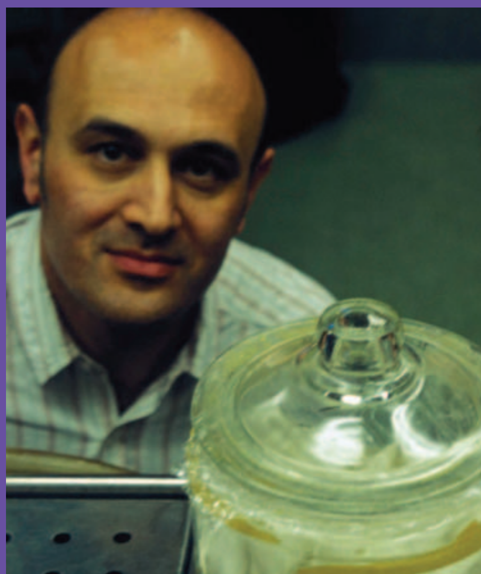
A report prepared for the Royal Society of Chemistry and the Institute of Physics by
Prof. Peter Elias and Dr Paul Jones, Warwick Institute for Employment Research,
University of Warwick, and Dr Sean McWhinnie, Royal Society of Chemistry

Representation of Ethnic Groups in Chemistry and Physics

The Royal Society of Chemistry and the Institute of Physics
May 2006





RSC | Advancing the Chemical Sciences

Institute *of* **Physics**

Focus of the research

This study presents a statistical picture of the progress of England- and Wales-domiciled students from different ethnic groups through the various stages of the educational system into undergraduate chemistry and physics courses. It then examines undergraduate achievement in chemistry and physics and the subsequent study outcomes of the students at postgraduate level. This leads to the identification of key differences between different ethnic groups' achievements and decision making.

"Many black Caribbean, Pakistani and Bangladeshi students fall at the first hurdle – often before students have the chance to specialise in chemistry or physics."

Key findings

The study seeks to understand the processes by which different ethnic groups leave academic chemistry and physics. Students may discontinue the study of chemistry or physics either voluntarily (choosing not to study chemistry or physics although qualified to do so) or involuntarily (failing to achieve the prerequisite qualifications to continue). Students may discontinue, or not qualify to continue, at different times – from the point of deciding to stay on at school to study A-levels; through the choice of subjects at A-level and degree level (and the grades achieved); and the decision whether or not to undertake postgraduate study if qualified to do so. The progress of specific ethnic groups through academic chemistry and physics is modelled using the metaphor of a "leaky educational pipeline", which comprises six stages. Progress along this pipeline by ethnic group, and the propensity of individuals in specific ethnic groups to drop out at each stage, is reported based on notional cohorts of 10 000 school-leavers for each ethnic group. Each of the summary points below relates to a stage along the pipeline.

The analysis is carried out using data collected via the Department for Education and Skills (DfES) National Curriculum Assessment, the Youth Cohort Study (YCS) of England and Wales, and the Higher Education Statistics Agency (HESA).

The first stage of the educational pipeline is the achievement of five GCSEs within the range of grades A*–C. There are notable differences in achievement at GCSE by ethnic group. Based on the benchmark standard, Chinese and Indian pupils perform best, followed by white pupils, while people from black Caribbean, Pakistani and Bangladeshi backgrounds perform less well. The consequence of this for chemistry and physics is that significant attrition of ethnic-minority groups takes place at this very early stage. Many black Caribbean, Pakistani and Bangladeshi students fall at the first hurdle – often before students have the opportunity to specialise in chemistry or physics. Consequently, numbers from these populations are much lower than might be expected, in relation to population size, at later stages of academic study.

The second stage is the achievement of an A-level in either chemistry or physics. Considering only students who achieve five GCSE passes at A*–C grades, all ethnic-minority groups, with the notable exception of black Caribbean students, are more likely to achieve an A-level in chemistry than their white counterparts. However, only Indian and Chinese students are more likely to achieve an A-level in physics than their white peers.

A comparison of physics and chemistry shows that, with the exception of white and Chinese students, other ethnic groups are significantly less likely to achieve an A-level in physics than chemistry. This may well be linked to the requirement of an A-level in chemistry to read medicine at university. In terms of the overall survival rates of particular ethnic groups, all ethnic-minority groups except black Caribbean are more likely to achieve an A-level in chemistry than white students. Overall, white students are three times as likely to achieve an A-level in chemistry as black Caribbean students. Overall in physics, only Indian and Chinese students are more likely to achieve an A-level than white students. Chinese students are almost three times

"In particular, medicine, dentistry, pharmacology and ophthalmics all have very high numbers of Indian and Pakistani students relative to their numbers in the undergraduate population as a whole."

as likely to achieve an A-level in physics as white students. However, black Caribbean students are only a sixth as likely to achieve an A-level in physics as their white counterparts.

The third stage of the educational pipeline is achievement of the qualifications to study chemistry or physics at undergraduate level. Approximately two-thirds of students achieving an A-level in chemistry are qualified to study chemistry at undergraduate level, based on prerequisite qualifications as outlined in the study; and approximately half of students achieving an A-level in physics are qualified to study physics at undergraduate level, based on combinations of subjects studied and grades achieved. Significant differences between ethnic-minority groups are not observed at this stage.

Evidence is found of systematic differences in subject choices by ethnic group for students choosing chemistry or physics over other subject areas at degree level, the fourth stage in the pipeline. This is most notable in physics where all ethnic-minority groups, except Chinese students, are under-represented relative to their numbers in the undergraduate population, and relative to numbers of students qualified to study chemistry or physics by their A-levels. Consequently, physics is very much white (and male) dominated.

In chemistry there is a less clear-cut difference between ethnic groups. Ethnic-minority groups in general are over-represented in chemistry, relative to their numbers in the undergraduate population, with the exception of black Caribbean students. However, even in this case the numbers are over-represented based on the numbers of potential undergraduate black Caribbean chemists.

Alternative areas of study

This report also compares alternative areas of study. Within science, engineering and technology (SET) subjects a general bias is found among ethnic-minority students against traditional areas of science, such as the physical sciences, the biological sciences and mathematics. In contrast, ethnic-minority groups in general tend to be over-represented in information, communication and technology (ICT), and computer science, compared with their white counterparts. Outside science, a very strong bias towards medicine and related subjects is found among non-white groups, especially Asian students. This supports the earlier observation that chemistry is a popular A-level subject with ethnic-minority groups because it is a prerequisite for medicine. In particular, medicine, dentistry, pharmacology and ophthalmics all have very high numbers of Indian and Pakistani students relative to their numbers in the undergraduate population as a whole.

In addition, ethnic-minority groups generally show a preference towards other vocational subjects, such as business and administration or law. Black Caribbean students, however, are different from most ethnic-minority groups, showing a general preference for arts, social sciences and humanities subjects.

The fifth stage of the educational pipeline is the achievement of a first or upper-second-class degree, which represents the normal qualifying standard for further study, especially at doctoral level. There is strong evidence of significantly different patterns of achievement in chemistry and physics by ethnic group at the conclusion of undergraduate studies. White students have much higher rates of success in achieving a first or upper-second degree, and thus are in a better position to access postgraduate chemistry, physics or related science courses. This differential achievement by ethnic group is found not only in chemistry and physics but across most subject areas. However, there is evidence that most of this differential achievement may be explained by subject choice and because many ethnic groups are over-represented in the undergraduate population relative to their white counterparts.

Postgraduate study in chemistry or physics is the sixth educational stage. Among students who achieve high standards at undergraduate level, ethnic-minority students are less inclined to study chemistry or physics at PhD level than their white counterparts. In contrast with this, ethnic-minority graduates in chemistry and physics are significantly more likely to go on to further study than their white counterparts. From this it can be inferred that ethnic-minority students tend to study subjects outside chemistry and physics at postgraduate level. This apparent drift away from chemistry and physics by ethnic-minority students presents an interesting avenue for future research.

"Among students who achieve high standards at undergraduate level, ethnic-minority students are less inclined to study chemistry or physics at PhD level than their white counterparts."

As well as the ethnic differences described, gender is a recurring theme throughout this study. Physics in particular and, to a lesser extent, chemistry tend to be male dominated. Moreover, the pattern of attrition is such that, in moving along the educational pipeline, the majority white male group has higher retention rates compared with other groups and therefore becomes an increasingly large majority in the later stages.

Socioeconomic considerations

Finally, not all of the differences described in the study can be attributed entirely to ethnicity. Different ethnic groups have different socioeconomic profiles and consequently it is not possible to say categorically whether the differences observed are the result of ethnic differences *per se* or whether socioeconomic factors play a part.

Nonetheless, it is clear that ethnicity is correlated with the progress of different groups along the educational pipeline in chemistry and physics. In addressing these differences the challenge for policy makers is to recognise the diversity of influences likely to be at work and to design policies that, regardless of colour, race and cultural background, will work to increase opportunities for under-represented minorities.

Contents

List of figures and tables

List of figures and tables

List of appendices

Abbreviations

DfES	Department for Education and Skills
EGR	Ethnic-gender representation
GCSE	General Certificate in Secondary Education
GNVQ	General National Vocational Qualification
HESA	Higher Education Statistics Agency
ICT	Information and communication technology
IOP	Institute of Physics
KS	Key Stage
LFS	Labour Force Survey
MChem	Master of Chemistry (four-year enhanced undergraduate degree in chemistry)
MPhys	Master of Physics (four-year enhanced undergraduate degree in physics)
ONS	Office for National Statistics
RSC	Royal Society of Chemistry
SET	Science, engineering and technology
UCAS	Universities and Colleges Admissions Service
YCS	Youth Cohort Study

1: Introduction

1.1: Scope of the study

As part of their agenda to address issues relating to student diversity in chemistry and physics, the Royal Society of Chemistry and the Institute of Physics commissioned this study to investigate patterns of ethnic-minority participation in the two subjects through the various stages of academic study and into the labour market.

The scope of the work is to use existing sources of data to create a statistical overview, broken down by ethnic group, and to compare participation rates between the groups at different stages of academic study. The aim is to identify transition points between educational stages where significantly larger or smaller proportions of particular ethnic-minority groups leave education in comparison with the majority white population.

The expectation is that, by identifying points where particular groups leave chemistry and physics, further work can be suggested to investigate factors that affect these differences. Although it is recognised that different ethnic groups exhibit different socioeconomic characteristics, which may affect educational participation rates, it is beyond the scope of this study to investigate these additional issues.

1.2: Background

This report addresses the participation of ethnic groups using the metaphor of a "leaky educational pipeline". The pipeline represents the rate at which students leave chemistry and physics by ethnic group during the different stages of academic study. The propensity of individuals to leave at each of the six stages is reported based on a notional cohort of 10 000 school-leavers per ethnic group. This analysis is carried out using data for England and Wales[1] from the Department for Education and Skills (DfES) National Curriculum Assessment, the Youth Cohort Study (YCS) of England and Wales, the Higher Education Statistics Agency (HESA) and the Labour Force Survey (LFS). The six stages break down the route through academic chemistry and physics into a temporal series of academic achievements, from GCSE through to doctorate study. The main purpose of this approach is to disentangle the effects of early education (based on GCSE grades); subject choice both at A-level and undergraduate study; and attainment in terms of achieving the qualifications to proceed to later stages of study.

Under-representation of certain ethnic-minority groups in chemistry and physics, notably young people from black Caribbean, Pakistani and Bangladeshi backgrounds, arises to some degree because low numbers of students from these groups achieve the requisite GCSE grades at school and therefore most are not qualified to continue with further study after the age of 16. The students belonging to the ethnic-minority groups mentioned above in general achieve fewer GCSEs (e.g. based on the benchmark standard of five GCSEs at grade A*–C; Demack *et al*. 2000; Gillborn and Mirza 2000) than students from other ethnic-minority groups. This is particularly the case in science and mathematics (Harrison *et al*. 2003). Consequently, students from these ethnic groups are less likely than students from other ethnic-minority groups to obtain an A-level. Thus students of black Caribbean, Pakistani and Bangladeshi backgrounds are less likely to be in higher education generally than students from other ethnic groups (Connor *et al*. 2003; Leslie and Drinkwater 1999).

Although these influences do not relate solely to chemistry and physics, the consequence for the physical sciences is that there is a significant attrition of numbers of black Caribbean, Pakistani and Bangladeshi students at the first hurdle – the transition from GCSEs to A-levels – often even before students have the chance to specialise in chemistry or physics *per se*. This results in a huge loss of potential talent. Consequently, patterns of ethnic representation across SET, both in science education and employment, correspond closely with these patterns of achievement at GCSE and indeed at Key Stage (KS) 3 (Jones and Elias 2004).

Taking into account this early attrition, this report proceeds to look for systematic biases and revealed preferences by ethnic group at various stages of higher education in chemistry and physics. This yields interesting results. Indian and Chinese students show a strong preference for science at A-level compared with other ethnic groups. In contrast, black Caribbean students reveal a strong aversion to both chemistry and physics, even at this early stage. In degree-level chemistry, most ethnic-minority groups – particularly Pakistani and Bangladeshi students – are over-represented relative to their numbers in the undergraduate population. In physics, however, ethnic-minority students tend to be under-represented compared with the white population.

This report also presents data on the ethnic-gender make-up of students of chemistry and physics. In general, university chemistry and physics is male dominated, physics being particularly so, and that pattern is followed within all ethnic groups. Thus university physics is very much white and male dominated.

This study presents a detailed statistical picture of ethnic-group participation in chemistry and physics, and in particular it highlights differences in participation between ethnic groups. The working assumption, or null hypothesis, is that, all things being equal, the distribution of ethnic groups will be random, and thus the ethnic make-up of a population at one educational or attainment level will be the same as that at the level below.

"Indian and Chinese students show a strong preference for science at A-level compared with other ethnic groups."

1. Scotland and Northern Ireland are excluded from the study owing to a lack of data.

Where differences are found between expected and real participation rates, explanations are not sought for why choices are made or why some ethnic groups under- or over-perform compared with others.

However, the study does suggest a number of reasons for the propensity of ethnic-minority students to study chemistry and physics.

