, A7, A8, A10, A11, A14, A30–A32, A35–A48 are all significant at $p < 0.05$.

students answering positively to one ‘physics’ question and negatively to another. In short, students do not appear to think in terms of the scientific disciplines in the way that curriculum designers or trained scientists do: they are much more inclined to make their decisions on a case-by-case basis. Perhaps this is the first lesson that should be learned from the ROSE survey.

SECTION A

Figure 3 shows that there is a general trend in responses: those with the highest means relate to the themes of health, sex, genetics, natural disasters and the origin of life, space and the universe. At the other end of the scale, questions with the lowest means tend to be more specific in their content and relate to topics that have a technical aspect (e.g. how nuclear power plants, rockets and satellites and petrol and diesel engines function). For those who are familiar with the Junior Certificate Science Syllabus, it is of note that the topic of ‘atoms and molecules’, which is at the heart of the chemistry portion of the syllabus, receives the lowest rating by girls and the third lowest rating by boys. Similarly, the topic of ‘how plants grow and reproduce’, which is a key part of the biology section of the syllabus, receives a very low rating from both boys and girls. Conversely, the majority of topics that receive the highest ratings do not form part of the formal syllabus.

Figure 4 illustrates results for questions where the pattern of responses revealed a marked gender difference. The responses show patterns that might be predicted using common stereotypical images of girls’ and boys’ interests. For example, girls are far more interested than boys in eating disorders, babies, and cosmetics, and boys are far more interested than girls in explosive chemicals, nuclear bombs and petrol/diesel engines. This pattern is typical of Western industrialised countries (for international comparisons, see page 61).

The themes of health, sex, genetics, natural disasters and the origin of life, space and the universe are of greatest interest to students



SECTION C

One of the main features of the responses to questions in Section C is that girls are more interested in the majority of topics than are boys. Only three of the means for girls' responses fall below 2.5: those concerning lasers, optical instruments and uses of crude oil. Means for the boys fall below 2.5 for eight of the eighteen questions. It is evident that the themes of questions that receive the highest interest are not featured in the Junior Certificate Science Syllabus (as in Section A). Perhaps this is not unexpected. The present approach to syllabus design is one where the essential focus is on presenting science as a body of knowledge based on a set of principles that are considered to be fundamental to biology, physics and chemistry. Discussion of the applications of science and its historical, philosophical and social foundations is either non-existent or it occurs as an exceptional 'extra' that fits uneasily alongside the scientific principles that are taught as the basis of the syllabus.⁸ I wonder if the National Council for Curriculum Assessment science syllabus committees could consider the use of topics such as the paranormal to elucidate the ways that scientists evaluate evidence and the types of information that scientists consider 'evidence'? It should be feasible to build a syllabus that incorporates both the key scientific principles and many of the topics that most interest students. However, it should be recognised that this would not be a simple matter and that the topics included or excluded would need to reflect the gender-related nature of many of the topics in the ROSE questionnaire.⁹ Some questions in Section C indicate that gender bias does not always fit with one's expectations. Both girls and boys are interested in how mobile phones, CDs, DVDs, TVs and radios and computers work. Thus, there are devices based on physics that students do find interesting that could be used to illustrate the application of a wide range of the key principles/theories of physics. Should one be surprised to find that none of these key twenty-first century devices receive attention in the Junior Certificate Science course and are only referred to in passing in Leaving Certificate Physics?

I wonder if the National Council for Curriculum Assessment science syllabus committees could consider the use of topics such as the paranormal to elucidate the ways that scientists evaluate evidence and the types of information that scientists consider 'evidence'?

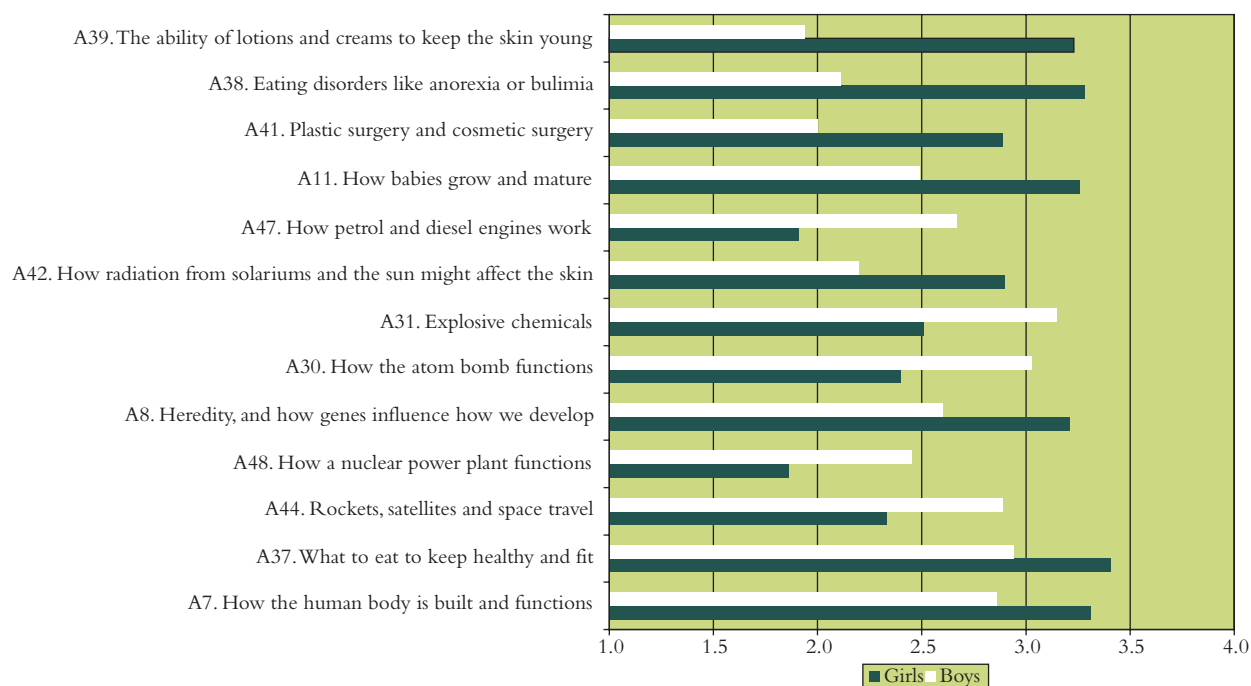


Figure 4 Responses to questions in Section A for which boys' and girls' means differ by at least 0.5.

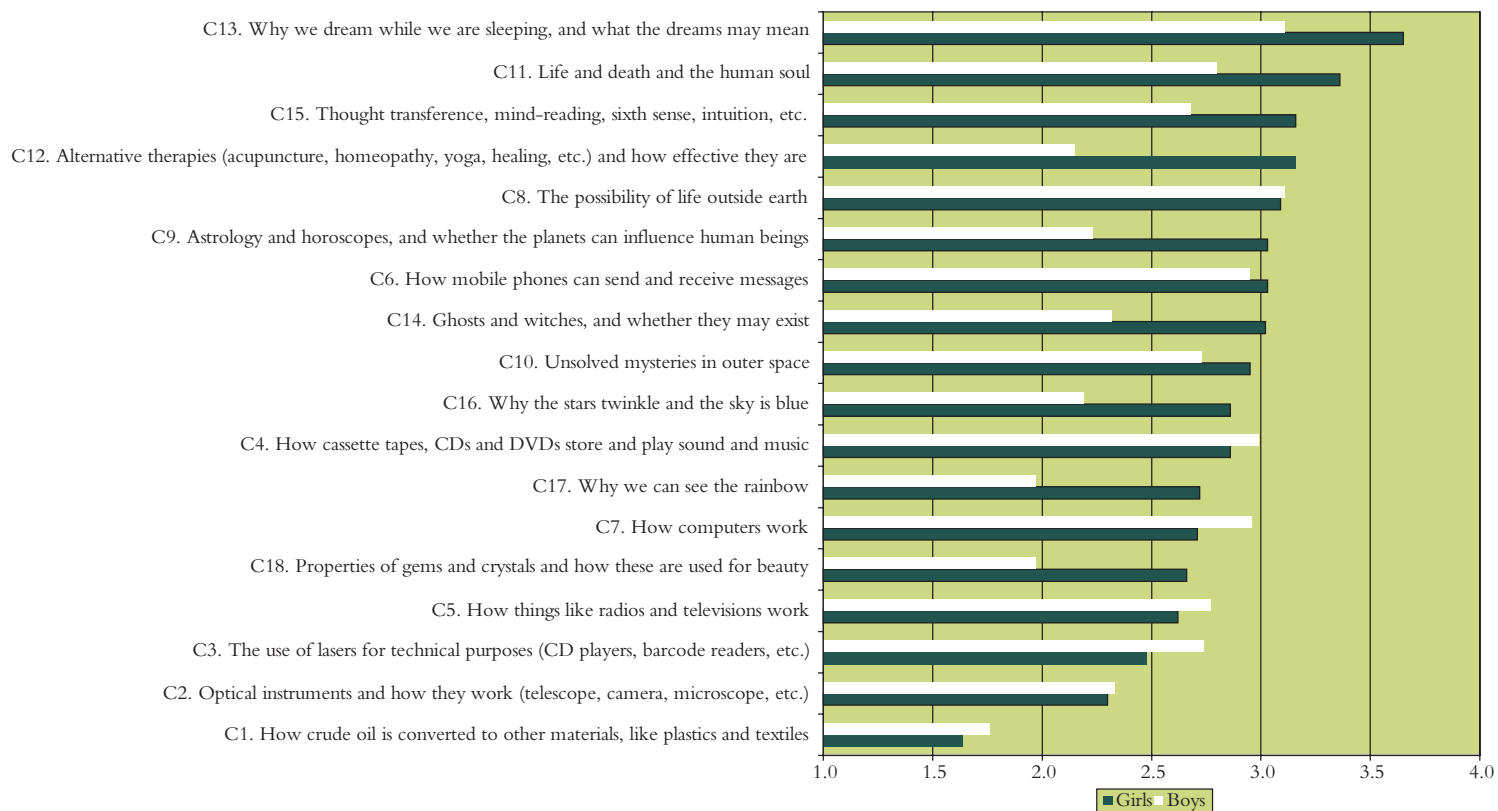
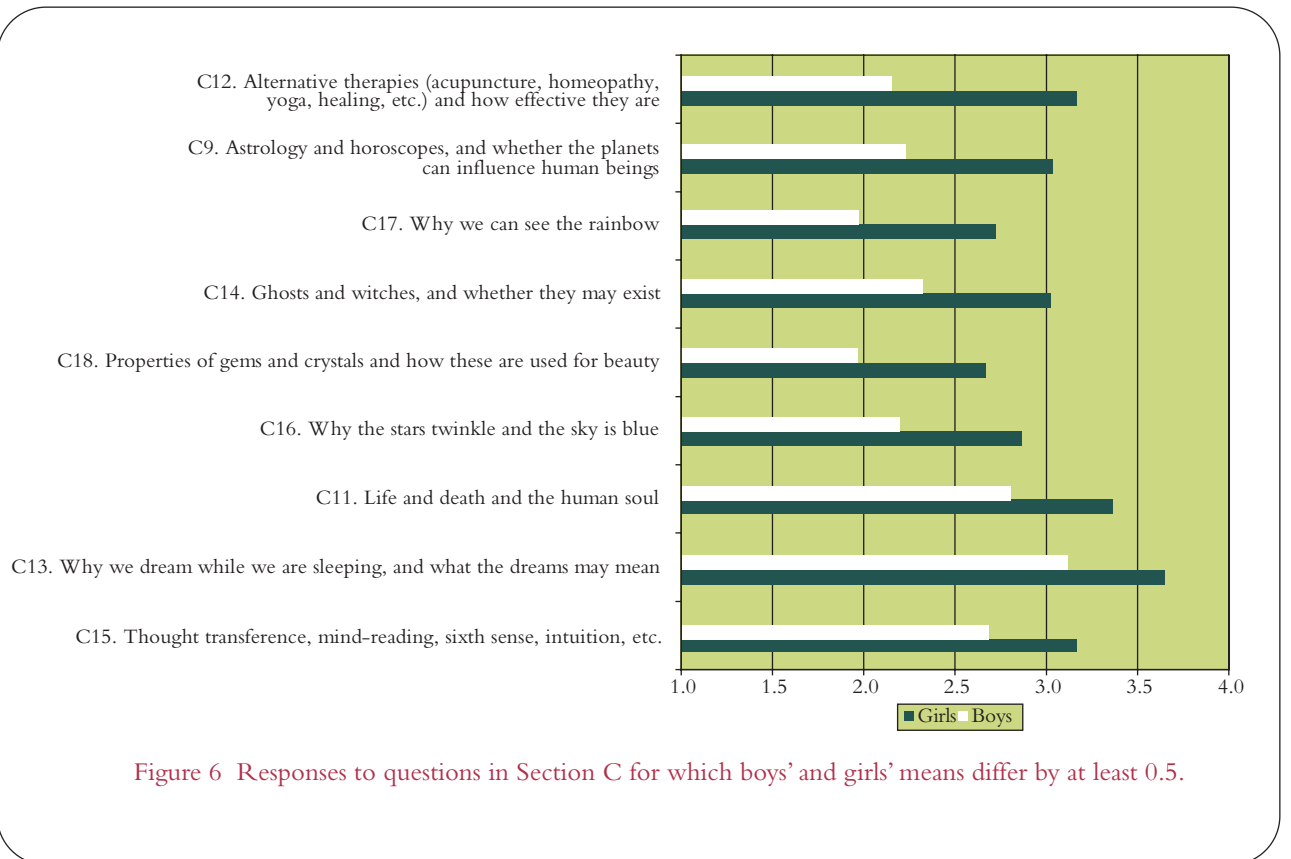


Figure 5 Responses to questions in Section C. Differences in means for questions C3, C5, C7, C9-C16 are all significant at $p < 0.05$.

SECTION E

The results of Section E show a pattern similar to those of Sections A and C. In the main, both boys and girls express interest in topics related to (i) health/disease and the human body, and (ii) space, the universe and the paranormal. With the exception of boys' interest in the use and repair of electrical equipment (E28), the topic of electricity is not of great interest. Neither are topics related to agriculture and to plants in general. See Figures 6, 7, 8 and 9.