- **The effect of peer group** Under-representation of a particular ethnic group at an early stage in the educational pipeline (e.g. at A-level) might be self-reinforcing and lead to a greater under-representation at a later stage (e.g. postgraduate study). This merits further investigation.

- **Family pressure** Differences in the subject choices made by different ethnic groups may have their origins in family attitudes towards education and towards what subjects and courses are seen as leading to professional careers. This family pressure may apply at any point so that students may be dissuaded from continuing their study of an apparently less vocational subject, such as chemistry or physics, in favour of further study in subjects such as law or IT.

- **The socioeconomic composition of ethnic-minority groups** It is well documented that the Indian and Chinese population are more likely to come from higher socioeconomic groups than other ethnic-minority groups (Modood *et al*. 1997; Owen *et al*. 2003), whereas the opposite is true, for example, for the Bangladeshi and black Caribbean populations. How the socioeconomic composition of particular ethnic groups affects subject choice, particularly relating to academic versus vocational study, would therefore be a fruitful area for further study.[2]

1.3: Structure

The remainder of this report is structured as follows: section 2 outlines the key concepts relating to the leaky pipeline and introduces the notion of “potential undergraduate scientists”; section 3 outlines methodology and data sources; and section 4 summarises broad findings by ethnic group in terms of progress along the leaky pipeline. Sections 5–8 provide a more detailed analysis of performance at GCSE, as well as subject choice and attainment at A-level, undergraduate level and postgraduate level. Section 9 draws conclusions and makes a number of recommendations for areas for further study.

2. For more on the socioeconomic background of ethnic groups, see the Office for National Statistics’ information on Focus on Ethnicity & Identity (http://www.statistics.gov.uk/focuson/ethnicity).

2: Key concepts

2.1: The educational pipeline

This study uses the concept of a leaky educational pipeline to describe the withdrawal of students from academic chemistry and physics. It breaks down the route that they take through academic chemistry and physics into a process of six stages, or transition/decision points, corresponding to landmark academic achievements, as shown in table 1. At each point there is a natural exit where individuals may choose to drop science and pursue alternative career choices or studies; or where they may fail to achieve the qualifications to continue in science. This study analyses progress along this pipeline by ethnic group, and the propensity of individuals within particular ethnic-minority groups to drop out at each point.

The first transition point (stage 1) relates to achievement in compulsory schooling, specifically gaining five or more GCSEs at grades A*–C. Although not specifically related to science education, this measure provides a proxy for the number of students who are likely to be able to continue successfully in further academic studies. It is a standard benchmark in terms of achievement at school (DfES, 2004) and provides an approximate measure of the pool of potential science (chemistry or physics) students at A-level.[3]

The second and third transition points are interconnected and relate to studies of chemistry and physics at A-level. In England and Wales, A-levels still provide the primary route from science at school into science at university, and, in the vast majority of cases, access to degree courses in chemistry and physics requires an A-level in the same subject (along with other stipulations, which are discussed later). The second transition point is the achievement of an A-level in chemistry or physics and covers the number of students who obtain an A-level in chemistry or physics at grade E or above. Those who pass through the third transition point are people who are suitably qualified to study chemistry or physics at university.

Students who pass this hurdle are referred to as "potential undergraduate scientists" (chemists or physicists). Different universities have different criteria for students to enter their courses, so a range of alternative definitions of potential undergraduate scientists are used. These are discussed in section 2.2.

The last three transition points along the pipeline relate to degree-level studies in chemistry and physics. The fourth stage is the study of chemistry or physics at undergraduate level, specifically by those undertaking either a first degree or an enhanced first degree (usually leading to an MChem or MPhys qualification). Analysis in this case focuses on the actual numbers of students, compared with the numbers of potential undergraduate scientists. The fifth stage is the achievement of either a first- or upper-second-class degree, and the study examines the proportion of undergraduate students in chemistry and physics who achieve these degree classes. A prerequisite for doctoral-level studies in chemistry or physics is normally the achievement of a first- or upper-second- degree. Routes into postgraduate study are complex and do not relate precisely to undergraduate degree classification. However, this measure provides a close proxy.

The sixth transition point is choosing to study for a doctorate in chemistry or physics and analysis focuses on the number of students who take up the opportunity of postgraduate study compared with those qualified to do so. The end of the educational pipeline is when students emerge with a doctorate in chemistry or physics.[4]

Table 1: A description of the stages along the educational pipeline

Compulsory schooling	
Stage 1	Achieving five or more GCSEs at grades A*–C
A-level studies	
Stage 2	Achieving an A-level in chemistry or physics
Stage 3	Potential undergraduate scientist: suitably qualified at A-level to study chemistry or physics at university
A-level studies	
Stage 4	Studying undergraduate chemistry or physics
Stage 5	Achieving a first- or upper-second in chemistry or physics
Stage 6	Studying for a doctorate in chemistry or physics

Table 2: Three definitions of a potential undergraduate chemist/physicist

Chemistry	Physics
Chemistry A-level, *plus*	**Physics A-level, *plus***
At least one other science or mathematics subject at A-level, *plus either*	A-level mathematics, *plus either*
UCAS 12	**UCAS 12**
12 UCAS points in total, with grade C or above in chemistry, *or*	12 UCAS points in total, with grade C or above in physics, *or*
UCAS 18	**UCAS 18**
18 UCAS points in total, with grade C or above in chemistry, *or*	18 UCAS points in total, with grade C or above in physics, *or*
UCAS 24	**UCAS 24**
24 UCAS points in total, with grade C or above in chemistry	24 UCAS points in total, with grade C or above in physics

2.2: Potential undergraduate scientists

A key aim of analysing the information about A-level studies is to identify the proportion of young people, by ethnic group, who might be considered potential undergraduate chemists or physicists. This concept is useful in providing an ethnic profile of the pool of students from which chemistry and physics departments recruit at undergraduate level. It

3. The correspondence between GCSE performance and access to A-level courses is not exact and indeed varies across schools and colleges. The choice of this proxy measure was determined primarily by the availability of data.
4. Numbers on taught masters programmes in physical sciences are generally small compared with other subject areas, so this stage is not considered separately.

also provides a useful benchmark for measuring the leakage of potential talent from chemistry and physics courses immediately after A-level studies.

The definition of potential undergraduate chemists or physicists is based on two factors: the choice of subjects at A-level and their overall achievement in terms of grades. These requirements are summarised in table 2, where three alternative definitions are used, based on the Universities and Colleges Admissions Service (UCAS) points system (i.e. grade A = 10 points, grade B = 8 points, grade C = 6 points, grade D = 4 points and grade E = 2 points).[5] The requirement to get onto a chemistry or physics undergraduate degree course is not clear cut and varies greatly across universities, so three different points criteria are used: "UCAS 12" (most lenient), "UCAS 18" and "UCAS 24" (strictest). These are based on the range of typical entry requirements at the time of writing.

Note that the requirements to study chemistry include the study of chemistry plus one other science (possibly mathematics) at A-level, whereas the requirements for studying physics are stricter, with a requirement for physics plus mathematics at A-level.

5. Note that UCAS introduced a new points system in 2004 whereby A = 100 points, B = 80 points, C = 60 points, D = 40 points and E = 20 points.

3: Methodology

The purpose of this study is to quantify numbers of students at each stage of the pipeline described in section 2. This is done by ethnic group based on a notional cohort of school-leavers, where the size of the cohort is normalised to 10 000 in each case for ease of comparison. Numbers at each stage of the pipeline are established based on three separate data sources:

- The DfES' National Curriculum Assessment data on achievement at GCSE by pupil characteristics are used. These have census coverage and include all students in England, with detailed analysis by pupil ethnicity and gender.
- Data on achievement at A-level are obtained from successive cohorts of the YCS of England and Wales. This survey also provides estimates of the proportion of young people who are studying on degree courses at age 18/19, which gives a base from which achievement at A-level can be linked with numbers on degree courses.
- Student numbers on degree courses are based on HESA data. These provide a comprehensive picture of undergraduate and postgraduate study by subject and information on degree classification. For consistency, analysis of these data sets is restricted to students domiciled in England and Wales.

In addition to these sources, the LFS is utilised to provide further information about ethnic populations and economic activity. Each source is described in more detail below.

3.1: Data sources

3.1.1: National Curriculum Assessment

Data about achievement at GCSE by pupil characteristics are available from the DfES. The DfES publishes annual National Curriculum Assessment data, which provide detailed information about the performance of pupils in GCSE examinations, as well as information about attainment at GNVQ and at KS levels (including KS2 and KS3 in science). These data have census coverage with detailed analysis by pupil ethnicity and gender, as well as other dimensions. Whereas data throughout the rest of this study relate to England and Wales,[6] the proportion of pupils achieving five or more GCSEs at grade A*–C (i.e. the first stage of the pipeline) is based on data for England only.

It is unlikely that this biases the results unless pupil achievement by ethnicity in Wales differs significantly from that in England. However, it should be noted that students in Wales are much more likely to do A-level physics than those in England.

The National Curriculum Assessment data used in this study relate to pupils completing their GCSE studies in 2002, of whom there were 571 750 (of which 64 900 were from non-white ethnic-minority groups).

3.1.2: Youth Cohort Study

To establish a detailed picture of study at A-level, survey data must be relied on, and for England and Wales these derive principally from the YCS.[7] At the time of writing the DfES and the Office for National Statistics (ONS) do not publish census data about A-level achievement by ethnic group.

The YCS is a postal survey of approximately 10 000 school-leavers in England and Wales, with new cohorts introduced biannually. The survey is conducted on a voluntary response basis, and responses are weighted by the ONS to correct for bias in sample selection. Data are collected from a representative sample of young people. Individuals are initially sampled in the spring after completing their compulsory education (sweep 1: at which time they are 16/17); they are revisited two years subsequently (sweep 2: at which time they are 18/19).

The YCS records information about past educational achievement and current studies, as well as data relating to labour-market participation.

The analysis in this report utilises data from the second sweep of the YCS, in which individuals are questioned about their current academic studies and past academic achievements subsequent to completing compulsory education in year 11. This includes details of A-level studies, including subjects taken and grades achieved.

The survey is biannual and the four most recently available cohorts of the survey are utilised from 1996 (cohort 7) to 2002 (cohort 10). The information contained in the YCS includes academic achievements at 18/19 years, two years after the completion of academic study.[8] This information is used to analyse achievement in chemistry and physics at A-level, particularly to establish proportions, by ethnic group, at stages 2 and 3 of the pipeline.

The main drawback of using survey data (as opposed to census data) is that sample numbers are fairly small, especially for non-white ethnic-minority groups. Merging successive cohorts of the survey from 1996 to 2002 (i.e. the most recent four data sets) yields the sample sizes reported in table 3.

Note that owing to sampling of students in the YCS, figures reported at stages 2 and 3 are subject to sampling error. Standard errors are thus reported where pertinent.

3.1.3: Higher Education Statistics Agency

HESA is the central source for higher-education statistics in the UK. It collects census data on an annual basis from

6. Data for Scotland and Northern Ireland are more problematic. In particular, these regions of the UK are not included in the YCS. This means that the focus is on England and Wales.
7. Alternative sources of data include the National Child Development Study, the British Household Panel Study and the Longitudinal Birth Cohort Studies. However, these sources are generally inferior to the YCS in terms of detailed information about studies and samples by ethnic group.
8. By this point, most full-time students have completed their A-levels and are on the first year of their undergraduate degree programmes.

Table 3: Sample numbers in the YCS, based on merged cohorts 1996–2002

Ethnicity	Combined YCS sample
white	28 704
black Caribbean	140
black African	115
Indian	874
Pakistani	546
Bangladeshi	229
Chinese	189
mixed race	249
other	527
Total	**31 573**

Note: In cohort 7, a detailed ethnic breakdown for the black population is not available. Similarly, numbers for mixed race and other minorities are combined for this cohort. In these instances, totals are given for cohorts 8, 9 and 10 only.
Source: Youth Cohort Study

universities and from other higher-education institutions, including details relating to current students, staff and information about recent leavers. Two relevant data sets are utilised in this study:

- **The student data set** This is an annual census of students undertaking studies at UK universities at the time of survey, including students on both undergraduate and postgraduate courses.
- **First destination data set** This is an annual census of the activities of graduates approximately six months after completing their courses, including details regarding further study and economic activity. This data set provides information about the degree classification obtained by students on the completion of their undergraduate studies.

HESA student data set for the academic year 2002/2003 are used to analyse student numbers at both undergraduate and postgraduate level.[9] Primarily this is done in relation to chemistry and physics, but the data also provide information about student choice with regard to alternative areas of study (e.g. other science subjects or alternative vocational routes, such as medicine-related subjects, business and law). The first destination data set is analysed to examine achievement by degree classification and patterns of further study by ethnic group, based on data for the academic year 2001/2002.

Finally, note that to achieve consistency with GCSE and A-level data, the analysis of HESA data is restricted to students domiciled in England and Wales.

3.1.4: Labour Force Survey

The LFS is a sample survey of households living at private addresses in the UK. The surveys are conducted on a quarterly basis and provide data about approximately 65 000 employed people per quarter. The survey is conducted on a voluntary response basis, and responses are weighted by the ONS to correct for bias in sample selection. Information is collected from one household member (face to face initially, then by telephone interviews) about the education, training and employment of all household members, and each household in the sample is surveyed for five successive quarters subsequent to initial contact. The survey also records basic demographic details, including ethnicity and gender. The LFS is used in this study to provide subsidiary information about population sizes and economic activity.

The other potential use of LFS data in relation to employment destinations of chemistry and physics graduates (i.e. their occupations and industry destinations) is not pursued in this study. This is because of the very small sample numbers encountered when analysing ethnic-minority graduates.[10]

3.2: Linking Youth Cohort Study and Higher Education Statistics data sets

A crucial element of the methodology of constructing the educational pipeline outlined in table 1 is linking YCS and HESA data sets. The YCS provides detailed information about the proportion of young people obtaining A-level qualifications based on a survey sample. In contrast, HESA data provide estimates of the actual number of degree students based on census data. In linking these data sets it is useful to estimate the proportions of a notional cohort of young people studying chemistry and physics at degree level (stages 4–6).