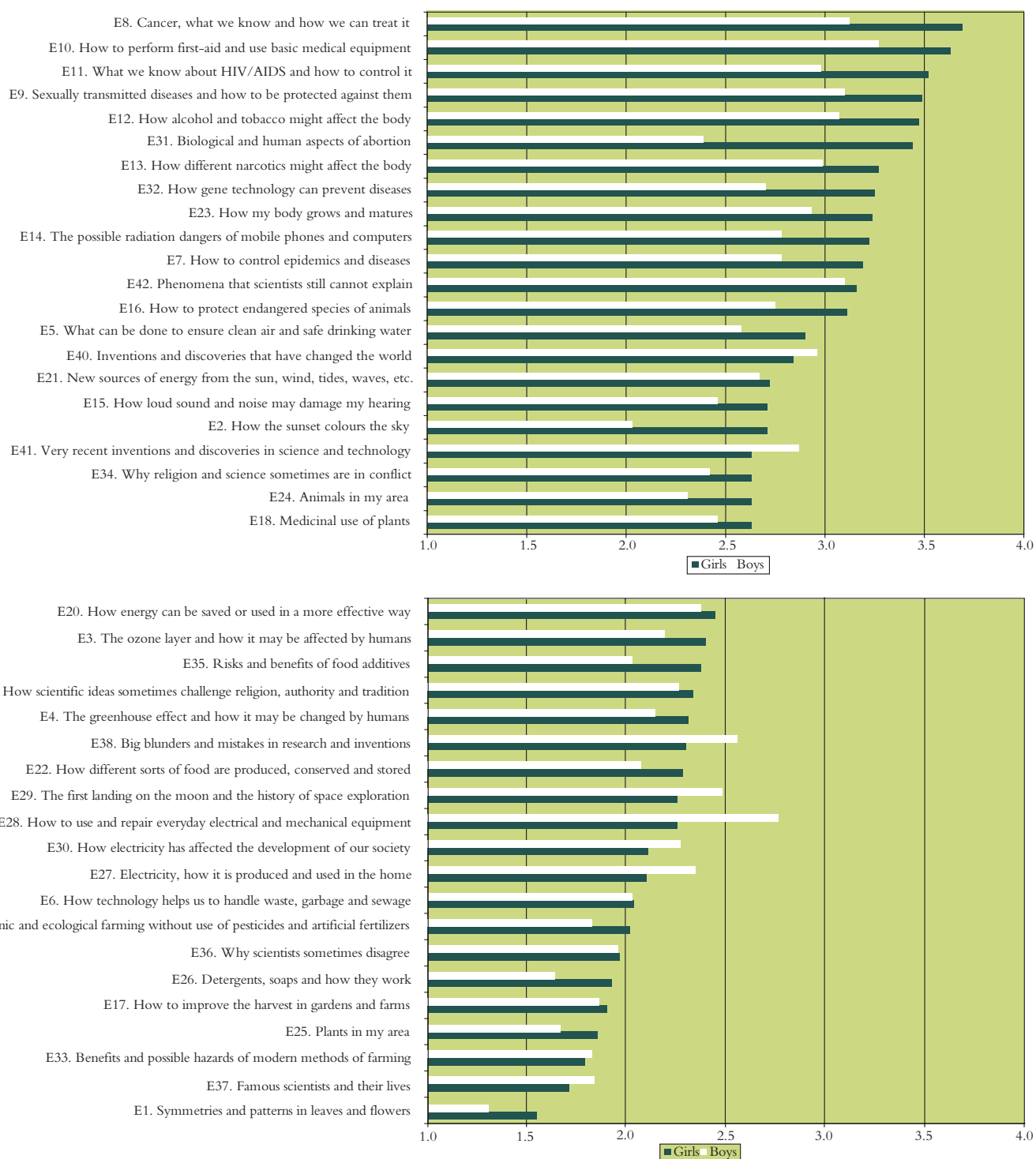
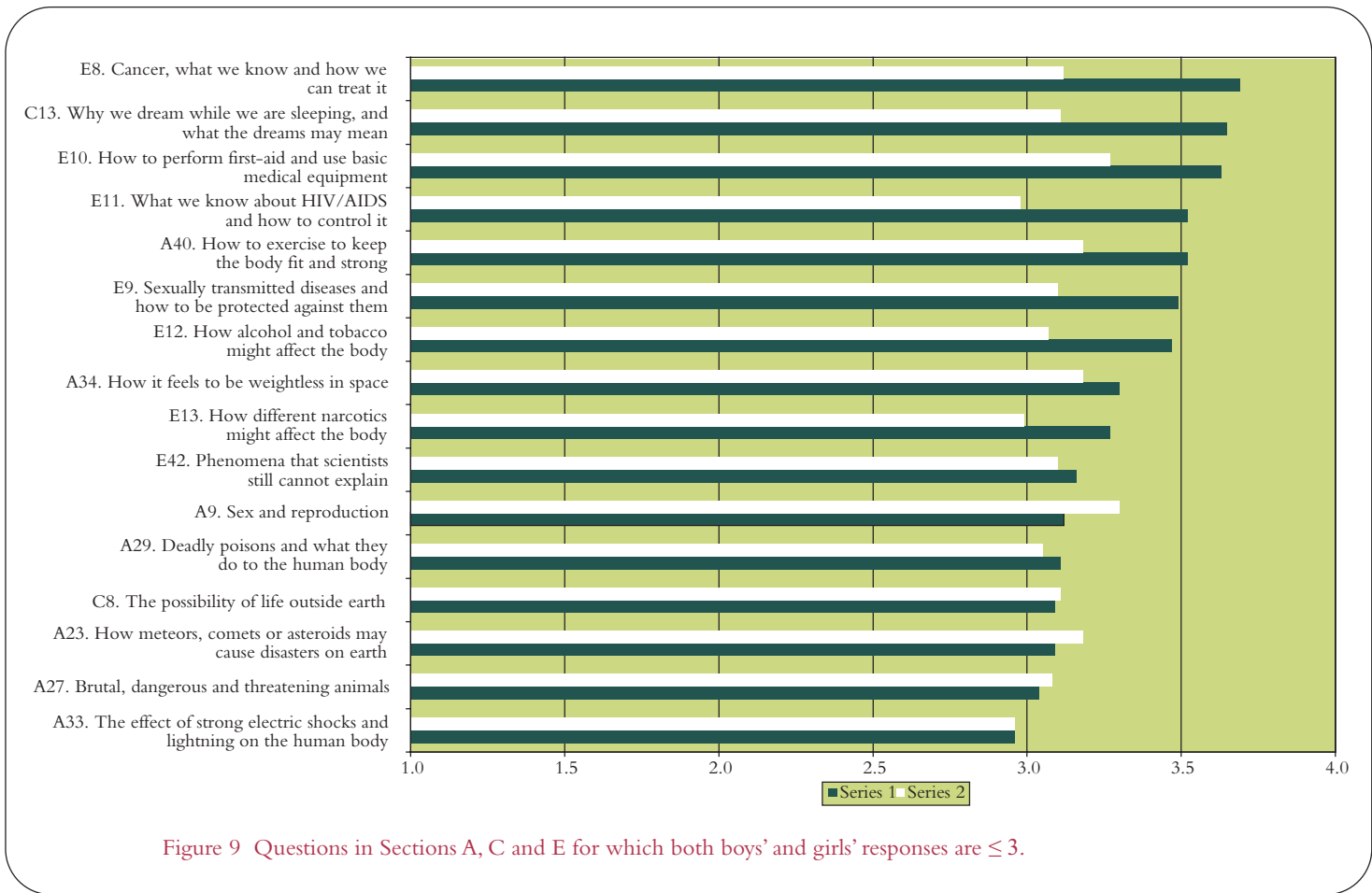
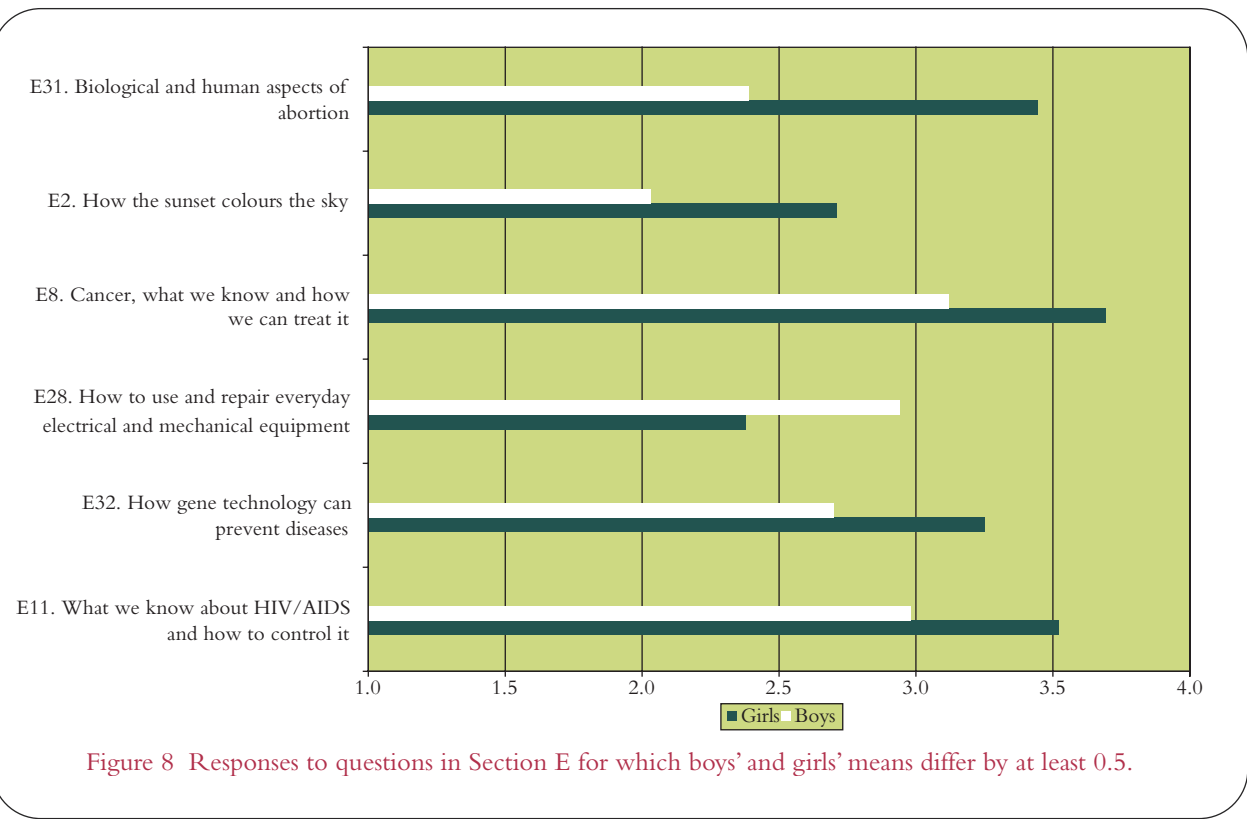


Figure 7 Responses to questions in Section E. Differences in means for questions E1–E5, E7–E16, E19, E22–E35, E38, E41 are all significant at $p < 0.05$.



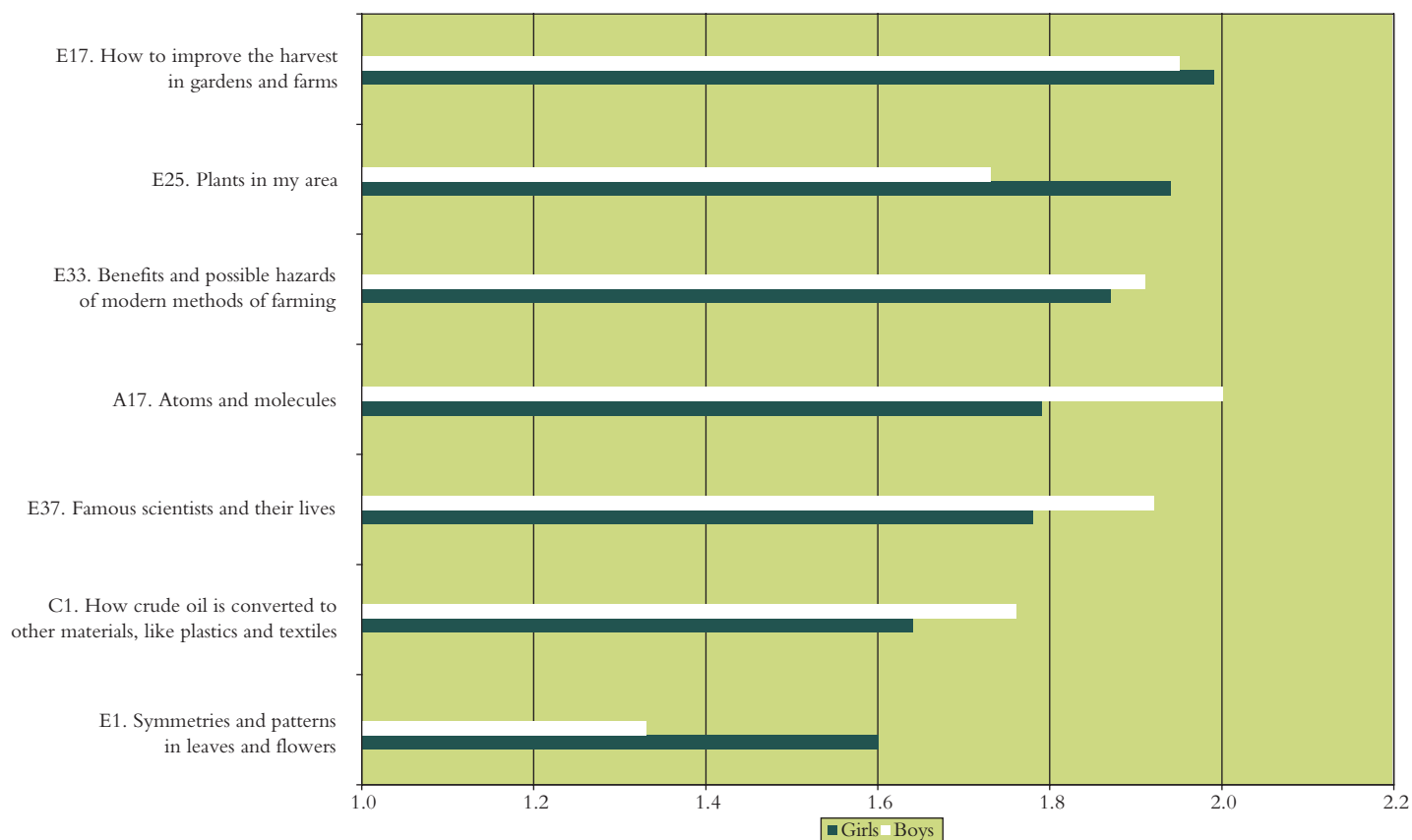


Figure 10 Questions in Sections A, C and E for which both boys' and girls' responses are ≤ 2 .

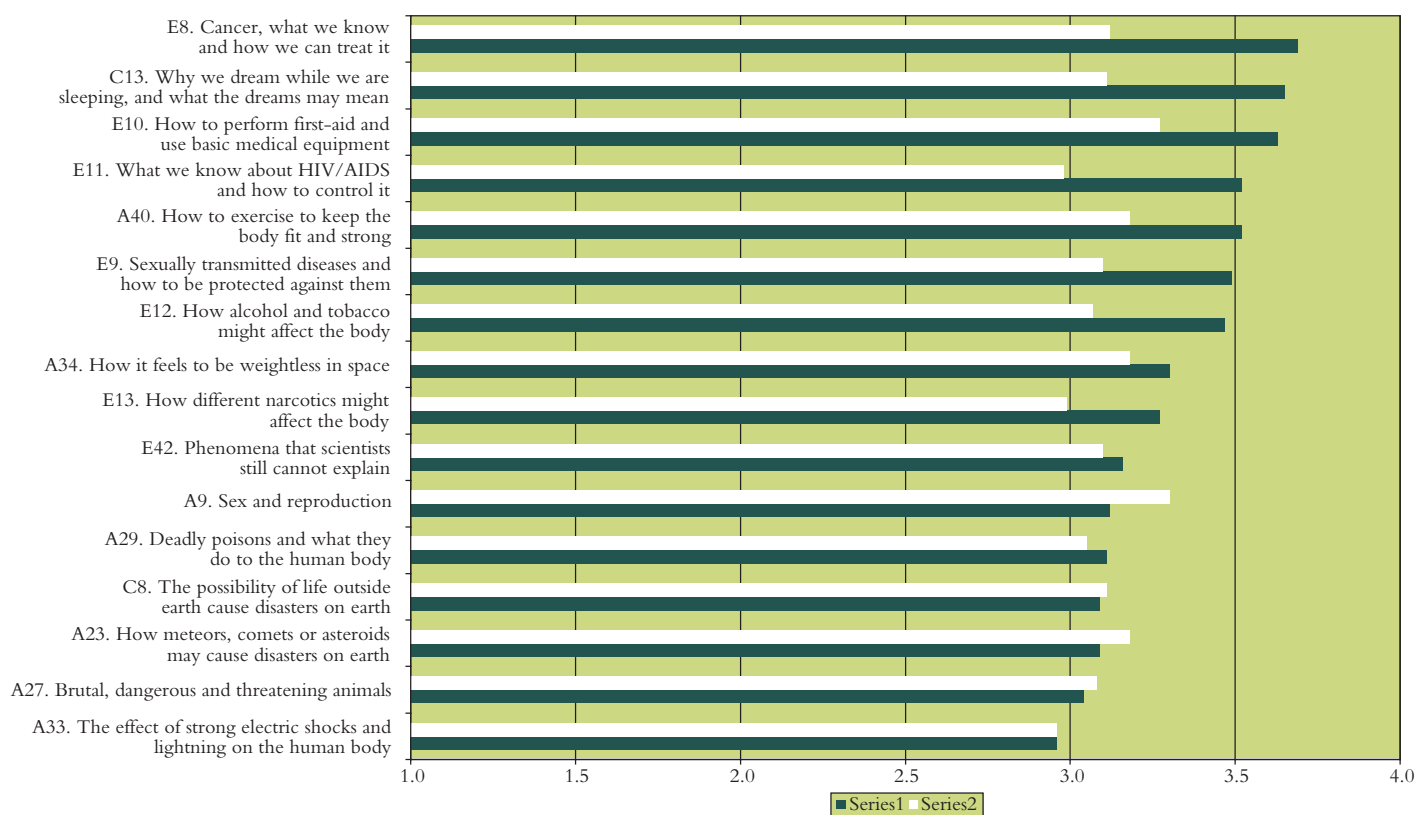


Figure 11 Questions in Sections A, C and E for which both boys' and girls' responses are ≤ 3 (approximately).

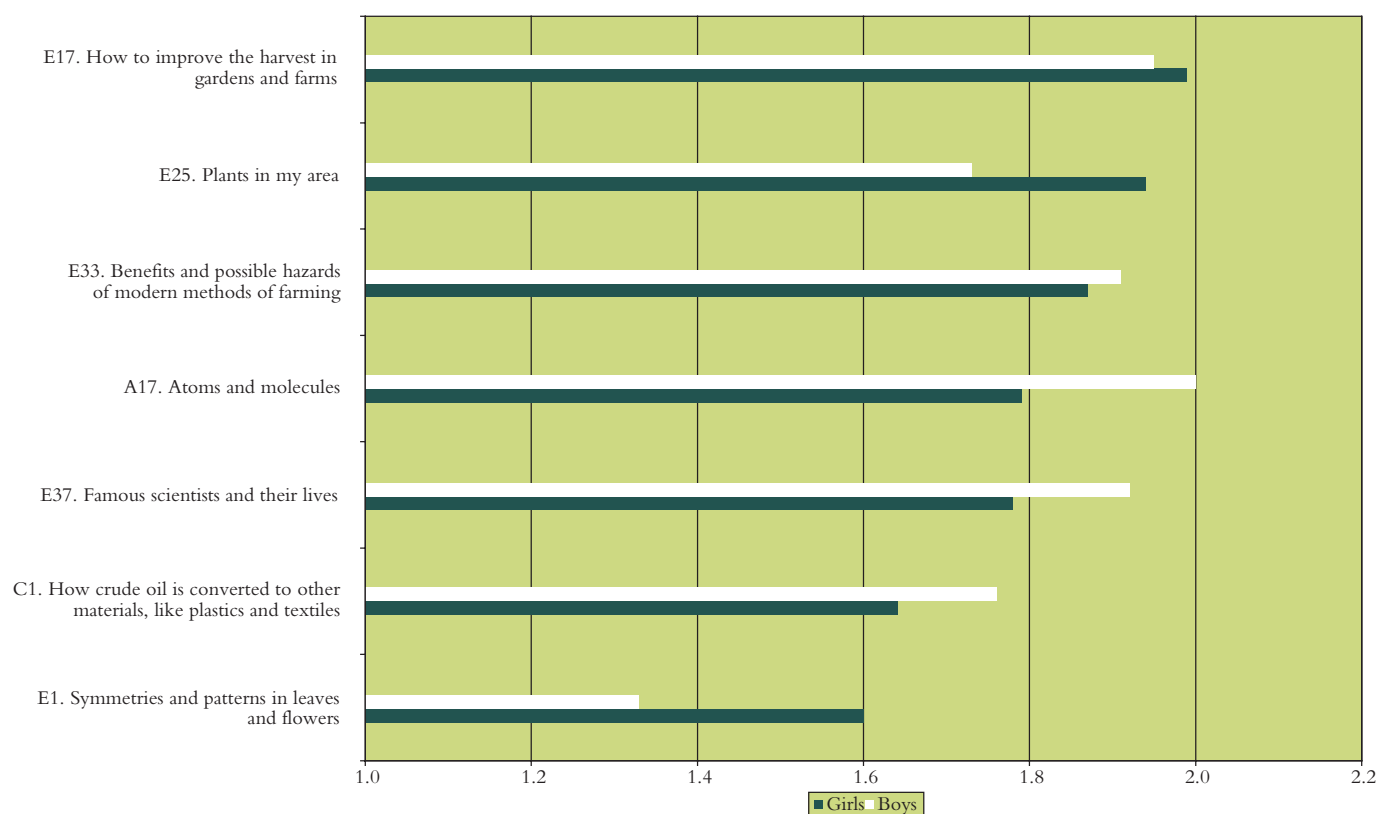


Figure 12 Questions in Sections A, C and E where both boys' and girls' responses are ≤ 2 .