To combine the data sets, the following procedure is used. A proportion of all school-leavers who are undertaking degree studies at age 18/19 is estimated based on sample data from the YCS. This figure is inflated to take into account that not all students start degree studies in the September two years after completing compulsory schooling, when they are 18/19. Having established proportions of young people in undergraduate degree studies by ethnic group, HESA data are used to track populations by ethnic group, into specific subject areas (i.e. chemistry and physics) at undergraduate level, and thereafter through to postgraduate study.

The second stage of this process provides the crucial link between YCS and HESA data sets. This is achieved by reconciling aggregate numbers in undergraduate studies from HESA, with aggregate estimates of student numbers based on YCS and LFS data. This can be illustrated with reference to the aggregate figures for England and Wales. (More detailed figures can be found in appendices 1a and 1b, where estimates of aggregate numbers at each of the six stages of the pipeline are presented.)

Based on HESA data from 2002/2003, there are 241 575 first-year undergraduate degree students studying for first degrees or enhanced first degrees who are domiciled in England and Wales. Comparing this figure with the number of young people of school-leaving age estimated from spring 2004, the LFS – which gives the size of the England and Wales school-leaving cohort as approximately

9. HESA data are also available for 1996/1997 and 2001/2002, and these are used for comparison, where appropriate.
10. This analysis was undertaken as an investigative data exercise combining Asian and black groups as broad ethnic categories. Even at this very coarse level of aggregation, sample numbers were prohibitively small. An analysis of broad employment patterns for the populations as a whole is available from the authors on request.

665 000 – leads to the inference that 36.3% of the school-leaving cohort undertake undergraduate studies at some stage.[11] However, using data from the YCS, a lower percentage of 21.7% is obtained.[12]

From this it is inferred that only 59.8% of undergraduates enter courses aged 18/19 (two years after completing compulsory schooling). This figure is used to adjust estimates of undergraduate participation in the YCS.[13]

3.3: Statistical significance

The study aims to look for statistically significant differences in participation and achievement between ethnic groups. Statistical tests are therefore used to look for statistically significant patterns in the data. Differences in participation and/or achievement are identified at each stage by ethnicity, and where appropriate by gender, and statistically significant differences between groups are identified. The nature of the data sets used in this study varies, and therefore so do the statistical tests.

YCS data are a sample survey and therefore estimates from these (i.e. proportions of students achieving a particular outcome by ethnic group) are subject to sampling error. Moreover, for some of the smaller ethnic groups, such as Bangladeshi and Chinese students, these sampling errors can potentially be quite large. When using this data set, significance tests are therefore performed, based on achievement relative to the white population and using a series of two-sample T-tests, to compare ethnic groups with the white population in a pairwise fashion. (This was applied, for example, when comparing the proportion of Indian students versus the proportion of white students who achieve an A-level in chemistry.)

These tests are based on the null hypothesis that there is no difference between ethnic groups, thus the results of the statistical tests are used either to accept or to reject this hypothesis.

The DfES and HESA data sets are both census data (data are collected from the whole populations and not from samples of those populations) and are therefore not subject to the usual sampling error. Using these data sets, distribution patterns of ethnic groups among subjects are compared with what might be expected if there were no systematic ethnicity/gender effects on self-selection into subject areas.

This is done using a series of chi-squared tests, which compare actual and expected student numbers based on the null hypothesis that there is a random allocation of students to subject areas by ethnic group (and therefore that participation/achievement rates will be equal), and this hypothesis is either accepted or rejected.

Standard errors are presented in the appendices, where appropriate, and reference is also made to statistical significance in the text. Throughout, significance is based on rejection of the null hypothesis at the 5% error level. More detail about the significance tests used is presented in appendix 10.

11. Implicit assumptions are made here that the school-leaver cohort is constant over time, as is the propensity to stay on in higher education.
12. This smaller figure may also, in part, reflect the upward trend in undergraduate numbers in the period 1996–2002.
13. The adjustment is based on multiplying the original proportion by a multiple of 1/0.598. In essence, this ensures that the estimates of the aggregate number of undergraduate students based on the school cohorts and the YCS (appendix 1) are equal to the aggregate number of undergraduate students in HESA data.

4: The educational pipeline

"The black Caribbean ethnic group has the lowest overall survival rate in academic chemistry and physics."

Fig. 1 (opposite): Overall survival rates and stage survival rates in academic chemistry.

The metaphor of the leaky educational pipeline is now summarised for each of the main ethnic groups.[14] The population moving through the pipeline starting with a (notional) school-leaving cohort gradually diminishes in moving from stages 1 to 6. The retention/attrition at each stage is the key consideration in assessing when and how students "drop out" of academic studies in chemistry and physics, by ethnic group. The data are presented in three different ways:

- Progress through the pipeline is summarised by reporting the number of students remaining, based on a notional cohort of 10 000 school-leavers per ethnic group. This figure gives the overall survival rate.
- At each stage the overall over- or under-representation of each ethnic-minority group relative to the majority white population is reported. In other words, comparisons are reported between the overall survival rate of the majority white population and the overall survival rate of a particular ethnic group.[15]
- For each stage the proportion of each group moving through from the previous stage is expressed as a percentage based on the number of people surviving relative to that at the previous stage.[16] This is the stage survival rate in moving from one stage to the next.

Figure 1 illustrates the leakage in chemistry, showing the survival rates in chemistry based on a notional cohort of 10 000 school-leavers per ethnic group, as well as the rates of retention at each stage. Similarly, figure 2 describes the pipeline for studies in physics.

The emerging picture is quite complex, so the pipeline is best described by means of an example based on the black Caribbean school-leavers. This group has the lowest overall survival rate in academic chemistry and physics, with only one student in 10 000 expected to undertake a doctorate degree in chemistry and fewer than one student in 10 000 expected to undertake a doctorate degree in physics. The key question is therefore: where are the main attrition points for this group?

This question is answered with reference to the white population (which can be used as a benchmark).

First, black Caribbean students on average are much less likely to achieve five or more GCSEs at grade A*–C than their white counterparts. Only 29.2% of black Caribbean students achieve this benchmark, whereas the corresponding figure for England- and Wales-domiciled white students is 49.5%. There is an overall under-representation of black Caribbean students at this stage (41%) relative to the white majority group. In this instance it is likely to be the result of external influences that have little to do with the study of science, such as socioeconomic factors, experiences of compulsory schooling and parental input. Although these factors may be exogenous as far as the science community is concerned, many black Caribbean students fall at this first hurdle and therefore never have the opportunity to make positive choices regarding the study of science. In this respect, lack of attainment at GCSE level alone potentially goes a long way to explaining the lack of black Caribbean scientists at university.

There appear to be two other key points of attrition for black Caribbean students. The first is in choosing A-levels. Figures 1 and 2 show that black Caribbean students are much less likely to take A-level chemistry or physics than white students. Of the population of white students achieving five or more GCSEs at grade A*–C, approximately 10% go on to do an A-level in chemistry or physics. These figures compare with only 6% (chemistry) and 3% (physics) for the black Caribbean population. Black Caribbean students appear to find physical science unattractive even when choosing A-levels.

There is also a high level of attrition during undergraduate studies. Black Caribbean students are much less likely to achieve a first- or upper-second-class degree than their white counterparts. The data show that this observation also applies in most other subject areas. For white students, 53% of those studying chemistry and 54% of those studying physics obtain a first- or upper-second-class degree. This compares with 36% and 29% respectively for black Caribbean students. Moreover, of the students obtaining a first or upper-second, a smaller proportion of black Caribbean students go on to study chemistry or physics at doctorate level. This suggests that, even at university level, black Caribbean students appear to be deterred compared with their white peers.

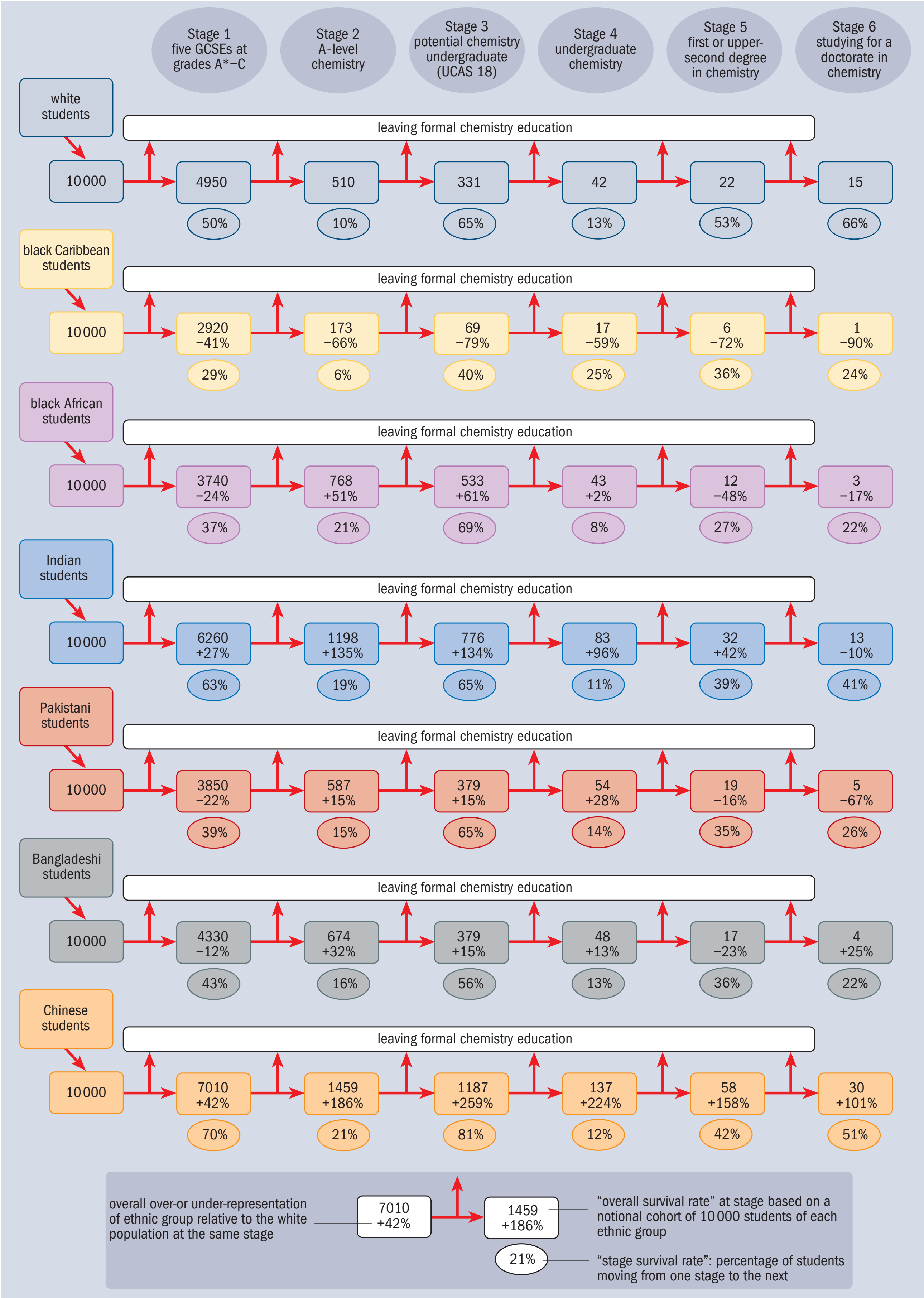
Complex picture

The picture of retention/attrition across all ethnic groups is quite complex. Along with black Caribbean students, black African, Pakistani and Bangladeshi students are also less likely to achieve five or more GCSEs at grade A*–C compared with their white counterparts.

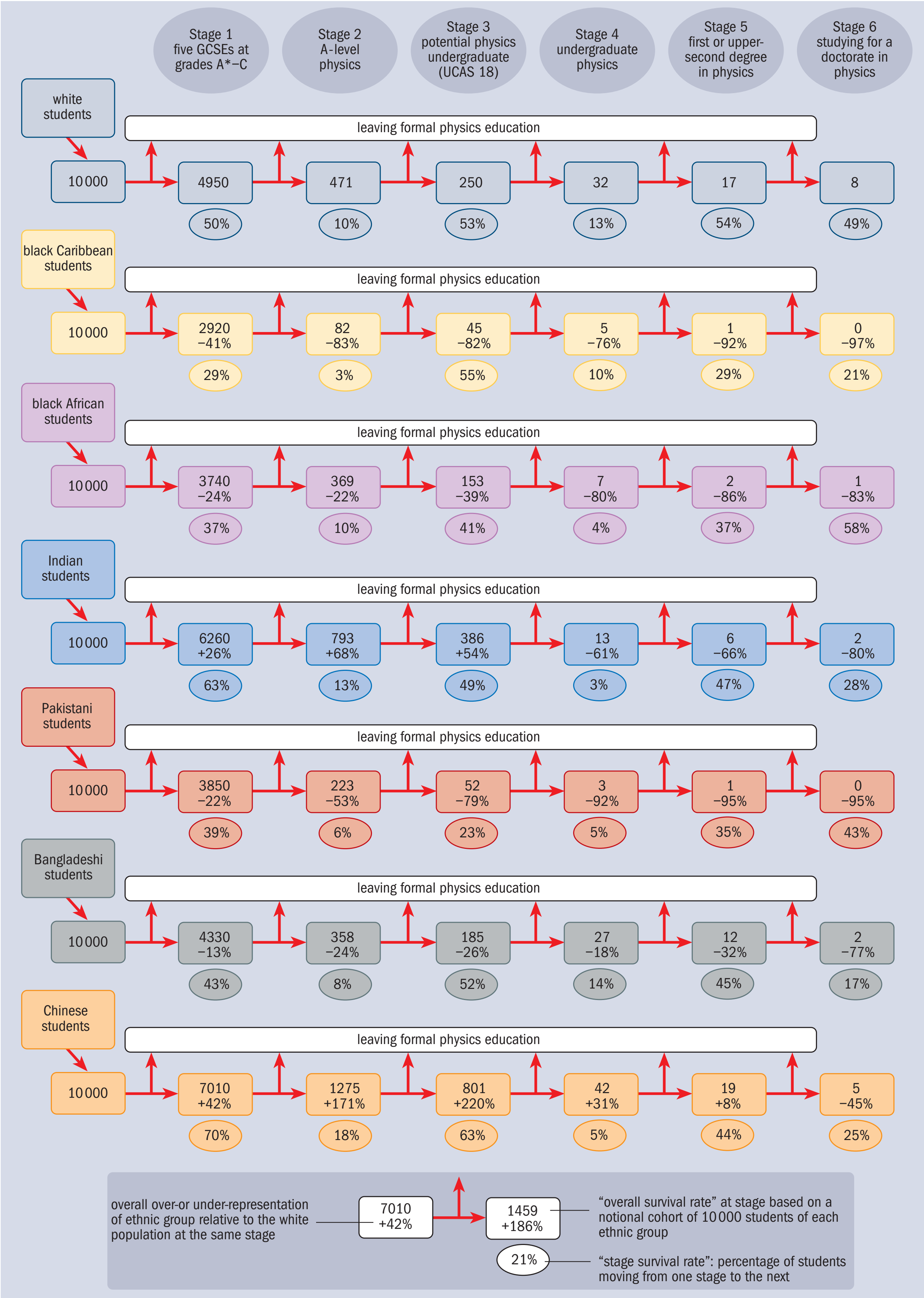
Among ethnic-minority groups, only black Caribbean students appear to have a particular aversion to chemistry and physics at A-level.