‘MY FUTURE JOB’ — SECTION B



It is apparent that both boys and girls are keen to make use of their individual talents and to seek personal involvement and some degree of autonomy in their future careers—see questions B9 (‘Using my talents and abilities’), B13 (‘Making my own decisions’), B15 (‘Working with something I find important and meaningful’), B16 (‘Working with something that fits my attitudes and values’). At the same time, responses to questions B12 (‘Having lots of time for my friends’) and B17 (‘Having lots of time for my family’) also emphasise that it is not just financial or some other extrinsic reward that these students hope to obtain from employment, although ‘earning lots of money’ is of high importance (B20) (much more so for the boys). In many of the responses that have an average score above 2.5, there is a strong sense that students value personal and social relations as much, and perhaps more, than material rewards. Perhaps this can be regarded as the naivety of youth, but it is an emphasis that potential employers might reflect upon if they are to encourage students to opt for careers in physical science and engineering. These two fields are not renowned for involving students on a deeply personal level or for putting emphasis on their ‘human dimensions’. Neither boys nor girls are looking for ‘an easy option’ (B5), which is a positive response given that their experience of school science generally leads about half of

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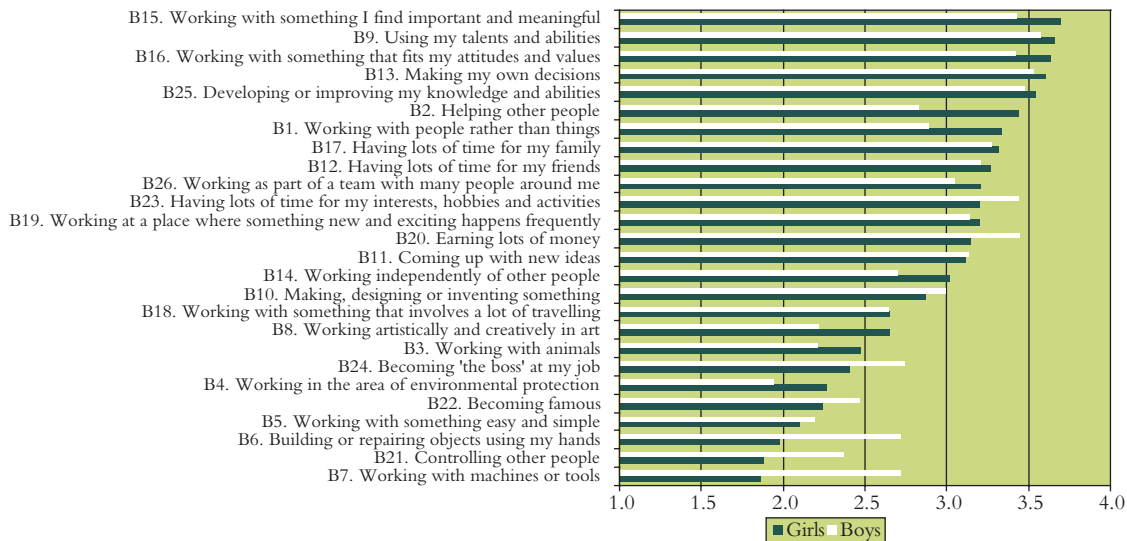


Figure 13 Means for responses to questions in Section B. Differences in means for questions B1–B4, B6–B8, B14–B16 and B22–B24 are all significant at $p < 0.05$.

them to regard science as a difficult, demanding subject (see Section 8 below). If one assumes that this cohort of students is representative of the wider population of students, it is apparent that there is a tricky balance for potential employers between giving students a feel for the variety of challenging and interesting jobs that are increasingly becoming available following third level study and giving them the impression that the technical expertise required for such jobs is demanding and too far removed from direct connection to human needs.

Neither boys nor girls are looking for 'an easy option', even though about half of them regard science as a difficult, demanding subject

The results presented in the lower part of Figure 13 show some marked gender differences in the pattern of responses. Girls

are more averse than boys to jobs that they think involve 'building or repairing objects' (B6) or 'working with machines or tools' (B7). On the other hand, students of either gender are more positively oriented to 'making, designing or inventing' (B10). One should be careful in interpreting these findings. It is not possible to be sure which images the questions conjure up in the minds of the students. If, for example, students envisage using picks and shovels or repairing cars then the results



reflect well-established patterns in studies of gender bias. However, what if the questions had been contextualised by, for example, mentioning the work of a radiotherapist (who certainly has to work with machines)?

The advertising industry knows that brand and image are of paramount importance in marketing. One very crude message that the responses to Section B sends to science educators and business alike is to consider carefully the brand image of science. Indeed, special care needs to be taken over how science and technology are presented to young people. Perhaps the key matter is placing the personal/human relevance of science at the heart of science education, rather than creating and maintaining a curriculum that sees its major concern as the development of the theoretical framework of the sciences, with some applications added on in the hope of 'lightening the load'.

One very crude message that the report sends to science educators and business alike is to consider carefully the brand image of science



‘ME AND THE ENVIRONMENTAL CHALLENGES’ — SECTION D



A person's attitude to the environment is conditioned by a very large number of factors. As is common with human attitudes/opinions in general, a person may hold a combination of views that to an onlooker may appear contradictory or not entirely consistent. Indeed, the reader may have this impression when considering some of the Irish students' views about the environment. Figure 14 shows a bar chart of the mean responses from girls and boys for Section D.

The first fourteen questions evaluate students' sense of their ability to influence the future direction of environmental change. The last four are indicators of what might loosely be called a spiritual dimension to their views on aspects of the environment. A preliminary analysis of the data shows that there are a number of patterns in the students' answers. For example, as might be expected, D15 ('Animals should have the same right to life as people') and D16 ('It is right to use animals in medical experiments if this can save human lives') are negatively correlated, so that students who respond in categories 1 and 2 in one respond in categories 3 or 4 in the other. Responses to D2, D17, D18, to D6, D7 and D14, and to D4, D5 and D11 also show similarities in patterns of response.

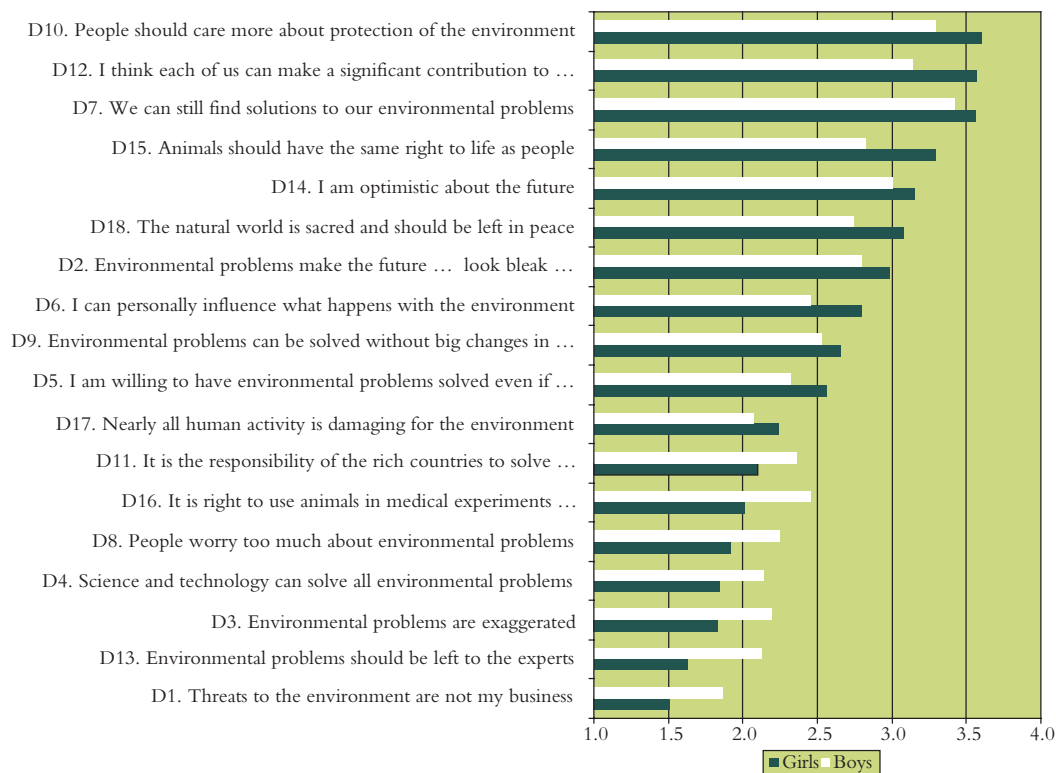


Figure 14 Means for responses to questions in Section D. Only the differences in the means for question D9 and D14 are not significant at $p < 0.05$. Note that bars for the negatively worded question D1 actually represent a very positive attitude to the environment.

Questions D7 ('We can still find solutions to our environmental problems'), D10 ('People should care more about protection of the environment') and D12 ('I think each of us can make a significant contribution to environmental protection') have the strongest positive responses, thus indicating that students' attach importance to individuals' responsibility to care for the environment and have a pronounced sense of optimism for the future.

When answering question G10 ('Science and technology are the cause of the environmental problems') both boys' and girls' averages are very close to 2.5, thereby indicating that opinion is divided about the degree to which science and

technology are responsible for damaging the environment. The answers to D4 ('Science and technology can solve all environmental problems') show that students are less optimistic about science's ability to solve these problems; but the relatively high average responses to question D7 ('We can still find solutions to our environmental problems') indicates a far from hopeless attitude to resolving environmental problems. However, apart from the students' willingness to adopt some (undefined) personal responsibility for action, it is not clear in what ways, or to what extent, they believe their actions can make a difference. Their uncertain stance in this respect is also indicated by question D5 ('I am willing to have environmental problems solved even if this means sacrificing many goods'). Here, overall responses are near the average of 2.5, but with the boys being less willing to make such sacrifices.

Overall, the pattern of responses suggests that both boys and girls have a positive outlook on the future and both believe that the solution to environmental problems lies in the hands of individuals rather than government or science or other (unspecified) experts.



‘MY SCIENCE CLASSES’ — SECTION F



Of all the sections of the ROSE questionnaire, it is Section F that may hold the greatest interest for readers of this document. First, as can be seen from Figure 15, answers to exactly half the questions have means greater than 2.5. However, this does not necessarily indicate a particularly positive outcome for these eight questions. It is evident that none of the means reach a value of 3. The frequency counts for the various choices of the ‘1’, ‘2’, ‘3’ and ‘4’ categories show that no more than 30% of students chose the extreme option ‘agree’ for questions F2 (‘School science is interesting’), F6 (‘I think everybody should learn science at school’), F7 (‘The things that I learn in science at school will be helpful in my everyday life’), F8 (‘I think that the science I learn at school will improve my career chances’), F10 (‘School science has increased my curiosity about things we cannot yet explain’) and F13 (‘School science has taught me how to take better care of my health’).

The majority of girls and boys believe that school science would increase their career chances (F8), that what they learn in science class will help them in their everyday lives (F7) and that it has increased their curiosity about things we cannot yet explain (F10). The majority also agree that school science has taught them how to take better care of their health (F13). For these questions, the girls are more positive in their opinions than the boys, although few of the differences in means



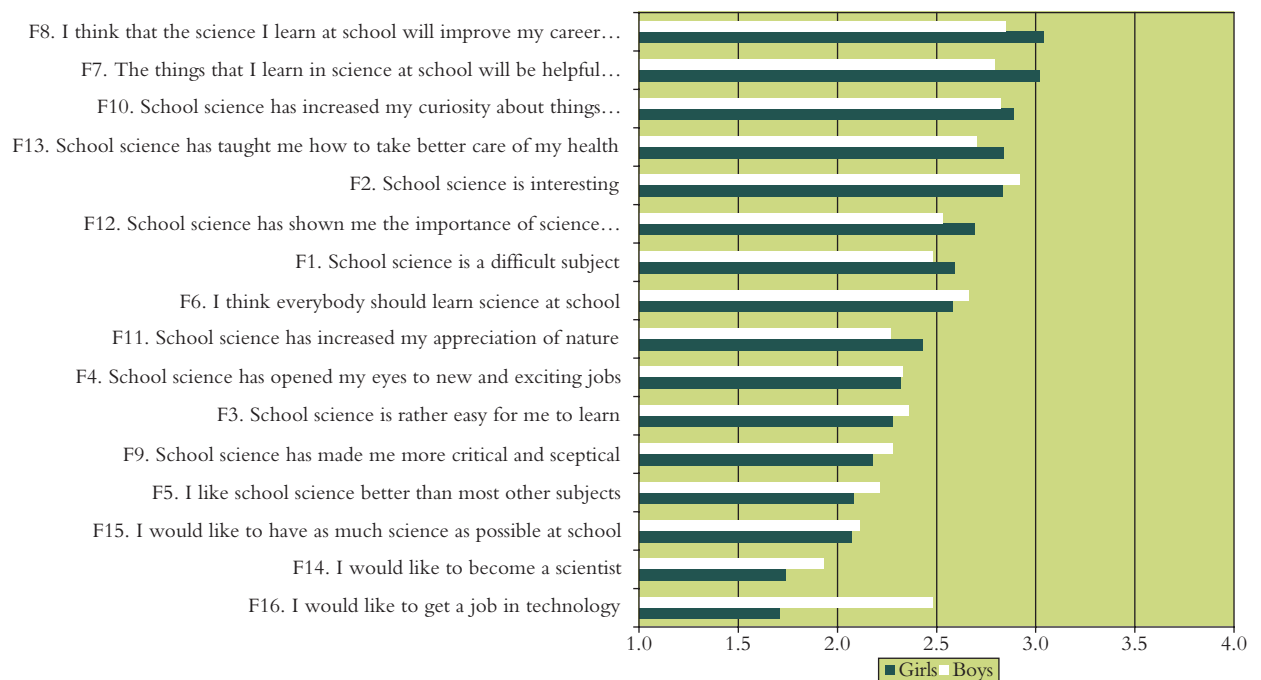
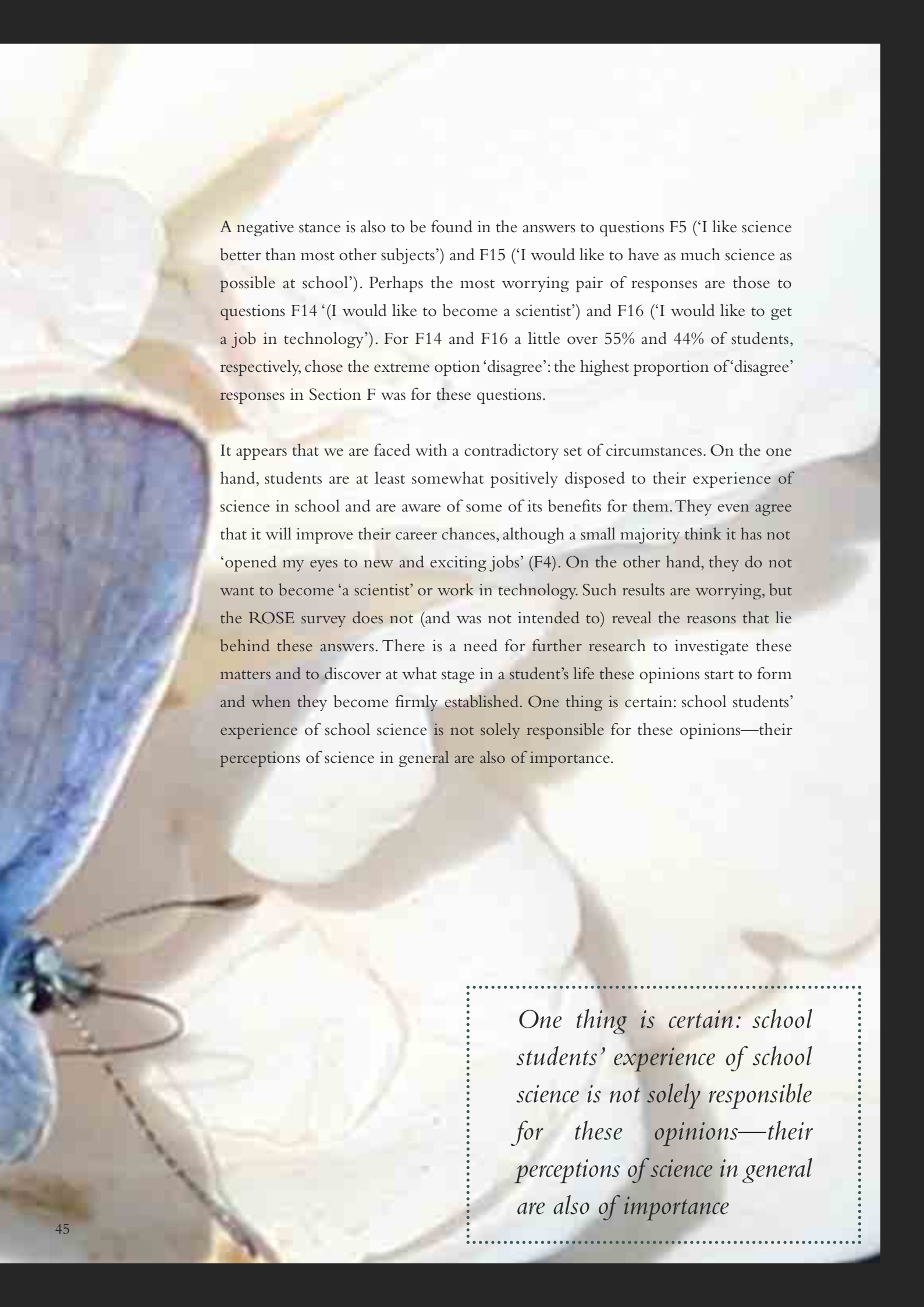


Figure 15 Means for responses to questions in Section F. Only the differences in the means for question F7, F8 and F16 are significant at $p < 0.05$.

are significant at the 5% level. It is pleasing that the majority of students find school science interesting (F2), although in this case girls are less inclined to agree with the statement than boys. In addition, the students believe that their experience of science has shown them the importance of science for 'our way of living' (F12), but with means only a little over 2.5, this is not an overwhelmingly positive endorsement. The frequency counts for the four categories of answer to F1 ('School science is a difficult subject') are almost equally split, with nearly 25% of responses in each category. As might be expected, there is a fairly strong negative correlation of -0.63 between the answers to F1 and F3 ('School science is rather easy for me to learn'). A slight majority of students (54.75%) chose either 'disagree' or 'low disagree' for this statement.





A negative stance is also to be found in the answers to questions F5 ('I like science better than most other subjects') and F15 ('I would like to have as much science as possible at school'). Perhaps the most worrying pair of responses are those to questions F14 ('I would like to become a scientist') and F16 ('I would like to get a job in technology'). For F14 and F16 a little over 55% and 44% of students, respectively, chose the extreme option 'disagree': the highest proportion of 'disagree' responses in Section F was for these questions.

It appears that we are faced with a contradictory set of circumstances. On the one hand, students are at least somewhat positively disposed to their experience of science in school and are aware of some of its benefits for them. They even agree that it will improve their career chances, although a small majority think it has not 'opened my eyes to new and exciting jobs' (F4). On the other hand, they do not want to become 'a scientist' or work in technology. Such results are worrying, but the ROSE survey does not (and was not intended to) reveal the reasons that lie behind these answers. There is a need for further research to investigate these matters and to discover at what stage in a student's life these opinions start to form and when they become firmly established. One thing is certain: school students' experience of school science is not solely responsible for these opinions—their perceptions of science in general are also of importance.

One thing is certain: school students' experience of school science is not solely responsible for these opinions—their perceptions of science in general are also of importance



‘MY OPINIONS ABOUT SCIENCE AND TECHNOLOGY’ — SECTION G



Responses to G2 (‘Science and technology will find cures to diseases such as HIV/AIDS, cancer, etc.’) show that students are optimistic about the ability of science to solve some of the key health problems faced by humans (see Figure 16). In fact, for questions G1 (‘Science and technology are important for society’) and G2 (‘Science and technology will find cures to diseases such as HIV/AIDS, cancer, etc.’) over 80% and 90% (respectively) of students chose options 3 or 4, with the majority of those choosing option 4 (‘agree’). This pattern of response is highly correlated with those of other questions in Section G. An exploratory factor analysis and later confirmatory analysis show that the six Eurobarometer questions together with G11 (‘A country needs science and technology to become developed’) and G12 (‘Science and technology benefit mainly the developed countries’) all load heavily on one factor. One might describe this factor as indicating an overall positive attitude to science and technology, perhaps tinged in the case of G12 (‘Science and technology benefit mainly the developed countries’) with an accurate awareness of the reality of present circumstances. It is noticeable that there is very little difference between boys’ and girls’ responses to these questions.

Students responses indicate an overall positive attitude to science and technology, perhaps tinged with an accurate awareness of the reality of present circumstances

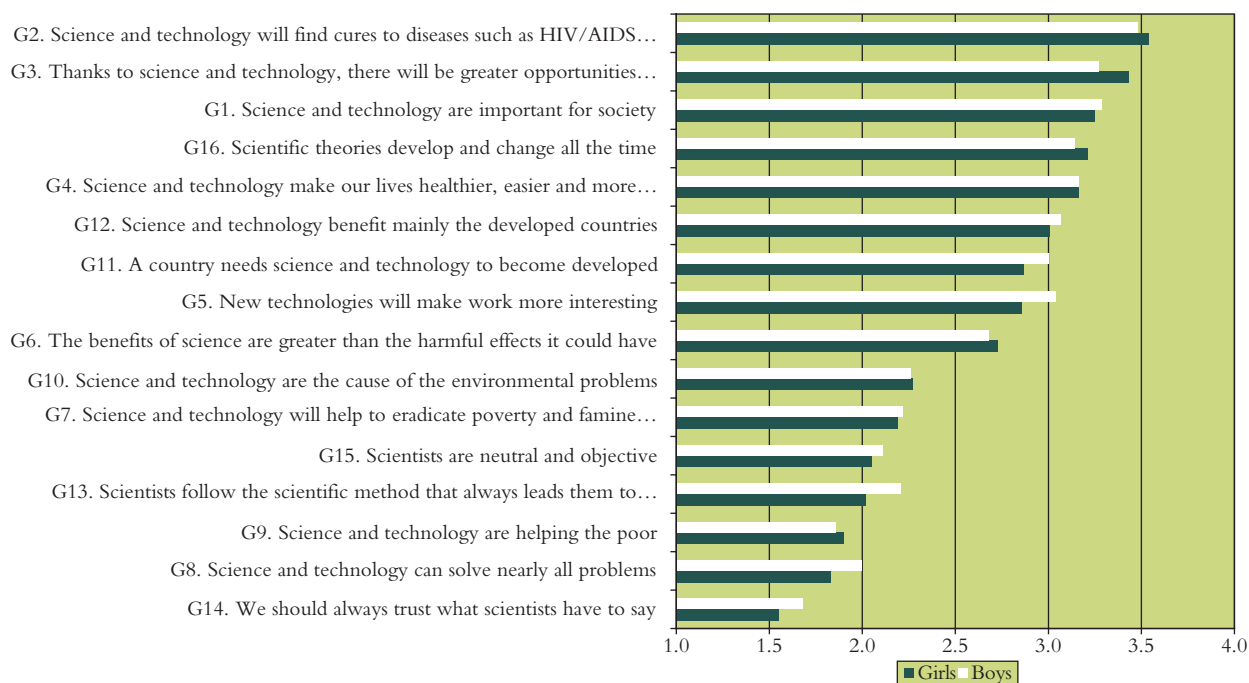


Figure 16 Means for responses to questions in Section G. Only the differences in the means for questions G3, G5, G8 and G13 are significant at $p < 0.05$.

Some questions in this section are identical to those used in the regular series of Eurobarometer surveys that track the European public's view on science and technology.¹⁰ Questions G1 to G6 are examples. Indeed, the pattern of answers to G1 to G6 is very similar to that obtained in the 2005 Eurobarometer survey (which seeks information from people aged fifteen years and over) and in the MORI polls carried out on behalf of the UK Department of Trade and Industry¹¹

Section G also investigated some aspects of students' understanding of the nature of science and their trust in scientists. Almost 86% of the students chose options 'disagree' or 'low disagree' for G14 ('We should always trust what scientists have to say'). If the emphasis is on the 'always' in G14 then perhaps one should be pleased that the students have a critical and thoughtful outlook—it is doubtful if one should 'always'



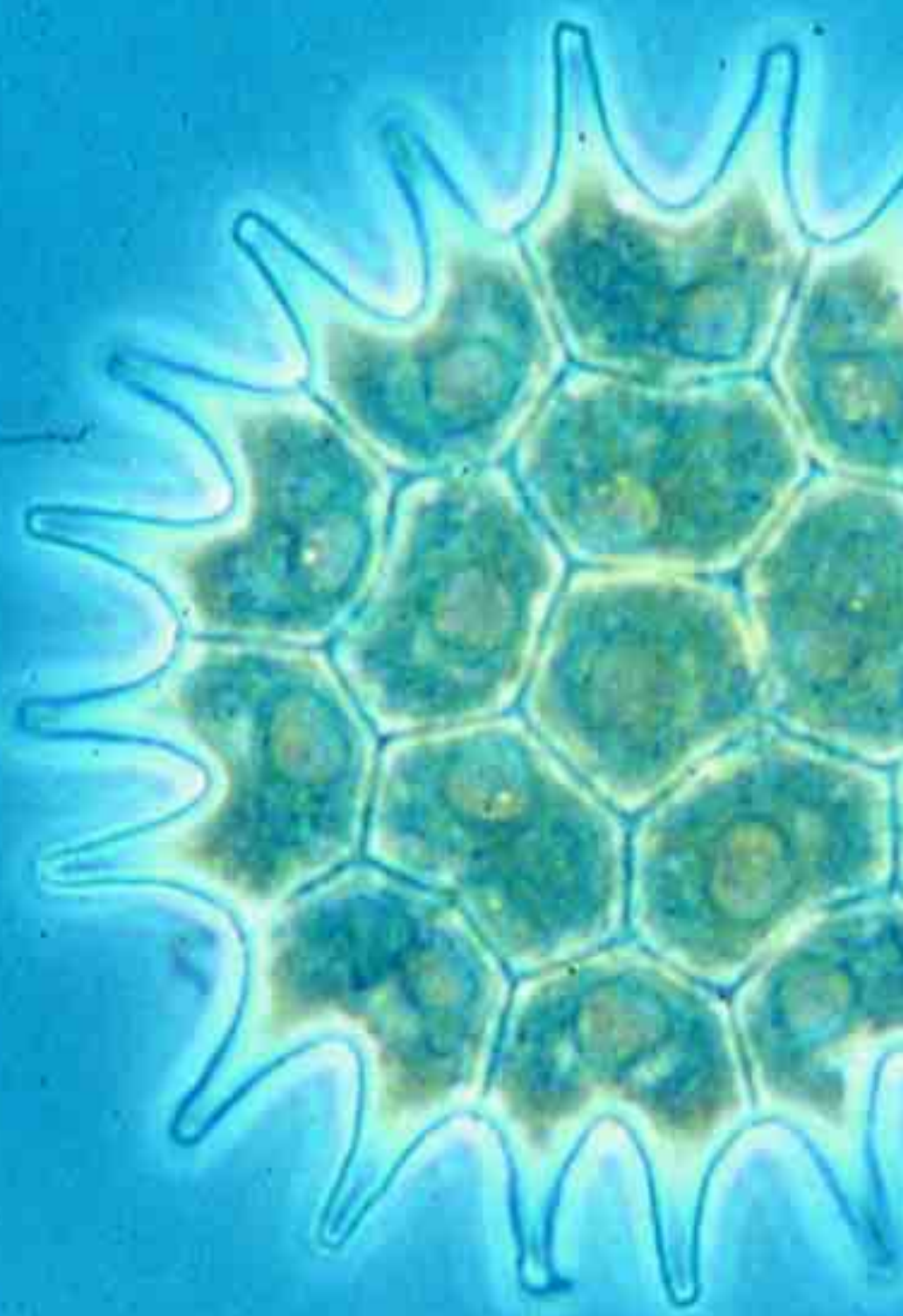
believe anyone just because of their title/status. On the other hand, it is not clear how the students interpret the term 'scientist'. The Eurobarometer and MORI polls ask about the level of people's trust in different categories of scientifically based occupations. For example, doctors and other health care professions receive higher levels of trust than

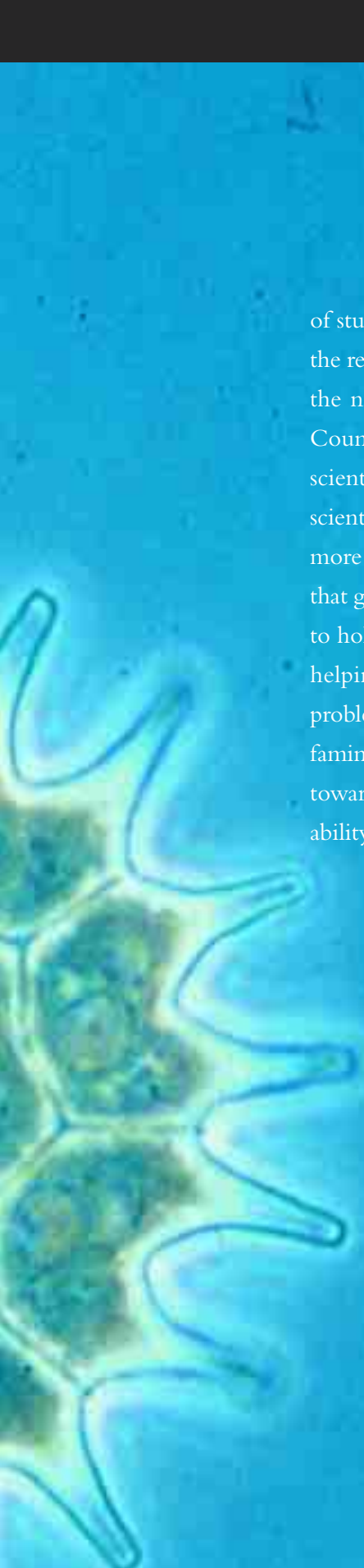
do scientists working in/for other organisations such as universities and charities, who in turn receive higher levels of trust than those scientists working for government agencies. Given the pattern of answers on the Eurobarometer questions (G1 to G6) one might expect that the students would show a similar set of responses if asked about specific professions associated with science.

It would be interesting to discover the reasons why the majority of students do not believe that 'scientists are neutral and objective' (G15). Sociologists of science frequently contend that scientists are rarely neutral and objective;¹² but why or how the students have come to this view is, at present, a mystery. Much the same can be said of the responses to G16 ('Scientific theories develop and change all the time'). At the research level, it is indeed the case that theories do develop and change; in school, students rarely, if ever, meet examples where conflict arises between competing theories. Indeed, school science has long been regarded as a pursuit that transmits scientific knowledge to students as if it were a body of facts certified as true for all time.

The answers to G13 ('Scientists follow the scientific method that always leads them to correct answers') show that the majority

Students are positively disposed towards science and technology in general but are far from convinced of their ability to effect change in relation to some fundamental issues



A microscopic image of plant cells, showing several cells with thick, wavy cell walls and green cytoplasm. The cells are arranged in a cluster, with some showing more prominent nuclei. The image is positioned on the left side of the page, partially overlapping the text area.

of students are not convinced that this is the case—and quite rightly so. However, the reasons why they responded in this way are unclear. Perhaps the students believe the naive claim made in many school textbooks (and endorsed in the National Council for Curriculum and Assessment syllabus documents) that there is a single scientific method. Do they respond negatively to the question because they regard scientists as fallible in that they often fail to follow ‘the’ method? Or are the students more sophisticated than one might think, knowing that there is no single method that governs the behaviour of scientists? It is noticeable that although students tend to hold science in high regard, they do not think that ‘Science and technology are helping the poor’ (G9) or that ‘Science and technology can solve nearly all problems’ (G8) or that ‘Science and technology will help to eradicate poverty and famine in the world’ (G7). Overall it appears that students are positively disposed towards science and technology in general but are far from convinced of their ability to effect change in relation to some fundamental issues.



‘MY OUT-OF-SCHOOL EXPERIENCES’ — SECTION H



Few of the questions in this section have an immediate bearing on school science education in relation to uptake of the physical sciences. For this reason they are not discussed here. However, the results are tabulated on the accompanying website. <http://www.ria.ie/publications/rose.html>



‘MYSELF AS A SCIENTIST’ — SECTION I

The stem of this question reads:

‘Assume that you are grown up and work as a scientist.

You are free to do research that you find important and interesting.

Write some sentences about what you would like to do as a researcher and why.

I would like to ...

Because ...‘



The students’ responses were categorised under the headings shown in Table 1. These categories were set by the ROSE team and were used to classify responses from all the ROSE countries. The entries in the table show the number of students whose responses fell into each category. Note that it is possible for a student to have given answers in several categories.

It is apparent that both boys and girls expressed an interest in biological themes to a far greater extent than in themes related to chemistry or physics. Indeed, the number of responses that mentioned ‘pure’ chemistry-related or physics-related research were remarkably low: just six for girls and

Both boys and girls expressed an interest in biological themes to a far greater extent than in themes related to chemistry or physics. The results are worrying as far as physics, chemistry, engineering and technology are concerned.



	Number (percentage) of responses			
	Girls		Boys	
Biology: human, body	34	(10.3)	31	(8.7)
diseases, medicine, cures	135	(40.9)	81	(22.6)
microbiology, gene technology	9	(2.7)	25	(7.0)
animals, plants, nature	39	(11.8)	29	(8.1)
other biology-related	16	(4.8)	7	(2.0)
Technology: computers, electronics, new technologies	5	(1.5)	18	(5.0)
motors, buildings, roads, cars, transport	2	(0.6)	17	(4.7)
weapons	0	(0)	5	(1.4)
other technology-related	8	(2.4)	10	(2.8)
Environment	10	(3.0)	14	(3.9)
Earth, weather, climate	3	(0.9)	2	(0.6)
Chemistry: atoms, reactions etc	3	(0.9)	4	(1.1)
Physics: electricity, heat, etc	4	(1.2)	5	(1.4)
Space, stars, planets, black holes, space travel	41	(12.4)	55	(15.4)
Psychology, human behaviour	12	(3.6)	4	(1.1)
Invent things	0	(0)	3	(0.8)
Do experiments, work in a laboratory	1	(0.3)	1	(0.3)
Paranormal, philosophical, mysterious, wonder	13	(3.9)	12	(3.4)
Social and economic sciences	1	(0.3)	2	(0.6)
Do not want to do research	0	(0)	0	(0)
Other	18	(5.5)	30	(8.4)
Responses giving reasons why choices have been made				
Curiosity, interests, seems fun, want to, exciting	158	(47.9)	168	(46.9)
Related to the profession I want	13	(3.9)	7	(2.0)
Important in general for society/humanity	48	(14.5)	47	(13.1)
Help people, animals etc	103	(31.2)	77	(21.5)
Get rich, popular, famous	0	(0)	6	(1.7)
Other	17	(5.2)	34	(9.5)

Table 1 Responses to Section I: Myself as a scientist.

nine for boys. Likewise, the number of choices related to technology for girls was just fifteen. The total of 50 for the boys is considerably greater, as would be expected, given the usual gender bias in relation to technology. However, even this number is far below the 173 biology-related entries mentioned by the boys. Again, not unexpectedly, the girls gave the largest number of entries of interest in the biology sections—a total of 233.

Both boys and girls showed an interest in space and astronomy themes (41 for the girls, and 55 for the boys), but this should be considered in the context of the very low physics score. A gender difference is apparent here, but the figures suggest that if one considers space and astronomy as essentially associated with physics, then these topics/fields should be given more emphasis in physics curricula, especially if the subject is to be made more appealing to girls.