This point is illustrated by comparing the stage survival rates for black Caribbean students with those for other groups. The cumulative effects of small numbers of black Caribbean students achieving five GCSEs at grades A*–C, and a low take-up of A-level chemistry and physics, is illustrated by the overall under-representation of black Caribbean students at stage 2 of the educational pipeline (–66% for chemistry; –83% for physics).

14. For a general guide to definitions of ethnic groups, see http://www.statistics.gov.uk/about/ethnic_group_statistics/downloads/ethnic_group_statistics.pdf
Note: the way in which "other" and "mixed" ethnicity are defined differs in the YCS and HESA, making any linking of the two data sets impracticable for these groups.
15. The over- or under-representation is calculated using the formula 100((overall survival rate of ethnic group at stage X/overall survival rate of white group at stage X)–1).
16. These percentages can be thought of as quasi-probabilities (i.e. the probability of a representative individual remaining in academic chemistry or physics at each stage). Note also that the rate of attrition can be calculated on this basis as 100% minus the rate of retention.



Stage 1
five GCSEs at grades A*–C
Stage 2
A-level chemistry
Stage 3
potential chemistry undergraduate (UCAS 18)
Stage 4
undergraduate chemistry
Stage 5
first or upper-second degree in chemistry
Stage 6
studying for a doctorate in chemistry
white students
leaving formal chemistry education
10 000
4950
50%
510
10%
331
65%
42
13%
22
53%
15
66%
black Caribbean students
leaving formal chemistry education
10 000
2920 −41%
29%
173 −66%
6%
69 −79%
40%
17 −59%
25%
6 −72%
36%
1 −90%
24%
black African students
leaving formal chemistry education
10 000
3740 −24%
37%
768 +51%
21%
533 +61%
69%
43 +2%
8%
12 −48%
27%
3 −17%
22%
Indian students
leaving formal chemistry education
10 000
6260 +27%
63%
1198 +135%
19%
776 +134%
65%
83 +96%
11%
32 +42%
39%
13 −10%
41%
Pakistani students
leaving formal chemistry education
10 000
3850 −22%
39%
587 +15%
15%
379 +15%
65%
54 +28%
14%
19 −16%
35%
5 −67%
26%
Bangladeshi students
leaving formal chemistry education
10 000
4330 −12%
43%
674 +32%
16%
379 +15%
56%
48 +13%
13%
17 −23%
36%
4 +25%
22%
Chinese students
leaving formal chemistry education
10 000
7010 +42%
70%
1459 +186%
21%
1187 +259%
81%
137 +224%
12%
58 +158%
42%
30 +101%
51%
overall over-or under-representation of ethnic group relative to the white population at the same stage
7010 +42%
1459 +186%
21%
"overall survival rate" at stage based on a notional cohort of 10 000 students of each ethnic group
"stage survival rate": percentage of students moving from one stage to the next


Stage 1
five GCSEs at grades A*–C
Stage 2
A-level physics
Stage 3
potential physics undergraduate (UCAS 18)
Stage 4
undergraduate physics
Stage 5
first or upper-second degree in physics
Stage 6
studying for a doctorate in physics
white students
leaving formal physics education
10 000
4950
50%
471
10%
250
53%
32
13%
17
54%
8
49%
black Caribbean students
leaving formal physics education
10 000
2920 −41%
29%
82 −83%
3%
45 −82%
55%
5 −76%
10%
1 −92%
29%
0 −97%
21%
black African students
leaving formal physics education
10 000
3740 −24%
37%
369 −22%
10%
153 −39%
41%
7 −80%
4%
2 −86%
37%
1 −83%
58%
Indian students
leaving formal physics education
10 000
6260 +26%
63%
793 +68%
13%
386 +54%
49%
13 −61%
3%
6 −66%
47%
2 −80%
28%
Pakistani students
leaving formal physics education
10 000
3850 −22%
39%
223 −53%
6%
52 −79%
23%
3 −92%
5%
1 −95%
35%
0 −95%
43%
Bangladeshi students
leaving formal physics education
10 000
4330 −13%
43%
358 −24%
8%
185 −26%
52%
27 −18%
14%
12 −32%
45%
2 −77%
17%
Chinese students
leaving formal physics education
10 000
7010 +42%
70%
1275 +171%
18%
801 +220%
63%
42 +31%
5%
19 +8%
44%
5 −45%
25%
overall over-or under-representation of ethnic group relative to the white population at the same stage
7010 +42%
1459 +186%
21%
“overall survival rate” at stage based on a notional cohort of 10 000 students of each ethnic group
“stage survival rate”: percentage of students moving from one stage to the next

There do not appear to be strong negative biases against chemistry among ethnic-minority groups in terms of suitably qualified students choosing to study chemistry at degree level rather than other subjects. In physics, however, there is evidence of most ethnic groups (except for Pakistani students) being less inclined to study physics at degree level than their white counterparts.

Most striking are the different patterns of attrition from chemistry and physics during and after undergraduate studies. A strong statistical finding is that, almost without exception, ethnic-minority groups tend to do less well in their undergraduate studies in terms of achieving a first or upper-second degree classification. Moreover, of students who achieve these standards, non-white students are much less likely to study chemistry or physics at doctorate level. The reasons for this are unclear and require further research. However, because these groups are under-represented in these subjects relative to white students, it is possible that peer-group pressure not to continue studying chemistry or physics is greater among ethnic groups, and in particular among British Asian groups where there is a preponderance to study what may be regarded as more vocational subjects.

Fig. 2 (opposite): Overall survival rates and stage survival rates in academic physics.

5: Ethnicity and compulsory schooling

"The pool of potential scientists among some ethnic groups is being severely limited very early in the educational pipeline."

The differences in achievement in compulsory schooling by ethnic group (and gender) have attracted much attention over recent years, including initiatives to improve the performance of some ethnic-minority groups, such as the Aim Higher initiative for black Caribbean pupils. The picture of achievement before the age of 16 is one of high achievement among white, Indian and Chinese pupils but low achievement among other ethnic-minority groups. Evidence of this is shown in figure 3, which gives the proportion of pupils achieving five or more GCSEs at grades A*–C. Based on this measure, black Caribbean students perform notably worse in school than do other groups, but black African, Pakistani and Bangladeshi pupils also, on average, perform worse than their white counterparts. Note also that, in each case, gender is an important factor, with girls consistently outperforming boys at GCSE.

The relevance of these data for chemistry and physics is that the pool of potential scientists among some ethnic groups is being severely limited very early in the educational pipeline. Assuming that departure from academic studies is for the most part irreversible, then, *pro rata*, the proportion of Indian and Chinese students with the qualifications to access higher education in science will be approximately double that for black Caribbean students.

Fig. 3: Proportion of pupils achieving five or more GCSEs at grades A*–C, by ethnic group and gender.

Source: DfES, National Curriculum Assessment 2004

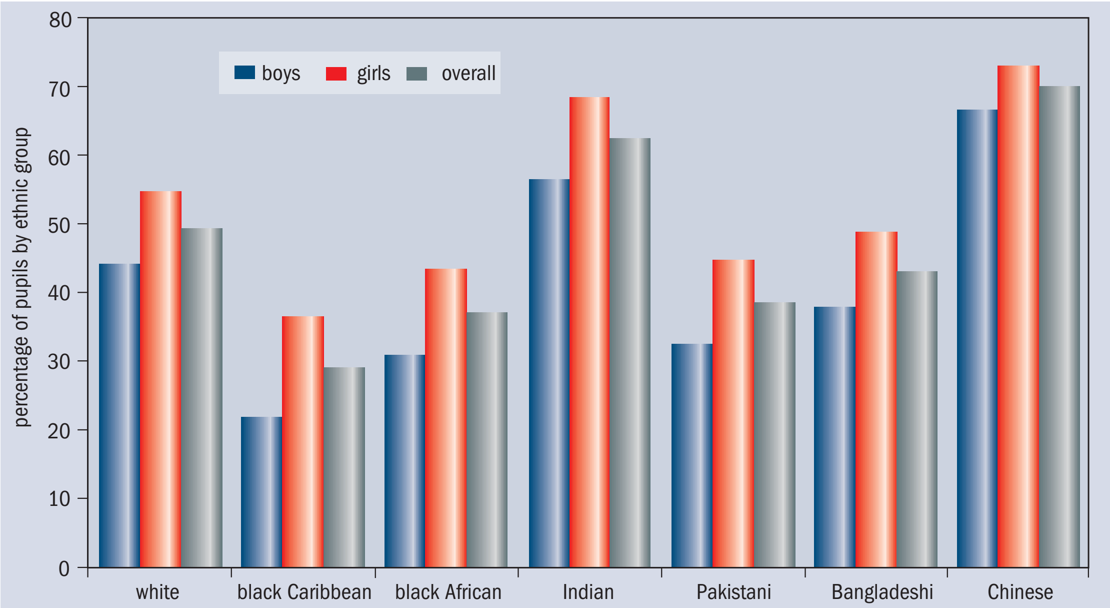
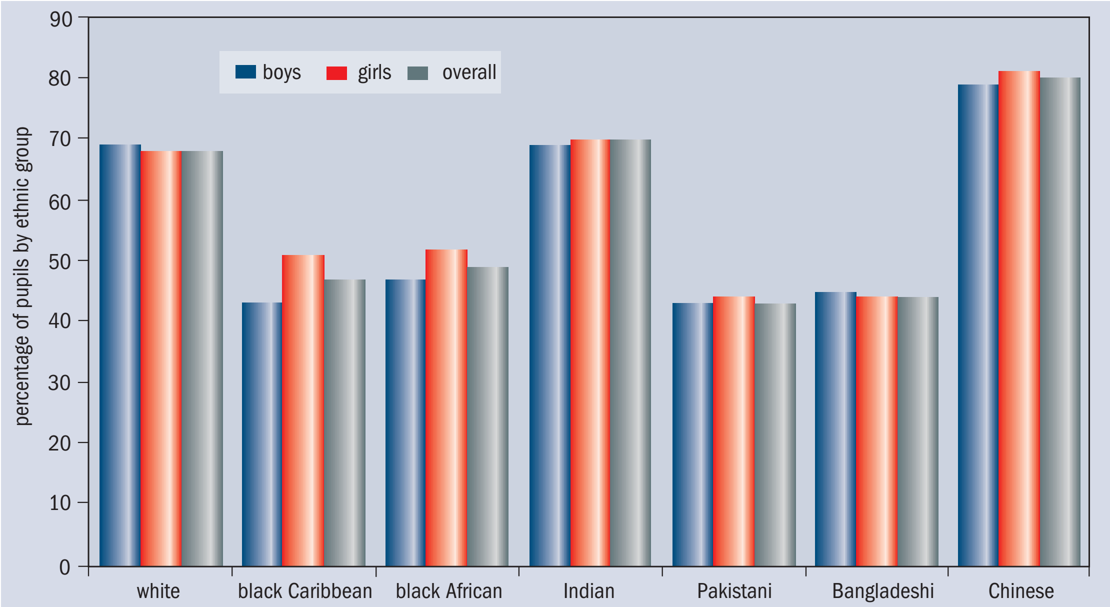


Fig. 4: Proportion of students achieving KS3 science, by ethnic group and gender.

Source: DfES, National Curriculum Assessment 2004



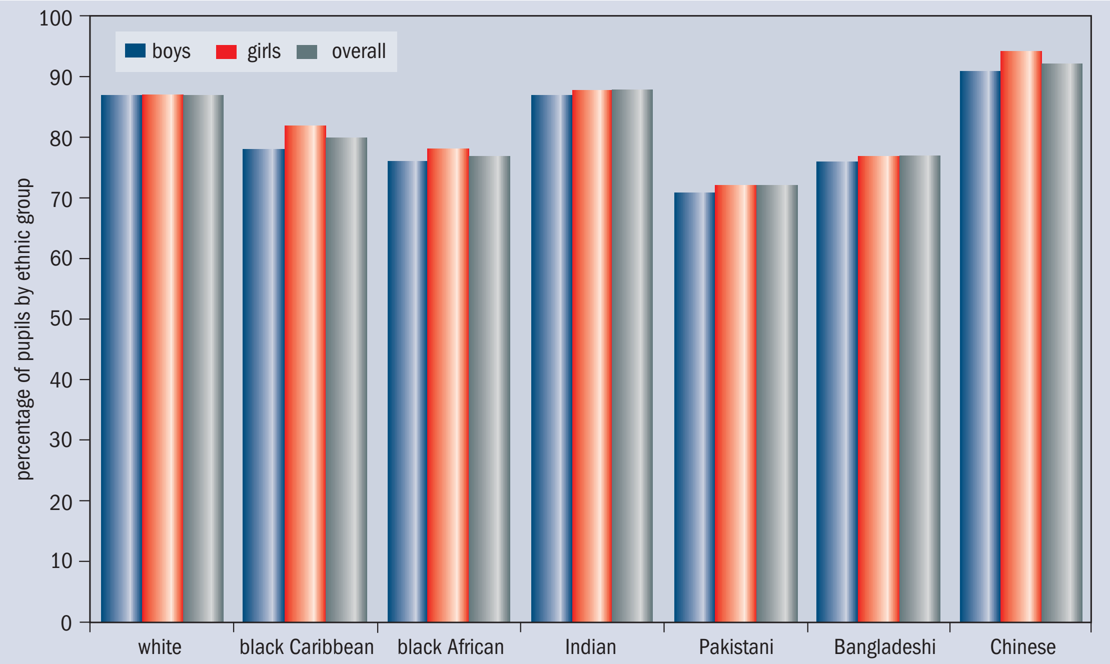


Fig. 5: Proportion of students achieving KS2 science, by ethnic group and gender.

Source: DfES, National Curriculum Assessment 2004

This evidence points to the fact that much of the attrition from science in some ethnic groups – noticeable much later in the representation of particular ethnic groups in scientific professions, in later life – starts at the first stage of the education pipeline (i.e. during compulsory schooling).

Data available about attainment at KS level reveal that this pattern of differential achievement by ethnic-minority group starts before GCSE. KS data provide specific information about science education in school. Figure 4 shows the proportion of students achieving the national target in science at the end of KS3 tests, which students take aged 14. The figure reveals a remarkably similar pattern of achievement by ethnic-minority group to the GCSE data shown previously, suggesting that the different academic achievement by ethnic group at GCSE is already manifest at this earlier stage. In addition, whereas this figure specifically relates to achievement in science, as opposed to the more general measure of five or more GCSEs at A*–C grades, the close correspondence of the data by ethnic group suggests that the choice of the stage 1 measure in the present study is appropriate.

Finally, it should be noted that differences in achievement in science by ethnic group are found in attainment results at the end of KS2 (when pupils are 11), although the magnitude of the difference is less dramatic than those found at KS3 and at GCSE. Figure 5 shows the proportion of students achieving the national standard at the end of KS2 in science by ethnic group and gender. It is worth noting the dramatic reduction in performance of black Caribbean boys. At KS2, this group's performance is in line with, or better than, a number of ethnic groups with about 78% achieving the national standard. However, only 22% of black Caribbean boys achieve five or more GCSEs at grades A*–C, which is a lower proportion than any other group.

6: Ethnicity and science at A-level

"Interestingly, black African female students are almost twice as likely to achieve three or more A-levels in a science subject."

For the vast majority of students in England and Wales the main route into studying physical sciences at university is A-levels. Therefore, whether or not individuals choose to study chemistry and physics along with other science subjects at A-level has a great bearing on the numbers progressing along the educational pipeline.

In particular, the tendency not to study science at A-level will ultimately restrict numbers entering university courses and professional science. Many students make the decision not to study A-levels at all, or do not successfully complete their A-level studies. The starting point is therefore to consider the proportion of young people at 18/19 obtaining at least one A-level in any subject.

Figure 6 presents these data, analysed by ethnic group and gender, based on the combined cohorts of the YCS 1996–2002.[17] This figure shows a very similar pattern of attainment at A-level to that at GCSE by ethnic group. There is wide variation in the achievement by ethnic group (particularly among males), with a significantly higher proportion of Chinese and Indian students achieving an A-level compared with the white population.

In line with performance at GCSE, a significantly lower proportion of black Caribbean, Pakistani and Bangladeshi students also achieve an A-level compared with the white population.[18]

6.1: Science subjects at A-level

Focusing more specifically on studying science at A-level, figures 7 and 8 show the percentage of young people, by gender, obtaining a science A-level, based on the combined cohorts of the YCS 1996–2002. The lower frame of each figure analyses this proportion further by number of science subjects studied. In this case, and subsequently, a science subject at A-level is defined using the DfES subject definitions used in the YCS. These are shown in appendix 2. The list includes single-subject chemistry and physics, other sciences (primarily biology) and mathematics, which incorporates further mathematics and statistics.

This analysis is extended in figure 9, which presents student numbers by subject area at A-level (i.e. chemistry, physics, mathematics or other science – primarily biology – based on the combined YCS cohorts 1996–2002). Figures are expressed as a percentage of all people aged 18/19 by ethnic group and gender.

Gender significance

The analysis reveals major differences in patterns of the study of science at A-level by ethnic group and gender. The differences by ethnic groups reported for A-levels as a whole are accentuated for science, especially among males. Young Chinese males are three times as likely to study a science subject as young white males; Indian males are twice as likely. Statistically significant higher proportions of Chinese and Indian students achieve a science A-level compared with the white population. Moreover, this observation holds for both gender groups.[19]

Another important observation is that, for men and women, Indian and Chinese students are significantly more likely to achieve three or more science A-levels than students from any other ethnic group. For males, relative to white students, Indian students are three times as likely, and Chinese students are four times as likely, to achieve

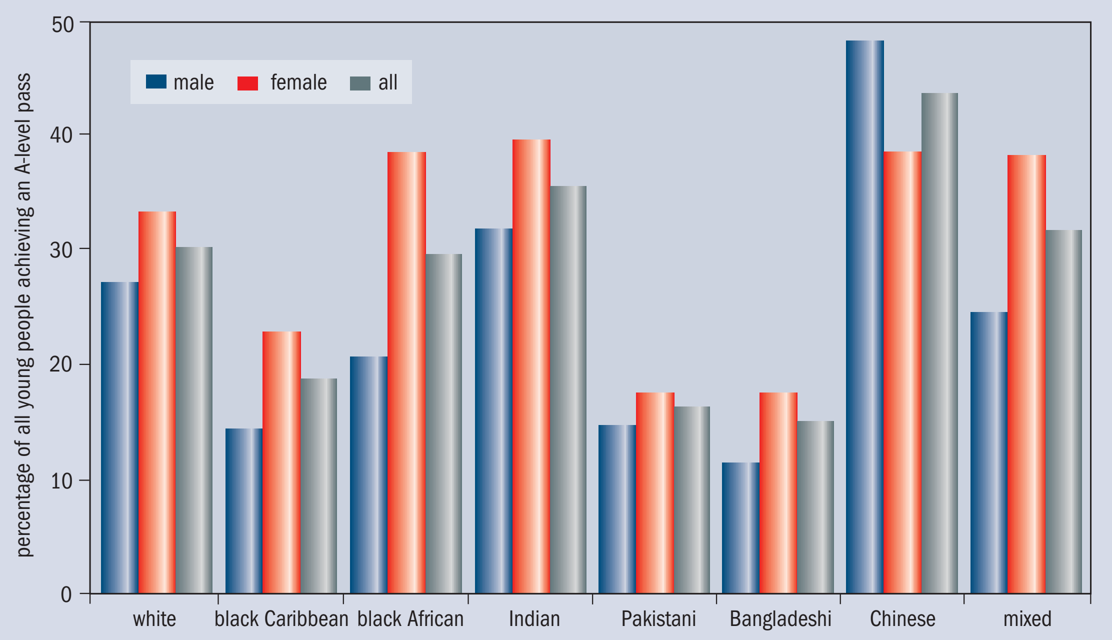


Fig. 6: Proportion of young people aged 18/19 achieving at least one A-level pass, by ethnic group and gender.

Source: Youth Cohort Study, 1996–2002

17. Trends in attainment over time by YCS cohort are shown in appendix 2, where non-white groups are combined to avoid small sample sizes.
18. Based on a two-sample proportions T-test.
19. Based on two-sample proportions T-test.

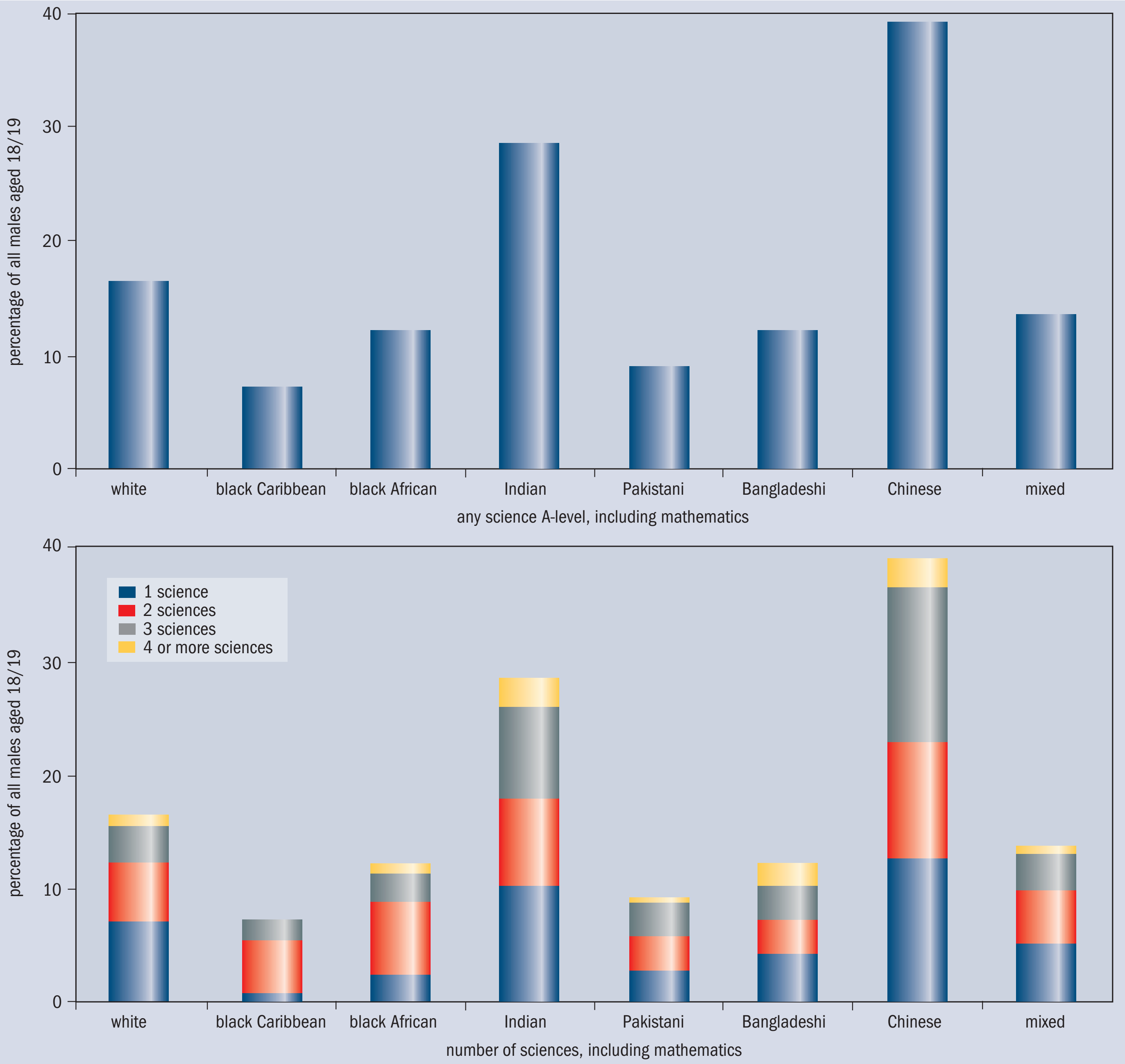


Fig. 7: A-level sciences for males, by ethnic group.

Source: Youth Cohort Study, 1996–2002

three or more science A-levels.

For females, similar differences are observed. Indian students are twice as likely, and Chinese students are three times as likely, to achieve three or more A-Levels in a science subject. Interestingly, black African female students are almost twice as likely to achieve three or more A-levels in science.

Vocationally driven choices

It is interesting to speculate that the significantly larger proportions of Indian and Chinese students achieving three or more science A-levels may reflect vocationally driven choices of A-level subjects, perhaps influenced by family pressure. In contrast, black Caribbean males are only half as likely to achieve an A-level in science compared with their white counterparts, and females are only a fifth as likely as their white counterparts. Both of these differences, when they are compared with the white population, are statistically significant.[20]

Other under-achieving ethnic groups are Pakistani and Bangladeshi students. A significantly lower proportion of these students (based on combined gender) achieve a science A-level when their results are compared with the achievement of the white population.[21]

Referring to figure 9, which shows subject choices in more detail, broadly similar patterns emerge. However, differences by gender emerge strongly in the study of physics at A-level. Males are much more inclined to study physics at A-level, with strong significant differences between gender groups; in chemistry, differences were not significant.[22] The

20–22. Based on a two-sample proportions T-test.