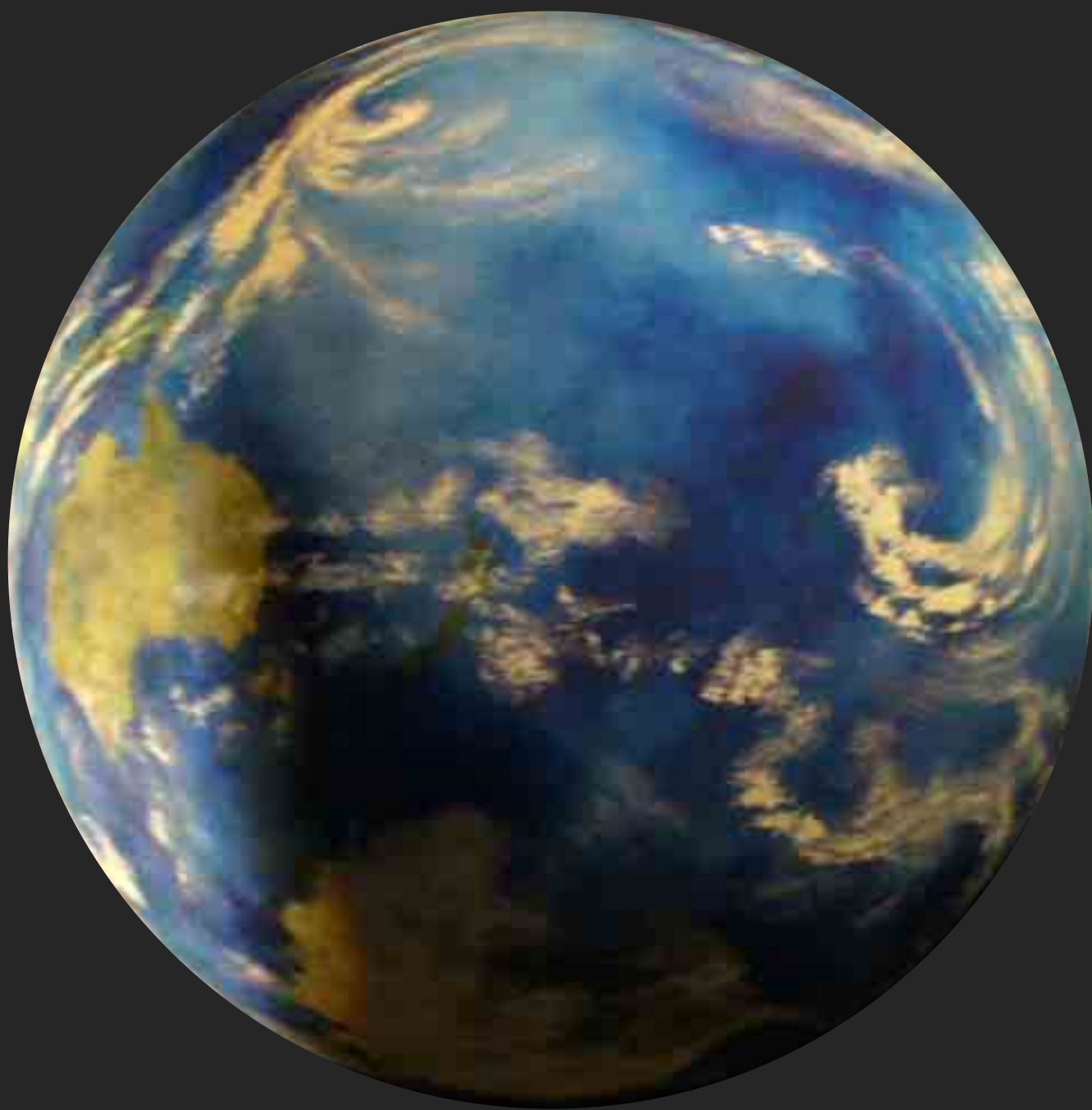
Given that the students gave free, unprompted responses to this section of the questionnaire, the results are worrying as far as physics, chemistry, engineering and technology are concerned (see Table 1). We do not know if the students did not mention activities in these areas because they had a distinct lack of interest in them, or if (for example) they were simply ignorant of opportunities for research and work in these fields. Science that tends to be covered in the media is strongly biased in favour of genetics/health issues. It is not uncommon for new ‘cures’ for various illnesses or diseases to be announced and given television time. Physics or engineering developments are rarely given any coverage. It would, for example, be a brave news editor that gave air-time to the announcement of a new chip-set by Intel or AMD or to a discussion of the drilling technology that allowed the Dublin Port Tunnel to be built.

The reasons given by both girls and boys for wanting to work in the areas they chose were dominated by their intrinsic interest—almost the same percentage of girls (47.9%) and of boys (46.9%) gave ‘curiosity, interests, seems fun, want to, exciting’ as their reasons (see Table 1). There was also a heavy emphasis on the

perceived importance of their choices for society and their role in helping people, animals, etc. This tends to emphasise the perception that students may have of the three main parts of science that they experience at school—biology is related to people and living things, with a clear link to medicine and other health-related developments in society, whereas physics and chemistry seem to lack that link. Adults trained in physics and chemistry and advanced biological science will know that behind every development in, for example, gene technology there lies a huge amount of chemistry, physics and engineering/technology, but for school students the link is far removed from their common experience. Similarly, people experience the fruits of pure and applied research in the physical sciences and technology/engineering to a huge extent in their everyday lives, but such applications as television, radio, iPods, computers, motor cars, etc. go largely unremarked: they are part of the ‘wallpaper’ of everyday living.¹³

The results of this section of the survey show that there is an especially large gap between the physics and chemistry aspects of school science in the Junior Certificate and Leaving Certificate courses and students’ interests.

There is an especially large gap between the physics and chemistry aspects of school science in the Junior Certificate and Leaving Certificate courses and students’ interests



INTERNATIONAL COMPARISONS



First, I would like to thank Professor Svein Sjøberg, Director of the ROSE project, for permission to use the data and to reproduce the graphs relating to this section. The data for all the ROSE countries was analysed and the graphs created by the small team in Oslo under Professor Sjøberg's direction.

The graphs showing the responses from the ROSE countries follow a similar format. The order of countries on the vertical axis follows the (inverse) size of their Human Development Index (consult <http://hdr.undp.org/>). Nordic countries appear at the bottom of the axis and African countries at the top of the axis, with Western, Central and Southern European countries, the Indian subcontinent and South East Asia falling between the two. Thus, Western industrialised nations fall into the lower half and less industrialised economies fall into the upper half of the continuum. The horizontal axis represents the spread of values of mean responses to each of the questions. As before, the scale ranges from 1 ('disagree') to 4 ('agree').

There is a common pattern of responses among students in Western industrialised countries—it follows that the reasons that lie behind the Irish students' responses to the survey cannot just be due to the content of the Junior Certificate Science course, or the way it is taught

It is clear that that students from Western industrialised countries had far more negative responses than students from Africa and Asia. One possible explanation of the Western students' responses has been alluded to earlier. The products of advanced science and technology have become ubiquitous and are now very much 'taken for granted' in the West. People are no longer surprised that a cure for a type of cancer has been discovered or that one can operate electronic equipment at a distance. Such possibilities were, but one or two generations ago, the stuff of science fiction. When, for example, penicillin first became widely available and polio became preventable through the use of a vaccine, they were heralded as amazing discoveries. Men such as Fleming and Salk were in some ways regarded as heroic figures—they did battle with, and overcame, nature. No longer are major scientific advances thought of in the same light, nor are scientists so venerated in their own time and milieu.¹⁴

In less-industrialised countries, many people's encounters with science are more immediate and novel, much as





they were in the West some 50 to 60 years ago. Perhaps they regard 'new technology' as really new and not just 'more of the same'. Perhaps the students in these countries look at the West and see with a fresh eye just how large a part science and technology play in society.

In any event, the international comparisons that follow show that there is a common pattern of responses among students in Western industrialised countries. It follows that the reasons that lie behind the Irish students' responses to the survey cannot just be due to the content of the Junior Certificate Science course, or the way it is taught.

There are too many questions in the ROSE survey and too little space in this document to allow discussion of all the international comparisons (please refer to the website <http://www.ria.ie/publications/rose.html> for links that lead to the full set of international comparisons). In the main, the only questions discussed are those for which the Irish responses are different from the general trend or where the similarity to the responses from other countries is especially marked.

‘What I want to learn about’— Sections A, C and E

Graphs showing the means for the ROSE countries suggest three generalisations: (i) there is far more agreement than disagreement across countries about what students would like and would not like to learn about; (ii) the gender differences shown in the Irish students’ responses tend to be shared across other Western countries, and (iii) the means for the Western countries are smaller than for the less-industrialised countries. Figures 17–30 illustrate these trends.

The responses to question E37 (‘Famous scientists and their lives’) is of interest in that it might throw light on the attitudes that young people have to science (see Figure 17). It is apparent that the Irish students are (once again) typical of students in the industrialised countries. However, (with a few exceptions) the lesser the degree of industrialisation, the greater is the interest shown by the students.

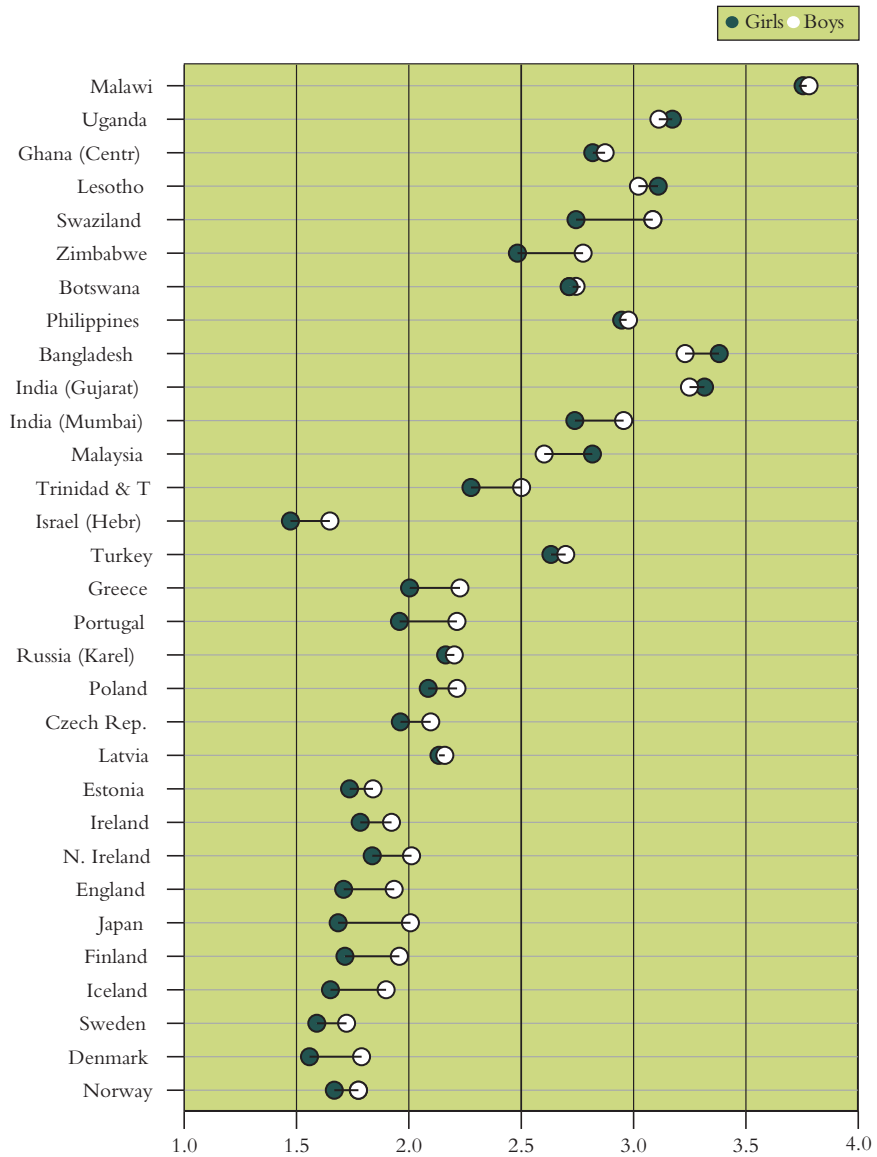


Figure 17 International means for question E37: Famous scientists and their lives.

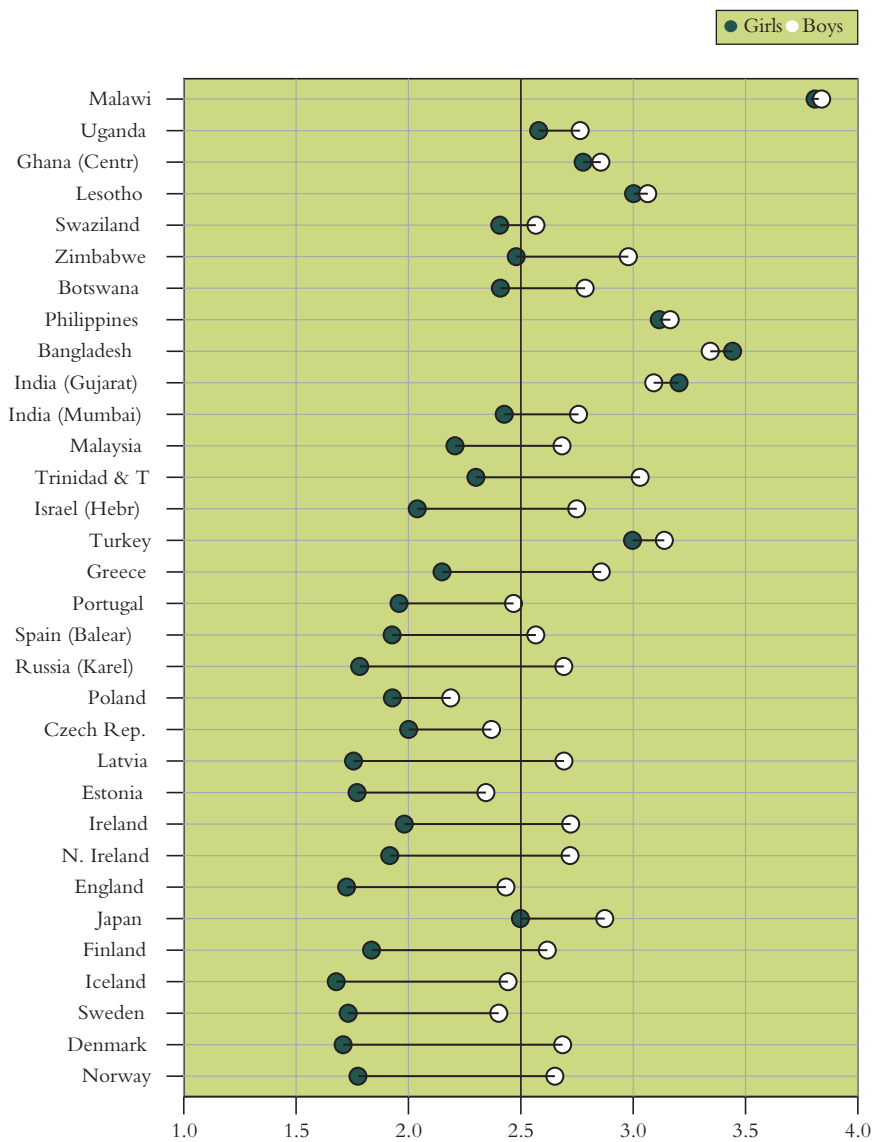


Figure 18 International means for question B6:
Building or repairing objects using my hands.

‘My future job’—Section B

In all questions, the Irish students responses grouped together towards the bottom left of the graphs, together with the responses from students in Nordic and other European countries. Figure 18 shows a consistent gender bias except in a few African countries and Indian states, with girls showing marked reluctance for jobs that involve ‘Building or repairing objects with my hands’. It may be that in countries with less difference between the girls’ and boys’ views, students of either sex are expected to undertake manual work on a daily basis, for example in farming.

Figure 19 shows the graph for question B12. The interest here is in the small difference between the Irish girls and boys compared to other industrialised countries, and the relative lack of concern for ‘having lots of time for my friends’ shown by the less economically developed countries. One may guess that for students in the latter countries, work of any description is highly valued, and by comparison the matter of friends is of little consequence. It is noticeable that the Nordic countries, which have a reputation for encouraging gender equality, have much larger differences in responses between the girls and boys than are shown in Ireland. Similarly large gender-based differences in the Nordic countries are found for many other questions (not just Section B). The means of Japanese girls’ and boys’ responses are sometimes very different from other industrialised countries. In international surveys, results relating to some aspects of the Japanese education system are often markedly different from findings from other economically developed countries.¹⁵

The responses to question B25 (‘Developing and improving my knowledge and abilities’), illustrated in Figure 20, show a marked degree of similarity for all countries.