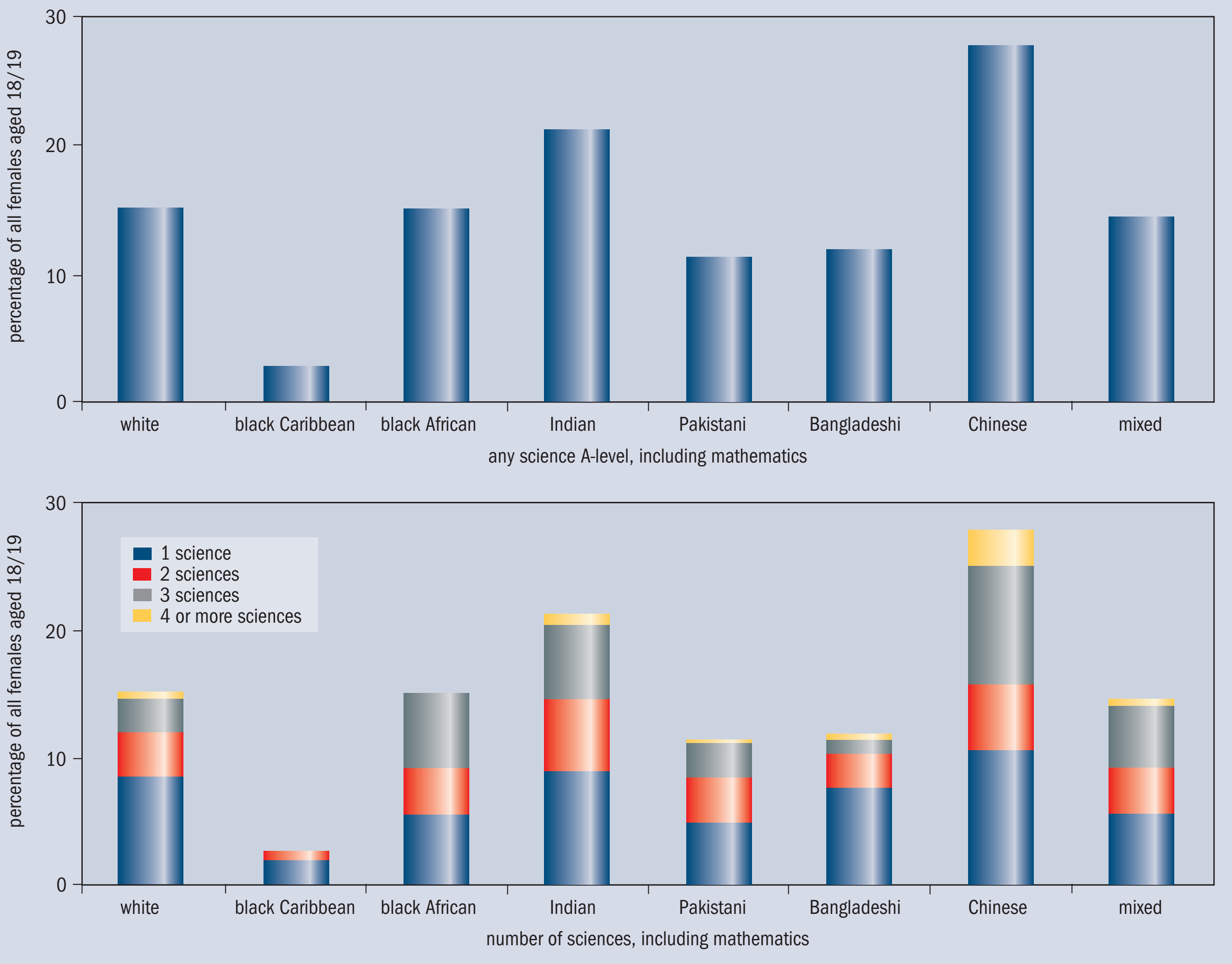


Fig. 8: A-level sciences for females, by ethnic group.

Source: Youth Cohort Study, 1996–2002

differences by ethnic group are along the lines of those discussed so far, with differences by ethnic group generally more pronounced among males.

Trends with time in attainment of chemistry and physics A-levels by YCS cohort are reported in appendix 4. Sample sizes for ethnic-minority groups are very small in a single cohort, so non-white groups are combined and compared with the white population.

6.2: Potential undergraduate scientists

Consideration of the next stage along the educational pipeline requires identification of the proportion of young people, by ethnic group, who might be considered "potential undergraduate scientists" (i.e. either potential undergraduate chemists or physicists), based on subject choices and achievement at A-level.

This concept is useful in providing an ethnic profile of the pool of students from which chemistry and physics is recruiting at higher levels.

The detailed concept of the potential undergraduate chemist or physicist is outlined in section 2, including prerequisite subject choices and grades obtained at A-level. The section gave three definitions according to different levels of achievement in A-level studies, based on the number of UCAS points achieved. In short, a potential undergraduate chemist is defined as achieving an A-level in chemistry, plus 12, 18 or 24 UCAS points (with a minimum of a grade C in chemistry, or grade B for 24 UCAS points); the potential undergraduate physicist is expected to achieve an A-level in physics and in a mathematics-related discipline plus 12, 18 or 24 UCAS points (with a minimum of a grade C in physics, or grade B for 24 UCAS points).

Applying these definitions to the pooled YCS data for 1996–2002 provides estimates of the proportions of potential undergraduate chemists/physicists. Figure 10 presents the proportions of the population aged 18/19 by ethnic group and gender who may be categorised as potential undergraduate chemists. The detailed figures, including standard errors and sample sizes, are presented in appendix 3. Similarly, figure 11 shows the proportions of the population aged 18/19 years by ethnic group and gender who may be categorised as potential undergraduate physicists. The detailed figures, including standard errors and sample sizes, are presented in appendix 4.[23]

23. Note that the standard errors on the proportions reported from the YCS are quite large in some cases, and in particular among ethnic-minority groups whose sample numbers in the survey are quite small. In contrast, standard errors for the majority white population are small, giving us a high degree of confidence with regard to our findings for this group.

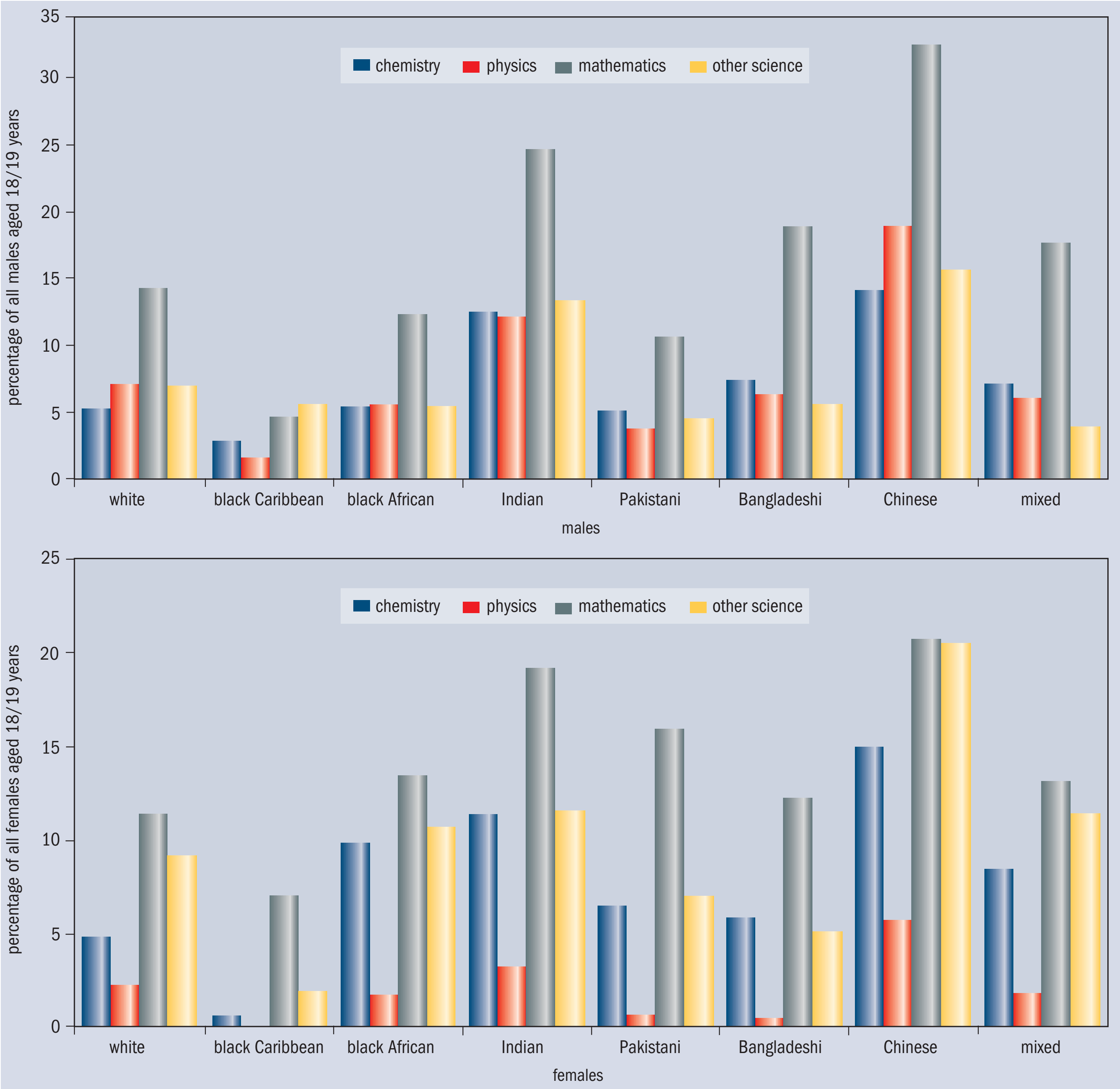


Fig. 9: Science subjects studied at A-level, by ethnic group and gender.

Source: Youth Cohort Study, 1996–2002

The results show marked differences across ethnic groups in terms of students qualified to study on undergraduate chemistry programmes. These differences tend to highlight the differences seen so far by ethnic group. That is, the Chinese and Indian populations – the highest achievers in terms of GCSE and A-level attainment – have by far the highest proportions of potential undergraduate chemists and physicists; members of both groups are significantly more likely to be potential undergraduate scientists than members of the white population, based on the three alternative measures and combining gender groups.[24] On a *pro rata* basis the Chinese and Indian populations have approximately double the proportion of potential undergraduate scientists than any other group.

Once again, this observation correlates with the propensity of some groups to seek to study medicine: candidates are likely to require an A-level in chemistry to study medicine and also to have at least 24 UCAS points.

In contrast, a very low proportion of the black Caribbean population qualifies as potential undergraduate scientists, and this is especially true for physics.[25]

Stark gender differences

In addition to differences by ethnic group, there are stark gender differences in proportions of potential undergraduate physicists. Not only is the proportion of females achieving an A-level in physics small, but applying the strictest criteria for defining potential undergraduate physi-

24. Based on a two-sample proportions T-test.
25. Note that, in this case, differences between ethnic groups are not significant, given the small proportions involved and the small sample base for black Caribbean students.

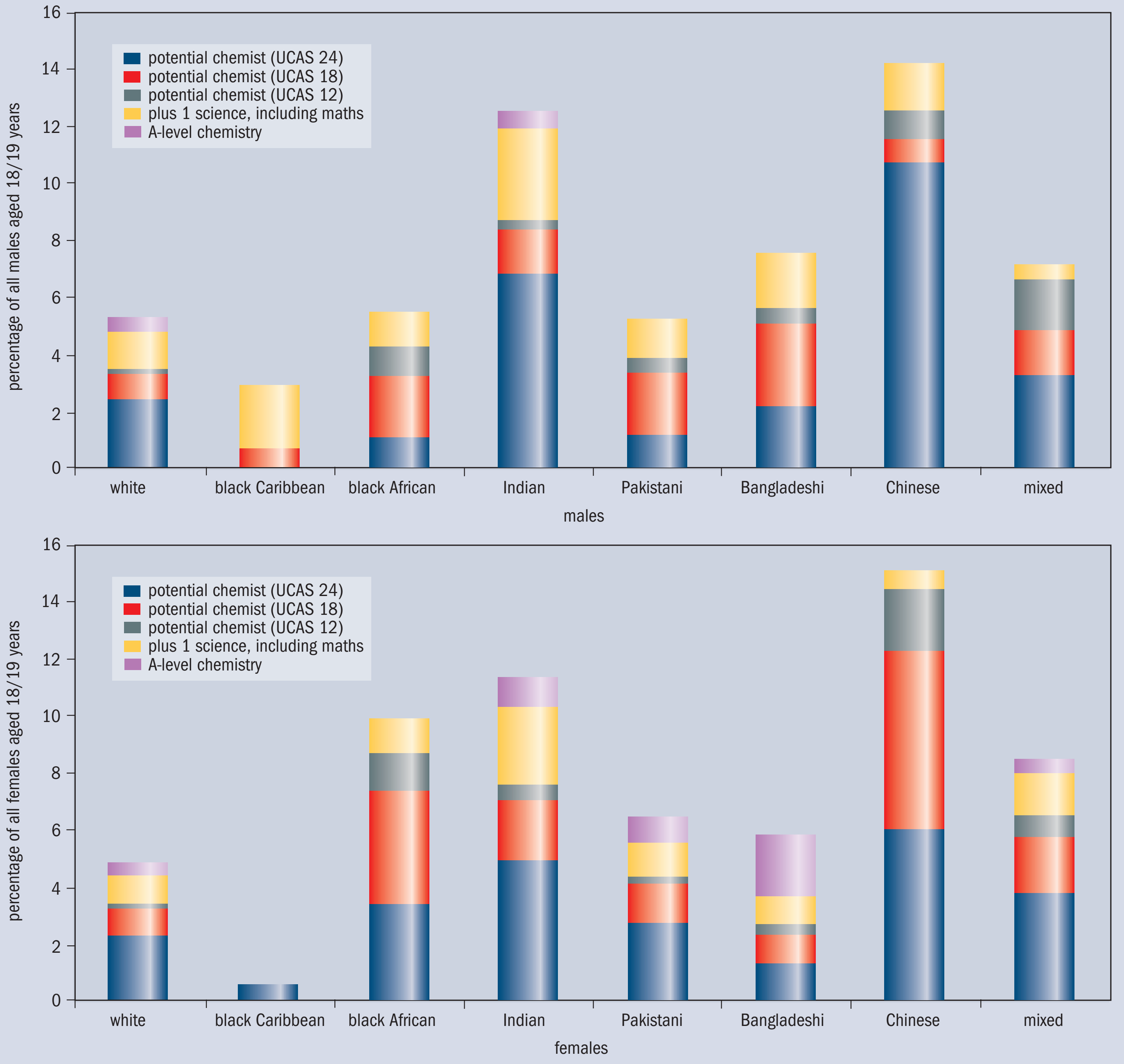


Fig. 10: A-level chemistry and potential undergraduate chemists.

Source: Youth Cohort Study, 1996–2002

cists (definition UCAS 24) gives a very small number of potential undergraduate female physicists outside the white and Indian populations.

For females, differences between other ethnic groups and the white population are not generally significant for the proportion of potential undergraduate scientists. However, this is in part the result of the small sample numbers that are available to be analysed.