It is noticeable that the Nordic countries, which have a reputation for encouraging gender equality, have much larger differences in responses between the girls and boys than are shown in Ireland

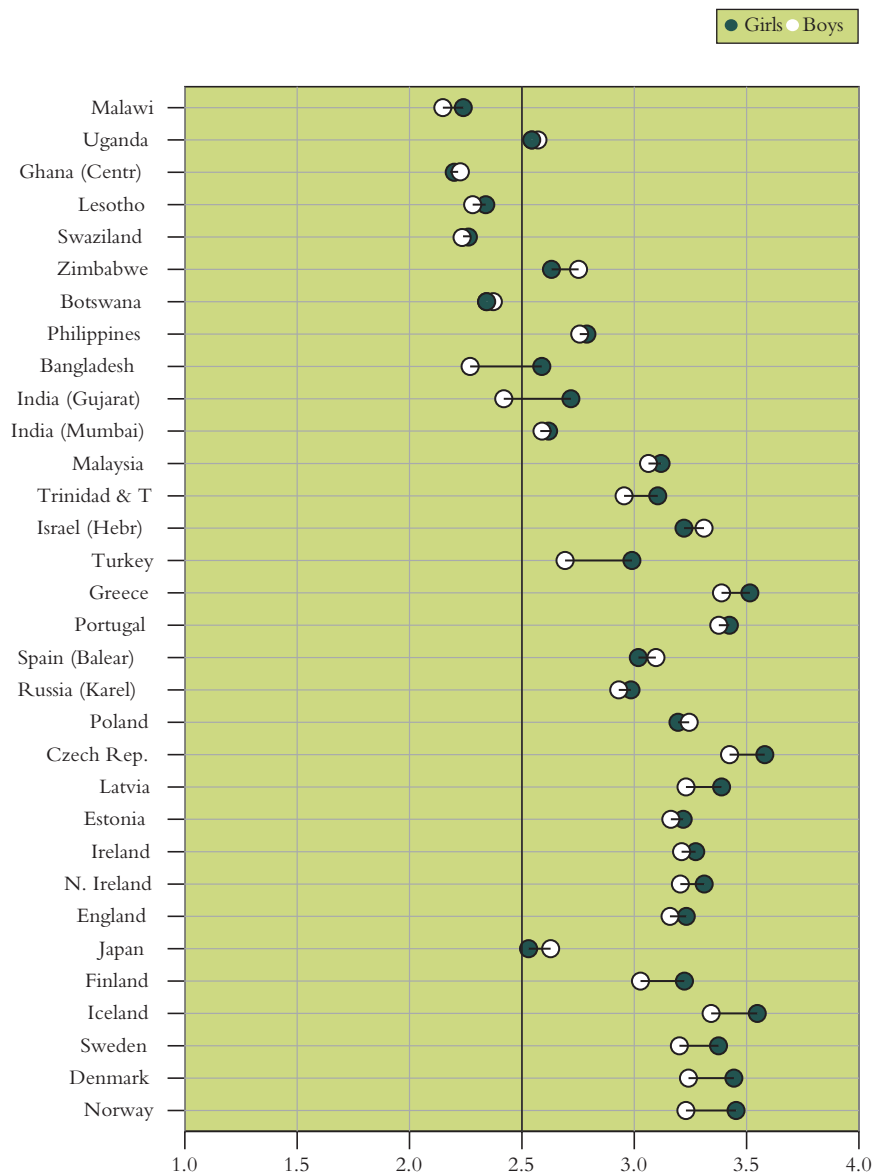


Figure 19 International means for question B12: Having lots of time for my friends.

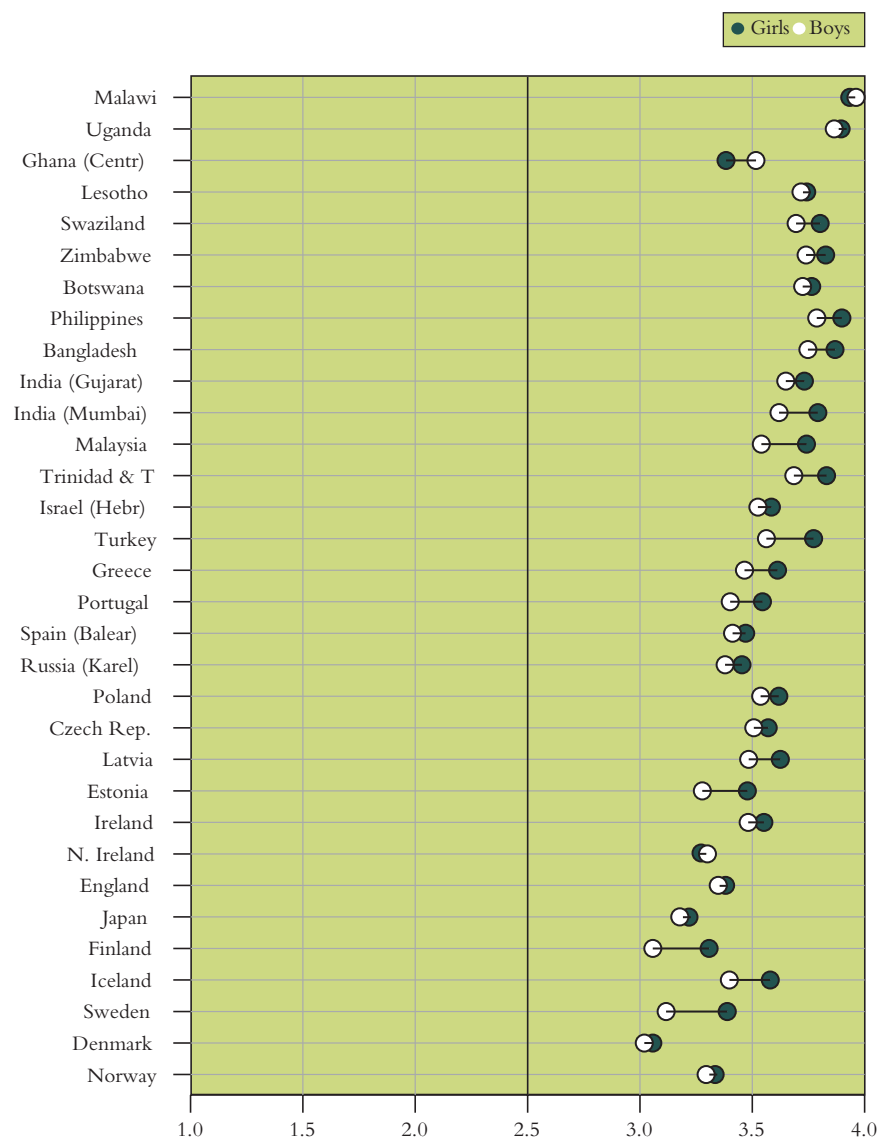


Figure 20 International means for question B25:
Developing or improving my knowledge and abilities.

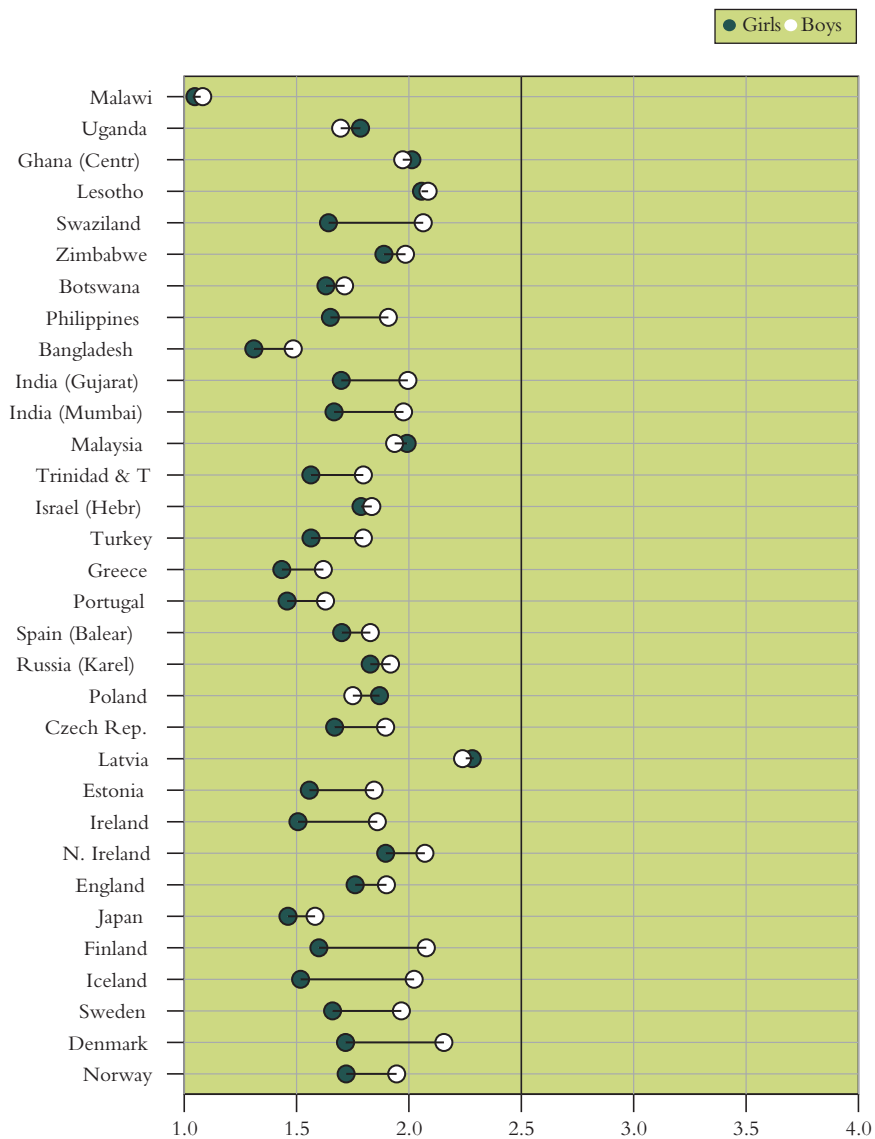


Figure 21 International means for question D1.
Threats to the environment are not my business.

‘Me and the environmental challenges’—Section D

The Irish students are typical of nearly all countries in disagreeing with the statement ‘Threats to the environment are not my business’ (D1) (see Figure 21). There is also a common gender bias in the responses.

There is a similar pattern for the Irish students and students in other countries in their responses to questions D2 (‘Environmental problems make the future of the world look bleak and hopeless’) and D3 (‘Environmental problems are exaggerated’); but in D4 (‘Science and technology can solve all environmental problems’) the common trend in variation from the industrialised to less-industrialised countries re-appears (Figure 22). In the main, students in the former countries are less likely to believe that environmental problems will be solved, with more positive responses being given by students in the African countries.

One question for which the Irish students’ responses may be of particular interest in comparison with those of other countries is D14 (‘I am optimistic about the future’). It is apparent (Figure 23) that the Irish students are rather more optimistic than students in the majority of other Western countries.



Figure 22 International means for question D4:
Science and technology can solve all environmental problems.

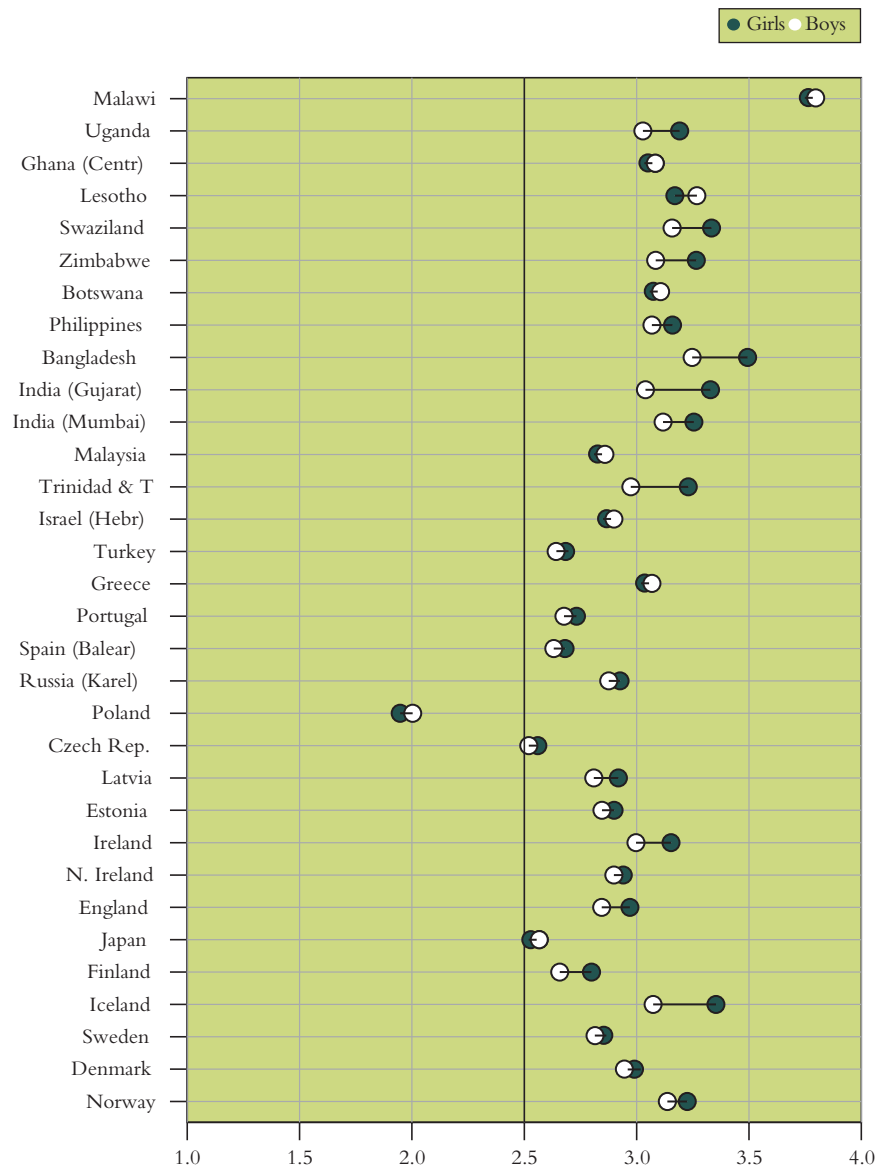


Figure 23 International means for question D14: I am optimistic about the future.

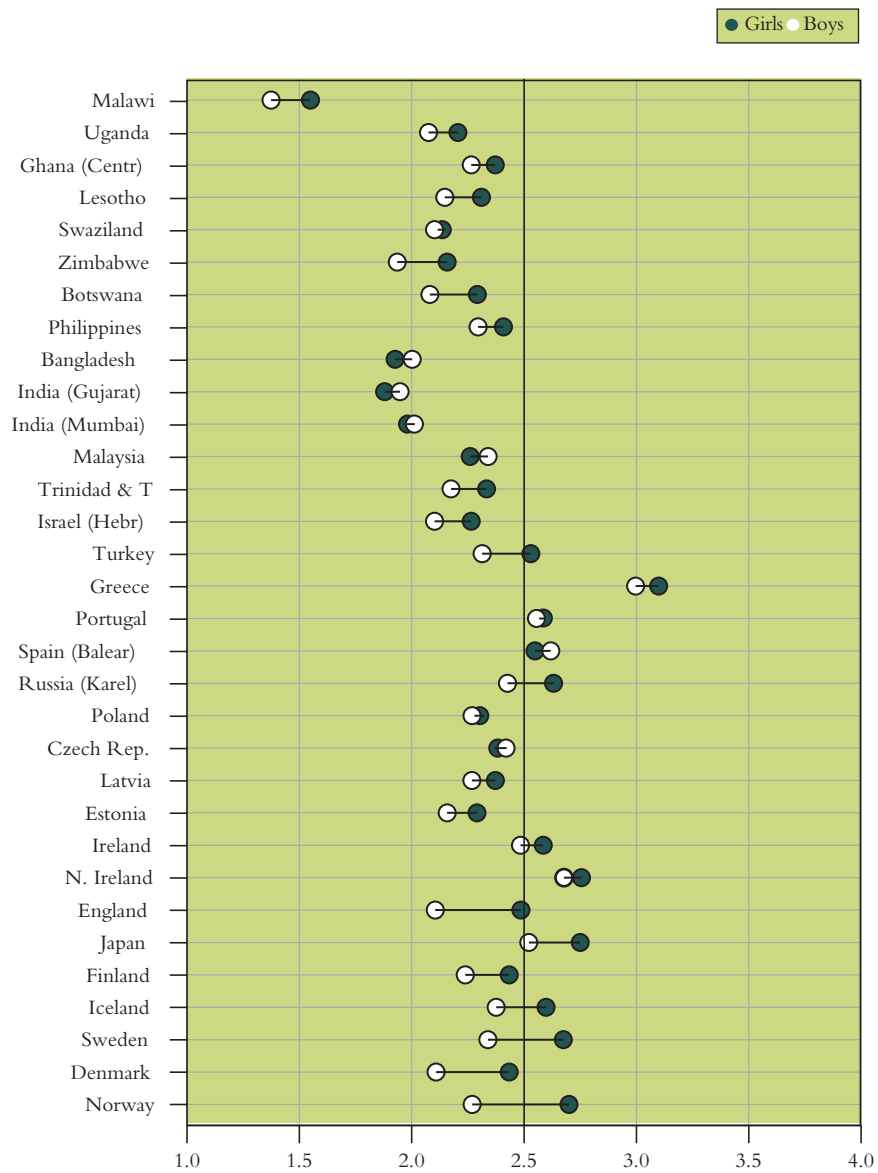


Figure 24 International means for question F1: School science is a difficult subject.

‘My sciences classes’—Section F

Question F1 asks students if they think science is a difficult subject (see Figure 24). The Irish students respond in a similar way to students in the other industrialised countries, but not with such a marked gender difference.

Figure 25 shows that students in all but two countries give positive responses to question F2 (‘School science is interesting’), with those in the less-developed economies being the most positive.

In relation to question F3 (‘School science is rather easy for me to learn’), Figure 26 shows that (once again) the Irish students are near the average of the industrialised countries, although a considerable range of opinions is expressed. It is evident that the gender difference between girls and boys is very small for the Irish group.

A glimpse of the graph for question F14 (‘I would like to become a scientist’) (Figure 27) again shows the general trend: students in the Western industrialised countries share an aversion to ‘becoming a scientist’; opinions of students in the less-industrialised economies are far more favourable.

The familiar pattern occurs again in Figure 28, showing results for question F16 (‘I would like to get a job in technology’), but the extent of the gender bias in the responses is one of the most marked additional features of this question. The Irish results are fairly typical: boys are more favourably oriented towards technology, but it is still a minority interest.

The Irish students respond in a similar way to students in the other industrialised countries, but not with such a marked gender difference. They share the general trend—an aversion to ‘becoming a scientist’.