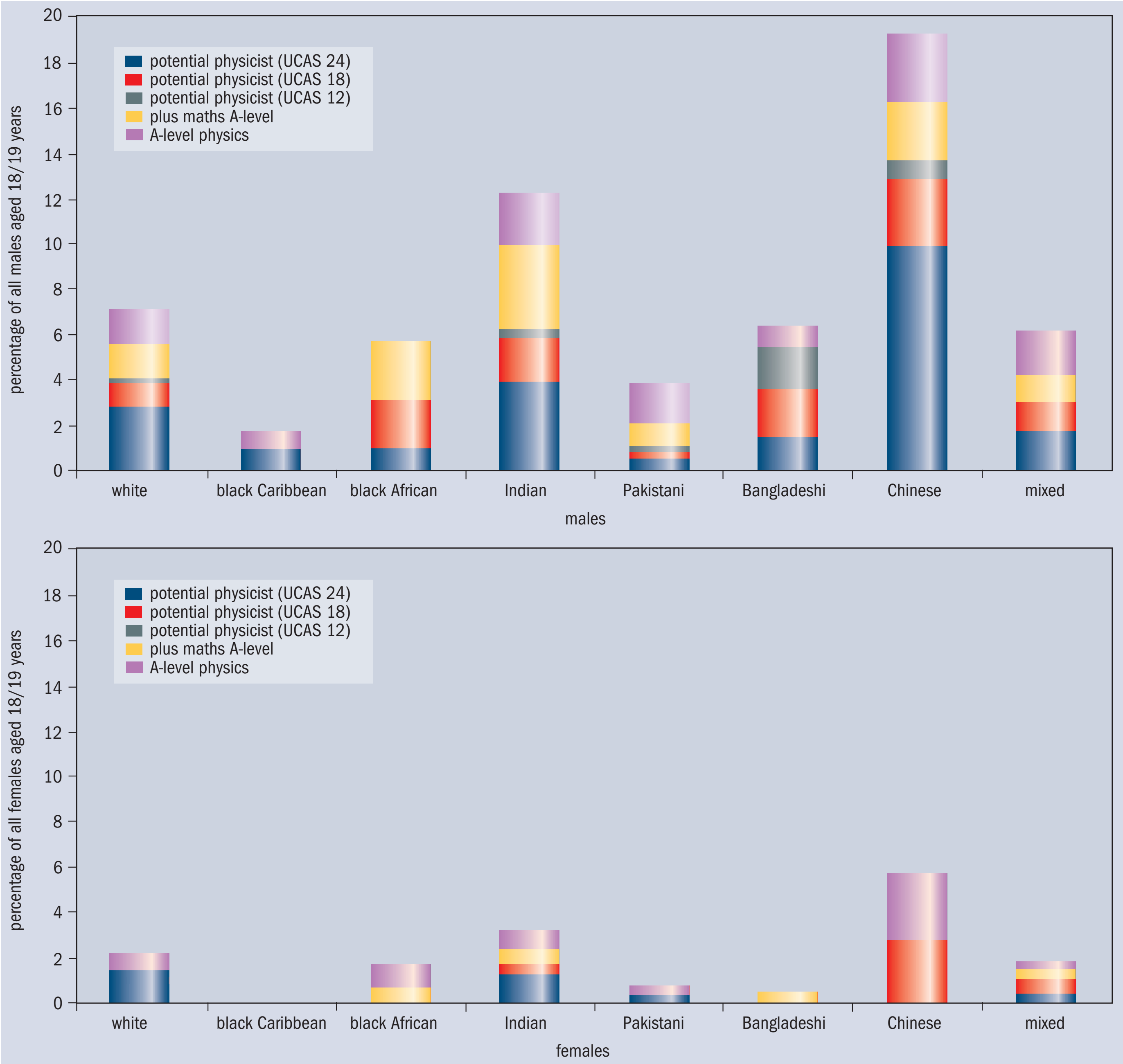


Fig. 11: A-level physics and potential undergraduate physicists.

Source: Youth Cohort Study, 1996–2002

7: Ethnicity and undergraduate studies

"The most under-represented ethnic groups tend to do the least well in their undergraduate studies."

The influence of ethnicity on the choice of studies at undergraduate degree level is now considered. In particular, this section examines the inclination towards studying chemistry and physics at undergraduate level compared with alternative subjects that might compete in attracting potential undergraduate scientists.

7.1: Ethnic-minority representation in undergraduate chemistry and physics

Utilising HESA 2002/2003 student data, the ethnic and gender breakdown of the undergraduate population in chemistry and physics, domiciled in England and Wales and studying for a first or enhanced first degree in chemistry and physics, is shown in figure 12. The charts show that both student bodies are ethnically white and male dominated. This is particularly the case in physics, where white males account for approximately three-quarters of the population and ethnic-minority females account for less than 3% of all students. Although chemistry is male dominated, it is more ethnically diverse than physics and has a more balanced gender profile.

These charts do not, however, convey the extent to which ethnic groups are under- or over-represented relative to their numbers in the undergraduate population. HESA data are not a representative survey of activities in the population, as is the case with YCS data, but are instead a census of students. Thus analysis is only possible of the ethnic structure within the student body domiciled in England and Wales. To normalise these data, the percentages for each subject ethnic-gender group are divided by the percentage of students in each of the respective ethnic-gender groups in the undergraduate student body as a whole, domiciled in England and Wales. The resulting figures have one taken away are then themselves expressed as percentages. The resulting figure yields the percentage under- or over-representation of each ethnic-gender group by subject area.

This is now referred to as a measure of ethnic-gender representation (EGR), the formula for which is shown below.

$$\text{EGR} = 100\left(\frac{\text{\% ethnic-gender group in subject X}}{\text{\% ethnic-gender group in undergraduate population}} - 1\right)$$

Using HESA student data for 2002/2003, evidence is found of pronounced ethnic differences in chemistry and physics. Using a chi-squared significance test, it is shown that students are not randomly allocated to physics and chemistry by ethnic group. Figures 13 and 14 present the measures of EGR for chemistry and physics. The charts show that white males, but not white females, are over-represented in both chemistry and physics relative to their numbers in the undergraduate population. Among ethnic-minority groups, ethnic Asian (Pakistani, Bangladeshi, Indian and Chinese) students, particularly Pakistani and Bangladeshi students but also Indian and Chinese students, are over-represented in chemistry relative to their numbers in the undergraduate population. This contrasts with black students, and in particular black Caribbean students, who are notably under-represented. In physics, the under-representation of all ethnic-minority groups, with the exception of Chinese, is clear. Females are also under-represented generally.

Lost potential

The transfer into undergraduate chemistry and physics courses relative to those identified as potential undergraduates is interesting (figures 1 and 2). For the most part, similar proportions of ethnic groups qualifying as UCAS 12 potential undergraduate chemists become undergraduate chemists. Interestingly, 25% of black Caribbean potential undergraduate chemists become undergraduate chemists – almost twice the proportion for white students. However, overall, black Caribbean students are significantly less likely to read undergraduate chemistry than their white counterparts (figure 1).

In contrast, overall, Indian and Chinese students are more likely to read undergraduate chemistry than white students: Indian students are twice as likely and Chinese students three times as likely. Interestingly, overall, Pakistani students are one-and-a-half times as likely as white students to read undergraduate chemistry. Again, these observations are in line with the higher proportions of Indian and Chinese students who are qualified to read chemistry.

Comparison between potential undergraduate physicists and those reading physics shows more variation in the proportions of students moving through. However, as the number of ethnic-minority students reading undergraduate physics is small, more variation would be expected. Having noted that, only Pakistani students are more likely than white students to transfer from being potential undergraduate physicists to become undergraduate physicists.

However, overall, relative to the number of young people in the population, only Chinese students are more likely to read undergraduate physics than white students. In fact, Chinese students are twice as likely as white students to read undergraduate physics.

Another comparison is with the students with three or more science A-levels. Given that significantly greater proportions of Indian and Chinese students than white students have three or more science A-levels, it is interesting to note that this does not result in similarly greater proportions of Indian and Chinese students reading chemistry and physics. However, as discussed later in this report, Asian students in particular favour medicine-related subjects.

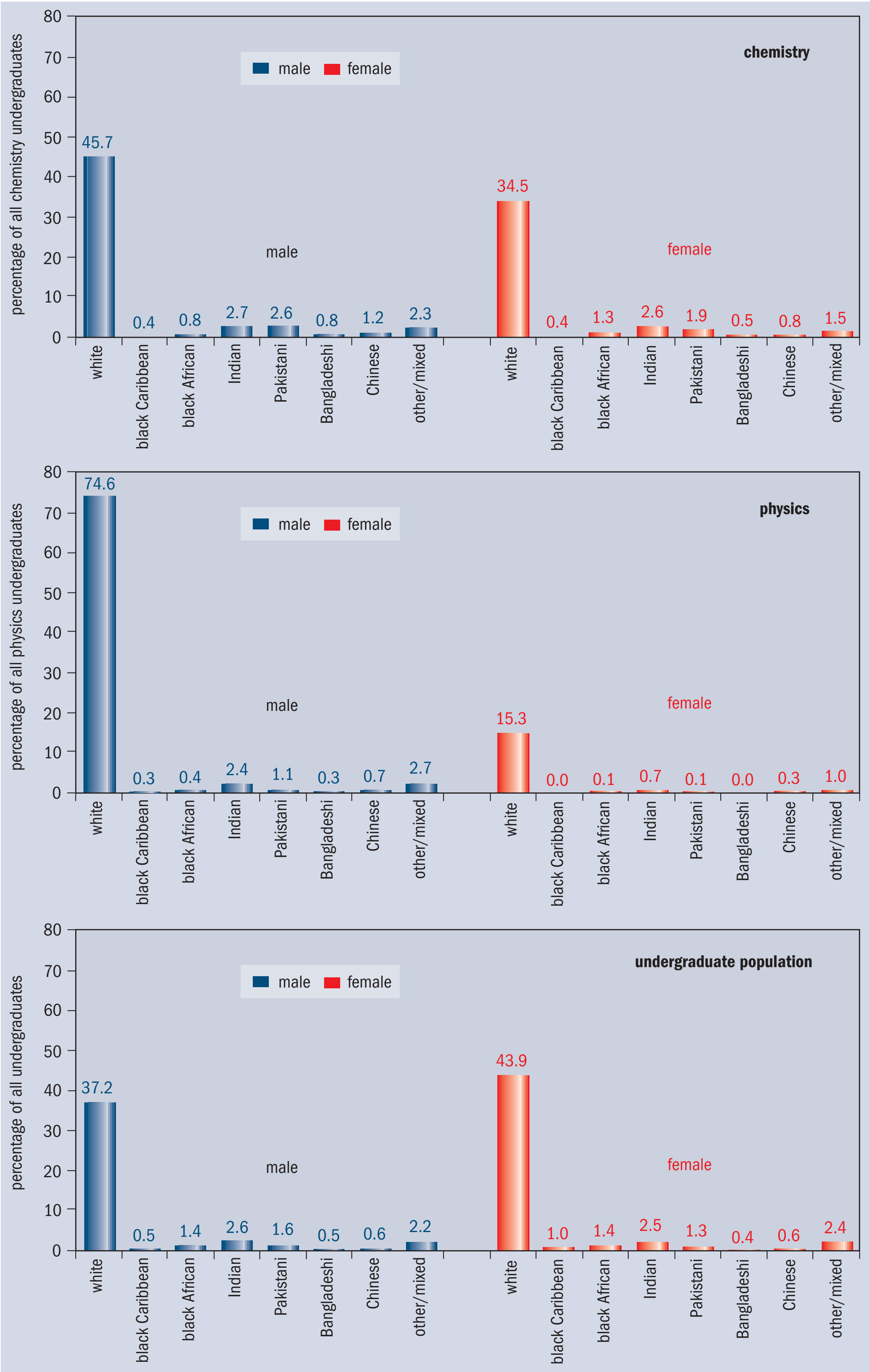


Fig. 12: Ethnic composition of undergraduate chemistry and physics.

Notes:

1. The percentages relate to England- and Wales-domiciled students studying for a first or enhanced first degree.
2. Numbers exclude those whose ethnicity is unknown.

Source: HESA student data set 2002/2003

Fig. 13: EGR in chemistry.
Notes:
1. Figures based on undergraduate students only.
2. England- and Wales-domiciled EGR is calculated with respect to the ethnic-gender breakdown of the undergraduate population as a whole.

Source: HESA student data set 2002/2003

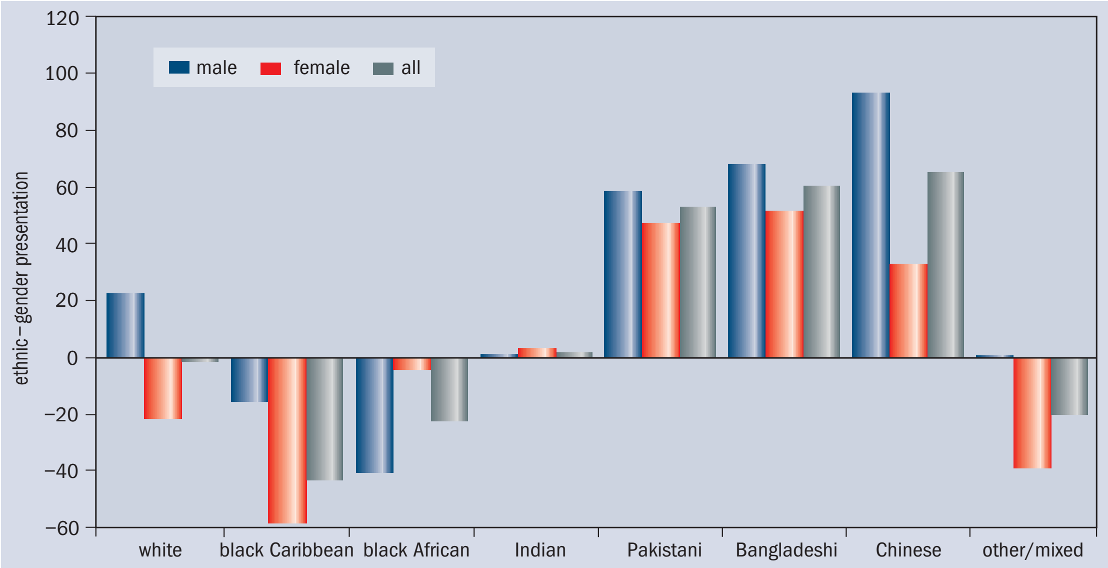
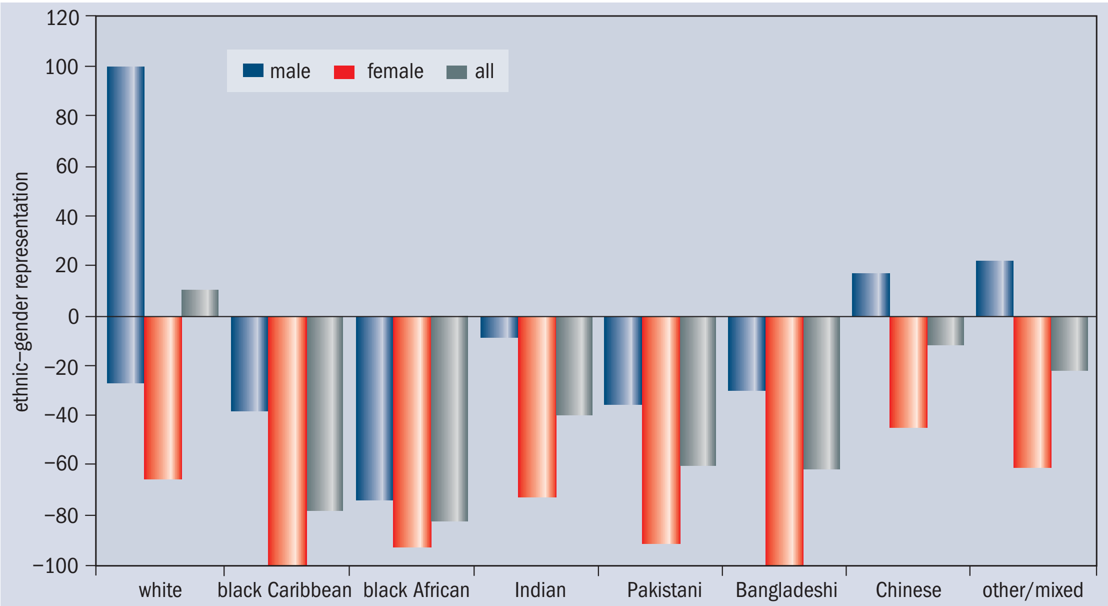


Fig. 14: EGR in physics.
Notes:
1. Figures based on undergraduate students only.
2. England- and Wales-domiciled EGR is calculated with respect to the ethnic-gender breakdown of the undergraduate population as a whole.