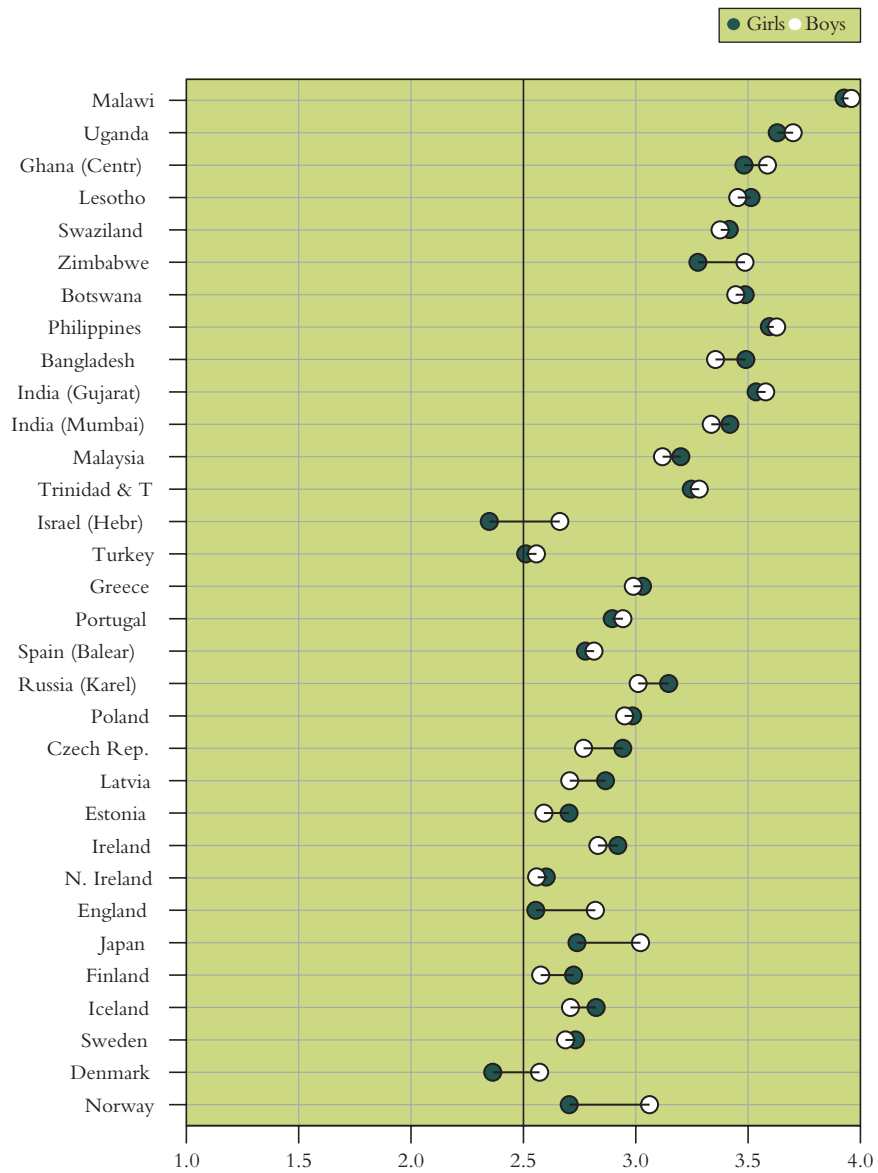


Figure 25 International means for question F2: School science is interesting.



Figure 26 International means for question F3: School science is rather easy for me to learn.

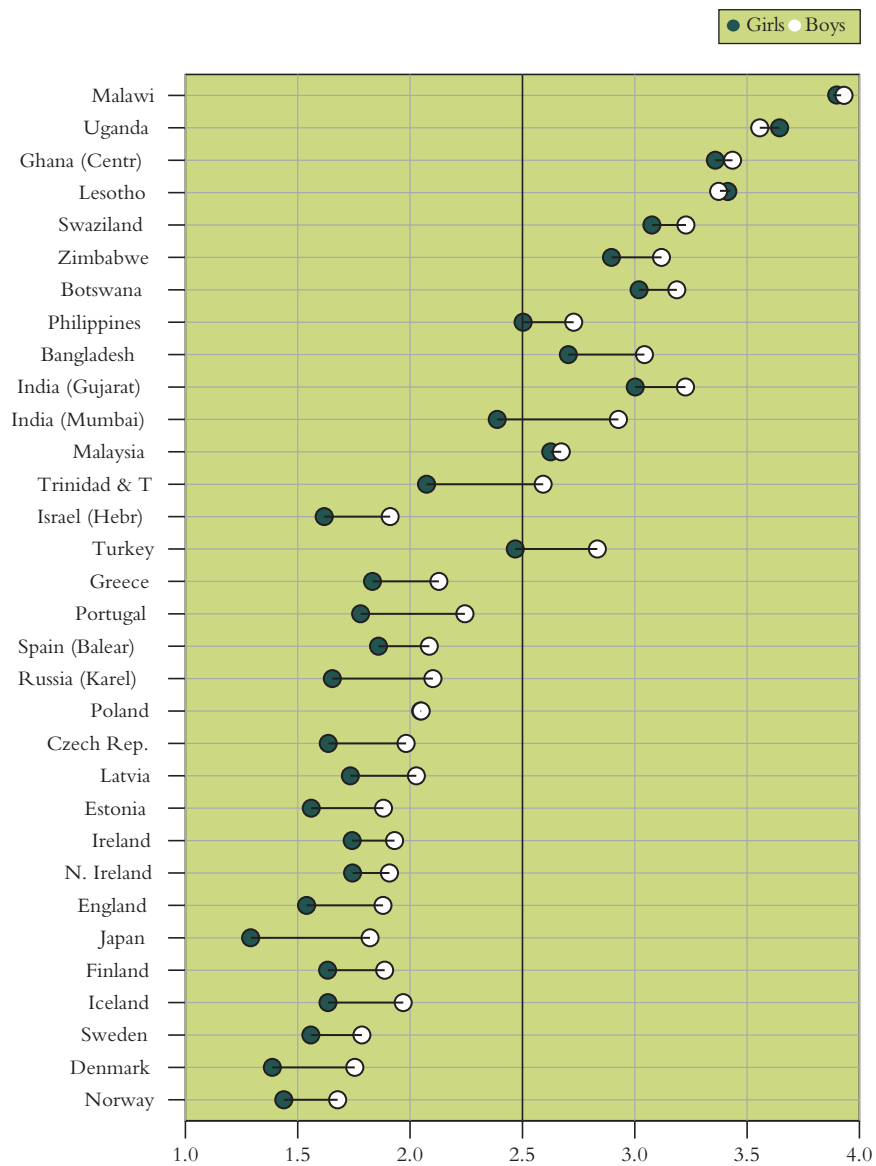


Figure 27 International means for question F14: I would like to become a scientist.

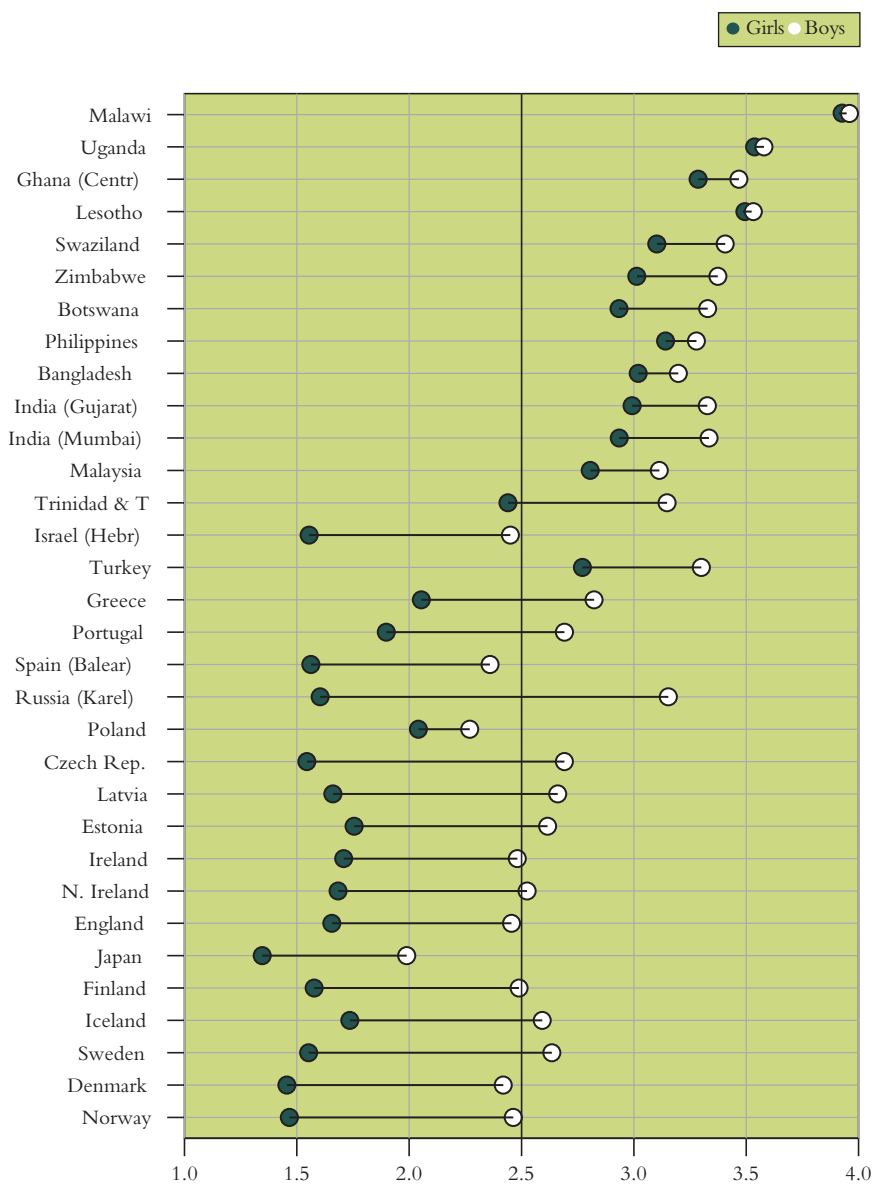


Figure 28 International means for question F16: I would like to get a job in technology.

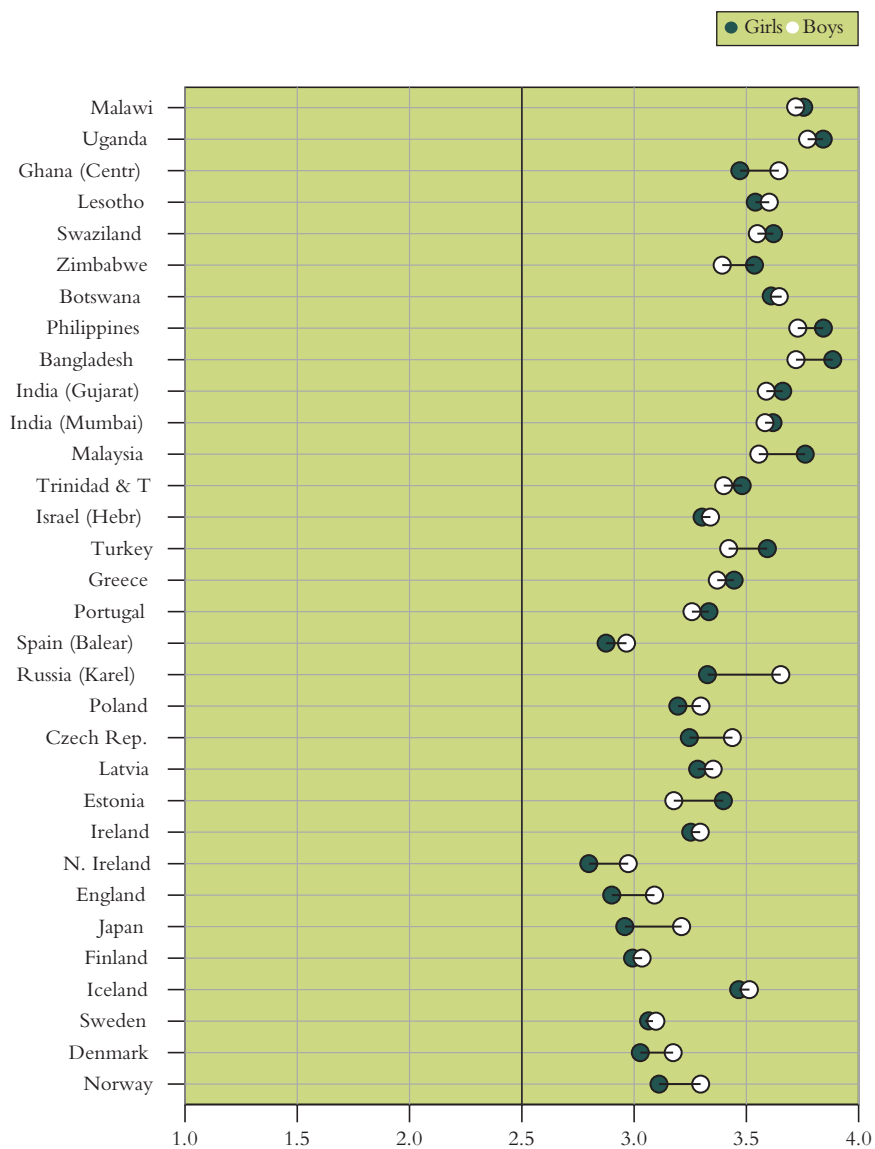


Figure 29 International means for question G1:
Science and technology are important for society.

‘My opinions about science and technology’—Section G

Here too the Irish students’ responses are in almost all cases typical of those from students in the Western industrialised countries. However, the means of a number of the responses for this section show a greater degree of uniformity than is apparent in other sections. For example, students in all countries (industrialised or not) agree that science and technology are important for society and that science is necessary for a country to become developed. Many other questions in this section indicate a generally positive outlook on science and technology—Figure 29 is typical of the general pattern.

However, students express more doubt about the use of science in other contexts: see G7—‘Science and technology will help to eradicate poverty and famine in the world’; G8—‘Science and technology can solve nearly all problems’; and G9—‘Science and technology are helping the poor’. There is a considerable difference between the boys’ and girls’ responses for G8 (Figure 30) and G9, with boys being more likely to agree with the statements.

The means for nearly all countries hover around the average of 2.5 for question G10 (‘Science and technology are the cause of the environmental problems’). There is general agreement that a country needs science and technology to become developed (G11) and that science and technology benefit mainly the developed countries (G12). Students in Western countries are more inclined to disagree with G13 (‘Scientists follow the scientific method that always leads them to correct answers’), with the Irish students’ means being typical. The Irish students’ doubts about putting their trust in scientists are shared by students in the great majority of other countries (see Figure 31). On the whole, students in most countries also do not think scientists are neutral and objective (G15).

Irish students’ doubts about putting their trust in scientists are shared by students in the great majority of other countries

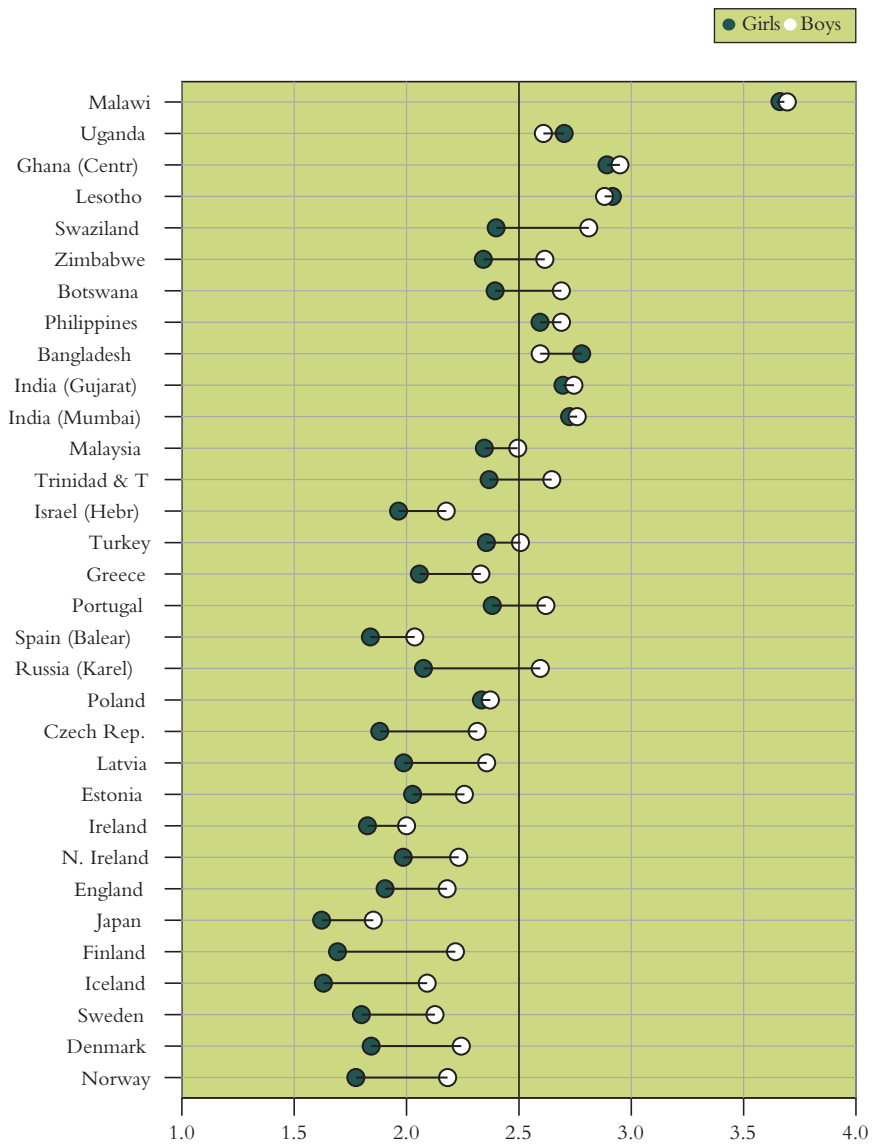


Figure 30 International means for question G8:
Science and technology can solve nearly all problems.



Figure 31 International means for question G14:
We should always trust what scientists have to say.



OVERVIEW

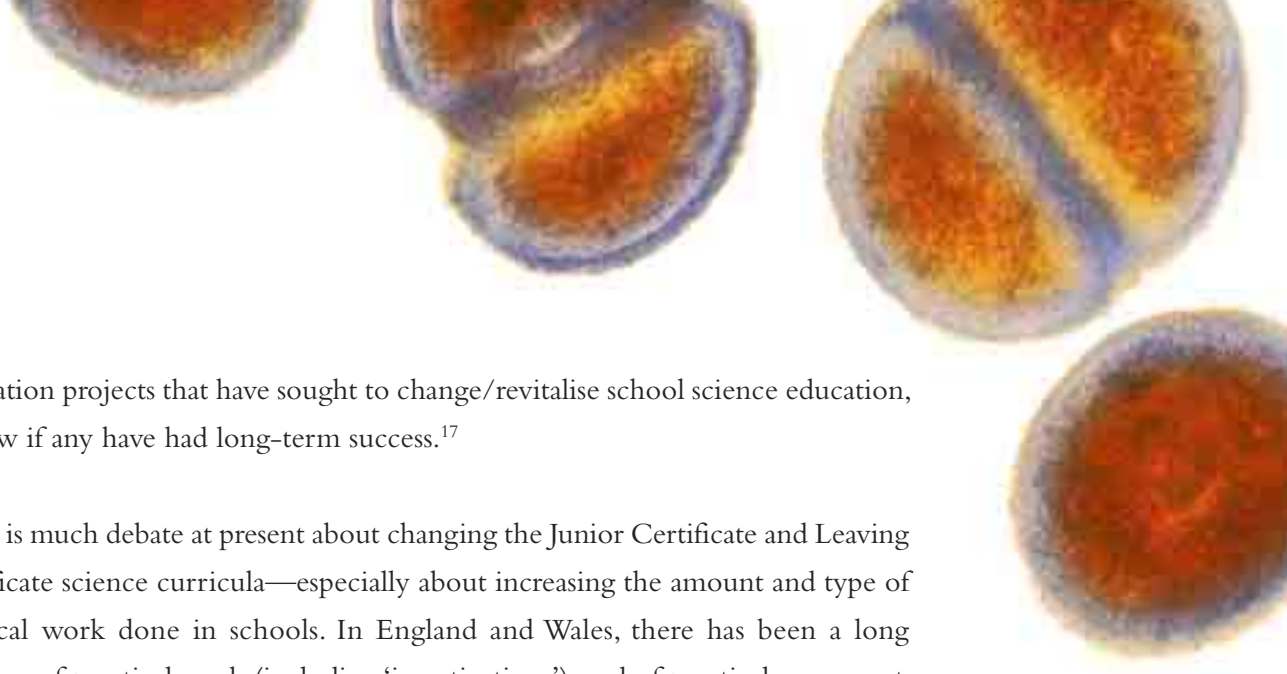


The ROSE survey is an attempt to listen to the ‘student voice’ in science education.¹⁶ The students’ responses form a complex data set that is impossible to summarise in a short space. However, some results point to important issues that need to be borne in mind when discussing the present state of school science education. I raise just five of them here.

1. The reasons why students are turning away from the physical sciences are very complicated. The fact that there has been a decline in interest in these topics (as reflected in subject choices) in so many industrialised countries means that the reasons are not to be found solely, if at all, in the nature of the school science syllabuses or teaching methodologies. Tempting as it is to change the nature of science education in schools in the belief that it is *the* way to change students’ outlook on the physical sciences, history suggests it is unlikely to be successful. Indeed, in the past there have been many curriculum

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innovation projects that have sought to change/revitalise school science education, but few if any have had long-term success.¹⁷

There is much debate at present about changing the Junior Certificate and Leaving Certificate science curricula—especially about increasing the amount and type of practical work done in schools. In England and Wales, there has been a long tradition of practical work (including ‘investigations’), and of practical assessment; yet, as noted earlier, student take-up of GCE A Level Chemistry and A Level Physics has been in decline there too.¹⁸ One may wonder why changing Irish syllabuses to include more practical work (and formally assessing it in some way) should radically change the responses of students in a way that has not happened elsewhere. Of course, it may do so; but the ROSE results suggest that if such a measure is taken in isolation, such an outcome is far from certain.

2. Student choice is driven by a large number of factors. It is possible that extra-school factors are of equal, and possibly more importance than those related to students’ experience of science in school. Camilla Schreiner’s work in analysing the Norwegian ROSE results¹⁹ is of great interest for the light it throws on the wider issues. In particular she discusses the tensions between students’ experience of growing up in a late-modern world and the demands made of them by the study of science. The former emphasises the personal response to, and fragmentary nature of, the experiential world, while the latter emphasises a rather ‘colder’, analytic, de-personalised account of the natural world. In particular, the Irish students show that they value aspects of science that relate to people. Many of them may not perceive the links that the physical sciences have with humankind except in a negative light; e.g. global warming, pollution, warfare. The science-based industries have done a very poor job at explaining themselves to Irish society. They may blame the media for a lack of interest in their activities unless those activities are the subject of some investigation or other. Nevertheless, there is a clear need for

science-based industries to be more proactive in raising their profile and the profile of science as

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it connects to humans. The emphasis here is key: if one wants to attract more young people into science, it is essential to engage them with the human context of science.²⁰

3. In discussing students' responses to their science education one should be careful to distinguish two related matters: *interest* and *motivation*. For example, the claim that performing practical work increases the motivation of students has very little support. It does, however increase the immediate degree of interest shown by students. It is important to recognise the difference: *motivation*, in the sense of a personal response that gives a strong sense of direction to one's present and future activity, is not the same as an *interest*. The latter tends to be represent a more fleeting, temporary response to an experience. Science teachers know that almost all students have their interest more readily awakened by the most mundane of practical tasks than by a theory lesson. However, in science lessons, a practical task is inevitably preceded and/or followed by an intellectually demanding session in which the results of the practical are explained by the teacher. That is, although a practical may be immediately interesting for the student, it can be a minor part of the overall experience of science class. It should not be forgotten that practical work in science has only the appearance of making science more 'concrete'. In reality, the explanations of the results always go beyond the evidence immediately available to the senses. A significant level of intellectual ability is needed to understand the wide range of abstract concepts used even at the Junior Certificate level. For many students the level of interest aroused by a practical is snuffed out by the level of theory with which the practical becomes entangled—and interest is not converted into motivation.

4. In spite of recent concern about the uptake of Leaving Certificate Physics and Leaving Certificate Chemistry, apparently there are sufficient students to fill the majority of places in science and engineering courses in the universities. Perhaps what is of major concern is the

There is a clear need for science-based industries to be more proactive in raising their profile and the profile of science as it connects to humans

perception that too few high-achieving students choose to study physics and/or chemistry, and of those that do study these subjects, too few

The key matter is placing the personal/human relevance of science at the heart of science education, rather than creating and maintaining a curriculum that sees its major concern as the development of the theoretical framework of the sciences

go on to follow mainstream physical science courses at third level. It is difficult to obtain statistics to confirm or deny the accuracy of this perception; but the evidence from the Leaving Certificate points demands of third level courses would support the view that high-achieving students do tend to be attracted to (for example) law, medicine and pharmacy rather than mainstream physics, chemistry or engineering courses. Thus the focus of concern over the absolute numbers of students studying Leaving Certificate Physics or Leaving Certificate Chemistry may be slightly misplaced: perhaps the essential problems lie in (i) attracting the brightest students to study the physical sciences, and (ii) encouraging those very bright students to continue on to mainstream science courses at third level. Perhaps industry or Government agencies' goals should be to increase the numbers of high-achieving students in schools studying the Leaving Certificate physical sciences in addition to increasing the total number of students studying the Leaving Certificate physical sciences.

5. Although there has been a high level of interest in the perceived link between school science education and economic prosperity, it should not be forgotten that science education has an important role to play in the general education of all

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young people. One can criticise the current provision of resources for science education in schools independently of any economic argument. In particular, one can question the ability of schools and



science teachers to respond to further demands made on them to increase the amount and variety of practical work that students do without the provision of technical assistance.

There is little doubt that school science syllabuses and teaching methods need to change, but arguments in favour of change should stand independently of

whether they would necessarily lead to wealth creation. We need to improve students' understanding of science as a body of knowledge and of its powers and limitations if they are to better understand themselves as human beings and appreciate their place in the world around them. Perhaps one step in that direction would be to listen to, and respond to, their interests as reflected in their responses to the ROSE questionnaire.

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NOTES

The web sites cited below have all been accessed in August 2006.

1. Camilla Schreiner and Svein Sjøberg (2004), 'Sowing the Seeds of ROSE. Background, Rationale, Questionnaire Development and Data Collection for ROSE (The Relevance of Science Education)—a Comparative Study of Students' Views of Science and Science Education', *Acta Didactica* 4/2004 (Oslo: Department of Teacher Education and School Development, University of Oslo). Available at: www.ils.uio.no/english/rose/publications/english-pub.html

2. For example:

Rodger W. Bybee and Bruce Fuchs (2006), 'Preparing the 21st Century Workforce: A New Reform in Science and Technology Education', *Journal of Research in Science Teaching* 43, pp 349–352.

USA National Academies of Science (2006), *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. On page 12, this publication carries the quote of an Intel spokesman Howard High in 2005: 'We go where the smart people are'. More accurately, Mr High should have said that Intel go where the smart, well-qualified people are. Ireland has no shortage of smart people, but the worry is that there is a shortage of smart, scientifically qualified young people.

Business-Higher Education Forum (2005), *A Commitment to America's Future: Responding to the Crisis in Mathematics & Science Education*. (Washington, DC: Business-Higher Education Forum)

Alan Smithers and Pamela Robinson (2006), *Physics in Schools and Universities II. Patterns and Policies* (Buckingham: University of Buckingham). Available at: www.buckingham.ac.uk/education/research/ceer/pdfs/physicsprint-2.pdf.

Financial Times (18th August 2006). The President of the Royal Society, Sir Martin Rees, is quoted as saying in relation to GCE A Level entries that physics was 'on the critical list'.

3. Department of Education and Science, *Report of the Task Force on the Physical Sciences* (2002), (Dublin: Department of Education and Science). A more recent publication that has revisited the issues is Royal Irish Academy (2006) *School Science Infrastructure: Can Ireland Deliver?* (Dublin: Royal Irish Academy).

4. Thomas Kellaghan and David Millar (2003), *Grading in the Leaving Certificate Examination: A Discussion Paper* (Dublin: Educational Research Centre).

5. Information about TIMMS (Trends in International Mathematics and Science Study) and PISA (Programme for International Student Assessment) can be found at timss.bc.edu and www.pisa.oecd.org.

6. However, the instructions on the questionnaire tell the students to leave an answer blank if they are unsure of their choice.

7. Analysis of the results has been carried out using a variety of methods, including cluster analysis, exploratory and confirmatory factor analysis using structural equating modelling and item response theory. Of course, there are some patterns in the data, but they do not appear capable of a simple, meaningful interpretation according to their categories in scientific disciplines.

8. For over twenty years there has been a growing interest among science educationalists about exploring the reasons why school science is essentially a-historical, disregarding the philosophical background to science. Michael Matthews gives some of the background (Michael R. Matthews (1995), *Science Teaching: The Role of History and Philosophy of Science* (London: Routledge)).

9. I am not advocating choice of syllabus content solely according to the criterion of popularity of topics among students. What I am suggesting is that it is still possible to teach students key scientific principles and to allow them to reach an understanding of wider aspects of science, if work was more often based upon topics in which students do express an interest.

10. European Commission (2005), *Europeans, Science and Technology Eurobarometer* (2005) European Commission. Results available at: http://ec.europa.eu/public_opinion/index_en.htm.

11. Department of Trade and Industry (2005), *Science in Society: Findings from Qualitative and Quantitative Research* (London: DTI). This poll reports that 86% of people think that science makes a good contribution to society and that 82% think science makes their lives easier.

12. A recent book by Harry Collins offers a well-balanced account of such issues embedded in a study of advanced scientific research: Harry Collins (2004), *Gravity's Shadow: The Search for Gravitational Waves* (Chicago: University of Chicago Press).

13. In passing one might note that the ideas that humans are particularly inquisitive creatures and that school students will 'naturally' be responsive to finding out about nature, the physical world, etc., as part of school science, are mistaken. Apart from a relatively short period in early childhood, humans are only too ready to accept their surroundings at face value. When did you ask yourself how a mobile phone works or how an LCD television works? If you did, did you take the trouble to find out?

14. There are exceptions, but they are relatively few (Einstein is one example).
15. Jon D. Miller, Rafael Pardo and Fujio Niwa (1997), *Public Perceptions of Science and Technology: A comparative study of the European Union, the United States, Japan, and Canada* (Bilbao: Fundación BBV).
16. Edgar W. Jenkins (2006), 'The Student Voice and School Science Education', *Studies in Science Education* 42, pp 49–88.
17. Consider, for example, the following extracts from *A Commitment to America's Future* (see note 2). Referring to the many initiatives in the USA to revitalise maths and science education, the document says 'What can be learned from these initiatives' collective failure to increase significantly American students' achievement in mathematics and science? One answer is that they provide information about what does not work....What they have in common is that they have nothing in common...Each past initiative was fundamentally flawed because it failed to plan intervention as a systemwide event.' (p. 9) 'The problem is that these efforts to improve mathematics and science education have been stand-alone interventions that were focused on reforming one or another component of the system...the system, being highly resistant to change, simply 'absorbs' such interventions and returns to its original shape' (p. 11).
18. See the Smithers and Robinson paper cited in note 2.
19. Camilla Schreiner (2006), *Exploring a ROSE-Garden: Norwegian Youth's Orientations Towards Science—Seen as Signs of Late Modern Identities* (Oslo: Faculty of Education University of Oslo). Available at: <http://www.ils.uio.no/english/ros2.e/publications/english-pub.html>.
20. The following quote is relevant to issues that lie behind student choice of jobs in science and technology: 'Student decisions about study and career paths are primarily based upon interest in a particular field, and on their perception of job prospects in that field. Educational content and curricula play an important role in raising and maintaining young people's interest in S&T. Positive contacts with science and technology at an early age can have a long-lasting impact. Negative experiences at school, due to uninteresting content or poor teaching, are often very detrimental to future choices. Furthermore, curriculum structures can also play an important role in preventing pupils from pursuing their natural preferences.



Accurate knowledge about S&T professions and career prospects are key elements of orientation, but are currently fraught with stereotypes and incomplete information. Science and technology face increasing competition for good students from new, more fashionable subjects in higher education.... Flexible, more attractive curriculum structures with updated S&T content should be devised.' OECD Global Science Forum (2006), *Evolution of Student Interest in Science and Technology Studies Policy Report*, p. 2.



B I B L I O G R A P H Y

Science and technology education in an American context

While the essays below focus on issues in science and technology education in an American context, they are nevertheless interesting in a more local context.

National Academy of Engineering (2006), Reforming engineering education, *The Bridge* 36, No. 2.

Pearson, Greg and Young, A. Thomas (eds) (2002), *Technically speaking: why all Americans need to know more about technology* (Washington DC, National Academies Press).

Singer, Susan R., Hilton, Margaret L. and Schweingruber, Heidi A. (eds) (2005), *America's Lab Report: Investigations in High School Science Committee on High School Science Laboratories: role and vision* (Washington, D.C.: National Research Council).

Recent additions to the literature on science education

The following books are relatively recent additions to the literature on science education and provide useful links to the primary literature. In particular, many of them deal with issues concerning students' perceptions of science and of the science education they receive.

Amos, Sandra and Boohan, Richard (eds) (2002), *Aspects of teaching secondary science: perspectives on practice* (London and New York: The Open University).

Black, Paul and Atkin, J. Myron (1996) *Changing the subject: innovations in science, mathematics and technology education* (London: Routledge/OECD).

Driver, Rosalind, Leach, John, Millar, Robin and Scott, Phil (1996) *Young people's images of science* (Buckingham: Open University Press).

Gilbert, John (ed.) (2004) *The RoutledgeFalmer reader in science education* (London: RoutledgeFalmer).

Hodson, Derek (1998) *Teaching and learning science. towards a personalized approach* (Buckingham: Open University Press).

Millar, R., Leach, J. and Osborne, J. (eds) (2000) *Improving science education* (Buckingham: Open University Press).

Millar, Robin, Leach, John and Osborne, Jonathan (eds) (2001) *Improving science education: the contribution of research* (Buckingham: Open University Press).

Monk, Martin and Osborne, Jonathan (eds) (2000) *Good practice in science teaching: what research has to say* (Buckingham: Open University Press).

Ratcliffe, Mary and Grace, Marcus (2003) *Science education for citizenship: teaching socio-scientific issues* (Maidenhead: Open University Press).

Reiss, M.J. (2000) *Understanding Science Lessons: Five years of science teaching* (Buckingham: Open University Press.)

ACKNOWLEDGEMENTS



I would like to thank the Principals, science teachers and students of the schools that took part in the ROSE survey. I owe much to the work of a group of practising science teachers, all of whom had successfully completed the MSc in Science Education course in Trinity College, and helped in the organisation of the survey: Rose Breslin, Geralyn Corcoran, Damienne Letmon, Kevin Maume, Carolyn Murphy, Tony Robinson and Greg Smith. My thanks also go to the anonymous referees of this paper for many helpful comments.

IMAGE CREDITS:

Cover images: Thomas Picard, datahead2@aol.com (www.sxc.hu)

Page 2: In July 1973, a groundbreaking discovery was announced in CERN's Main Auditorium: the Gargamelle group had found proof of the weak neutral current. The discovery confirmed the electroweak theory, which had predicted that the weak force and the electromagnetic force were different facets of the same interaction. © CERN

Page 10: Dora mitsonia, float_d@yahoo.com (www.sxc.hu)

Page 18: A low-light fluorescence image of Bose Einstein condensate – one million trapped rubidium atoms cooled to micro Kelvin temperatures captured using the Andor DV434 imaging camera. Courtesy Prof. M Chapman, School of Physics, Georgia Institute of Technology, Atlanta, GA..

Page 20/21 and page 46: freedigitalphotos.net

Page 32: 'Water Cube' swimming centre, Beijing. PTW Architects, CDDI, ARUP

Page 36: Hubbard Glacier, Alaska by Randall Hop, user name blitzkrieg, www.sxc.hu

Page 50/51: *Pediastrum* sp., a common algal species in Irish shallow lakes, by Kenneth Irvine

Page 86/87: MRSA bacteria. Biomedical Imaging Unit, Southampton General Hospital/Science Photo Library

All other images: www.sxc.hu