Source: HESA student data set 2002/2003



7.2: Ethnic-minority representation in SET, medicine and other subjects

As a comparison of wider subject choice, an analysis was undertaken to show what other subjects the potential chemistry or physics students might study.[26]

Consider the EGR in the three broad areas of study:

- SET;
- medicine and related subjects (excluding nursing);
- all other subjects (this group encompasses subject areas such as arts, social sciences and humanities).

Evidence is found of pronounced ethnic differences across subject areas. Using a chi-squared significance test, it is shown that students are not randomly allocated to these three subject areas by ethnic group.

Figures 15–17 present the measures of EGR in each subject area. The charts show that SET subjects are successful in attracting ethnic-minority students, relative to the numbers expected, based on the ethnic composition of the undergraduate population. Notably, with the exception of black Caribbean students, ethnic-minority groups are over-represented compared with white students. However, gender differences tend to dominate ethnicity aspects, with SET subjects proving far more attractive to males than females, irrespective of ethnicity.

In medicine and related subjects,[27] all ethnic-minority groups, except black Caribbean students, are over-represented compared with white students. Moreover, these subjects appear particularly attractive to Indian and Pakistani students. In contrast to SET subjects, medicine and related subjects are preferred more by females than males.

As expected from the data about medicine and subjects related to it, white students are over-represented relative to other ethnic groups in subject areas outside SET and medicine. Black Caribbean students are also significantly over-

26. Appendix 9 shows the ethnic breakdown by subject group for all subjects, along with ranked participation by ethnic group.
27. Nursing is excluded from the analysis of medicine and related subjects.

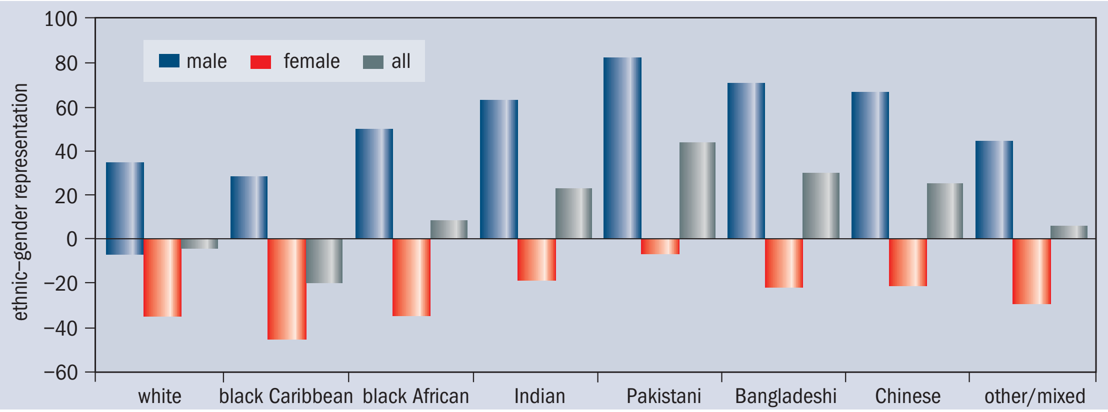


Fig. 15: EGR in SET subjects.
Notes:
1. Figures based on undergraduate students only.
2. England- and Wales-domiciled EGR is calculated with respect to the ethnic-gender breakdown of the undergraduate population as a whole.

Source: HESA student data set 2002/2003

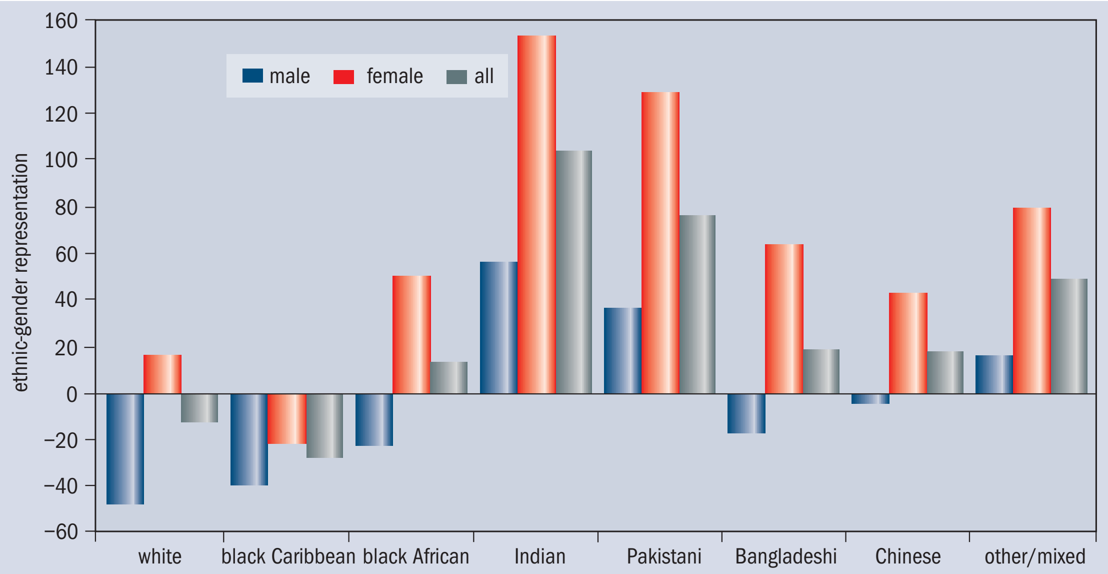


Fig. 16: EGR in medicine-related subjects.
Notes:
1. Figures based on undergraduate students only.
2. England- and Wales-domiciled EGR is calculated with respect to the ethnic-gender breakdown of the undergraduate population as a whole.

Source: HESA student data set 2002/2003

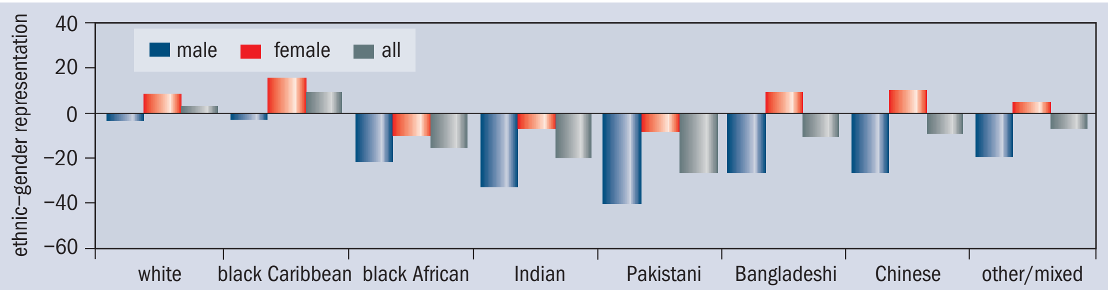


Fig. 17: EGR in other subject areas.
Notes:
1. Figures based on undergraduate students only.
2. England- and Wales-domiciled EGR is calculated with respect to the ethnic-gender breakdown of the undergraduate population as a whole.

Source: HESA student data set 2002/2003

represented in subjects outside science and medicine. These groups in general show a preference for arts, social sciences and humanities subjects (appendix 7). In contrast, ethnic Asian groups – especially Asian males – are very much under-represented in these areas.

It is worth noting that groups such as black Caribbean and black African students are more likely to attend a post-1992 university, where chemistry and physics courses are relatively rare. However, it is difficult to know whether institutional choice – for instance, preferring a local university, which, if it is a post-1992 institution is less likely to offer chemistry or physics – overrides subject choice for these groups, or whether the converse is true.

The SET group of subjects was examined further to identify which subjects were most attractive to students from ethnic-minority backgrounds. Figure 18 presents the analysis and shows the SET group broken down to five broad subject groups: biological sciences, physical sciences (including physics and chemistry), mathematical sciences, computer science, and engineering and technology. A chi-squared significance test reveals that students are not randomly allocated to these five subject areas when analysed by ethnic group.

The chart shows that ethnic-minority students tend to be under-represented generally, relative to their white counterparts, in what might be considered to be the traditional subject areas of science (i.e. biological, physical and mathematical sciences). In contrast, ethnic-minority students

Fig. 18 (p24): EGR by SET subject.
Notes:
1. Figures based on undergraduate students only.
2. England- and Wales-domiciled EGR is calculated with respect to the ethnic-gender breakdown of the undergraduate population as a whole.

Source: HESA student data set 2002/2003

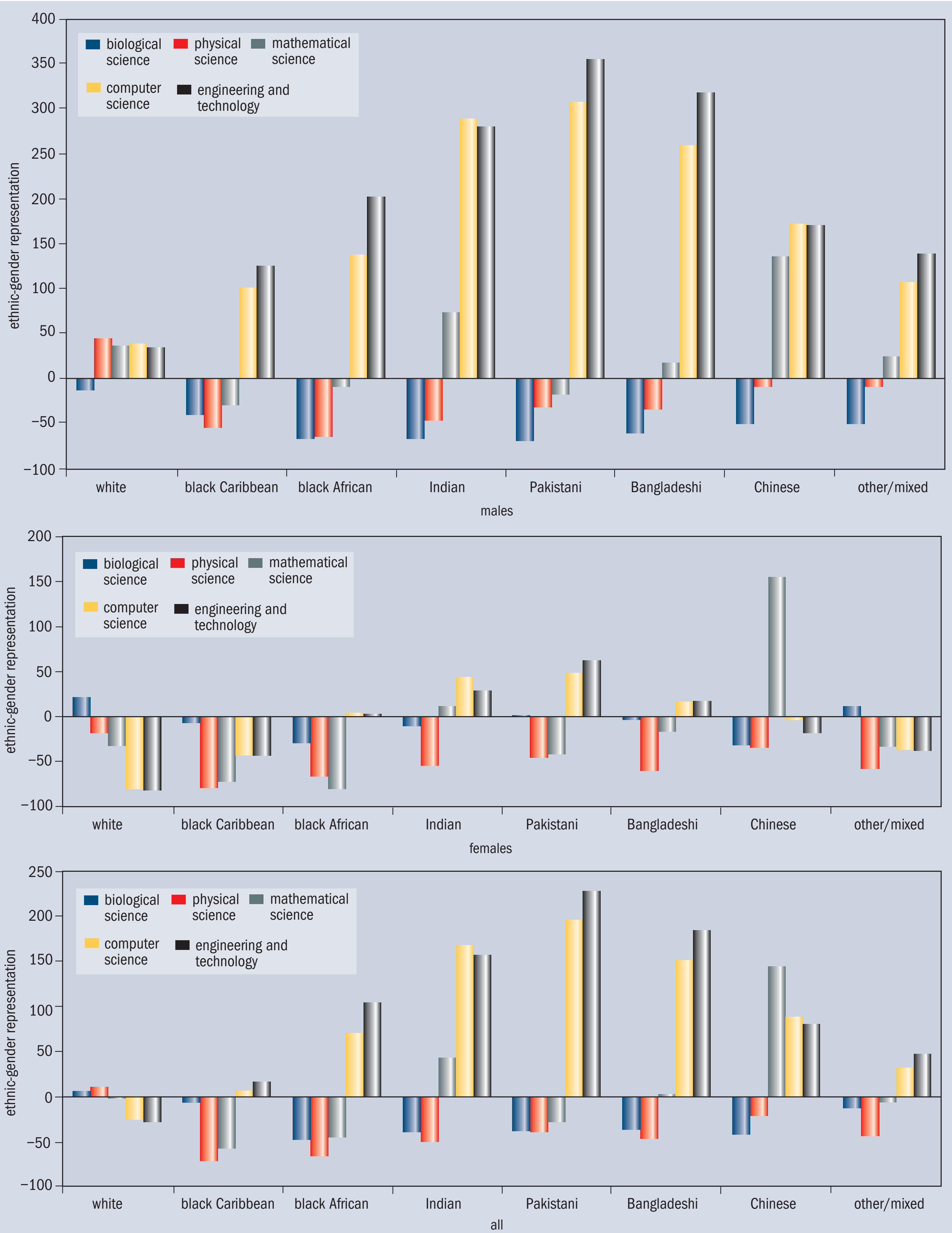


Fig. 18: For caption see p23.

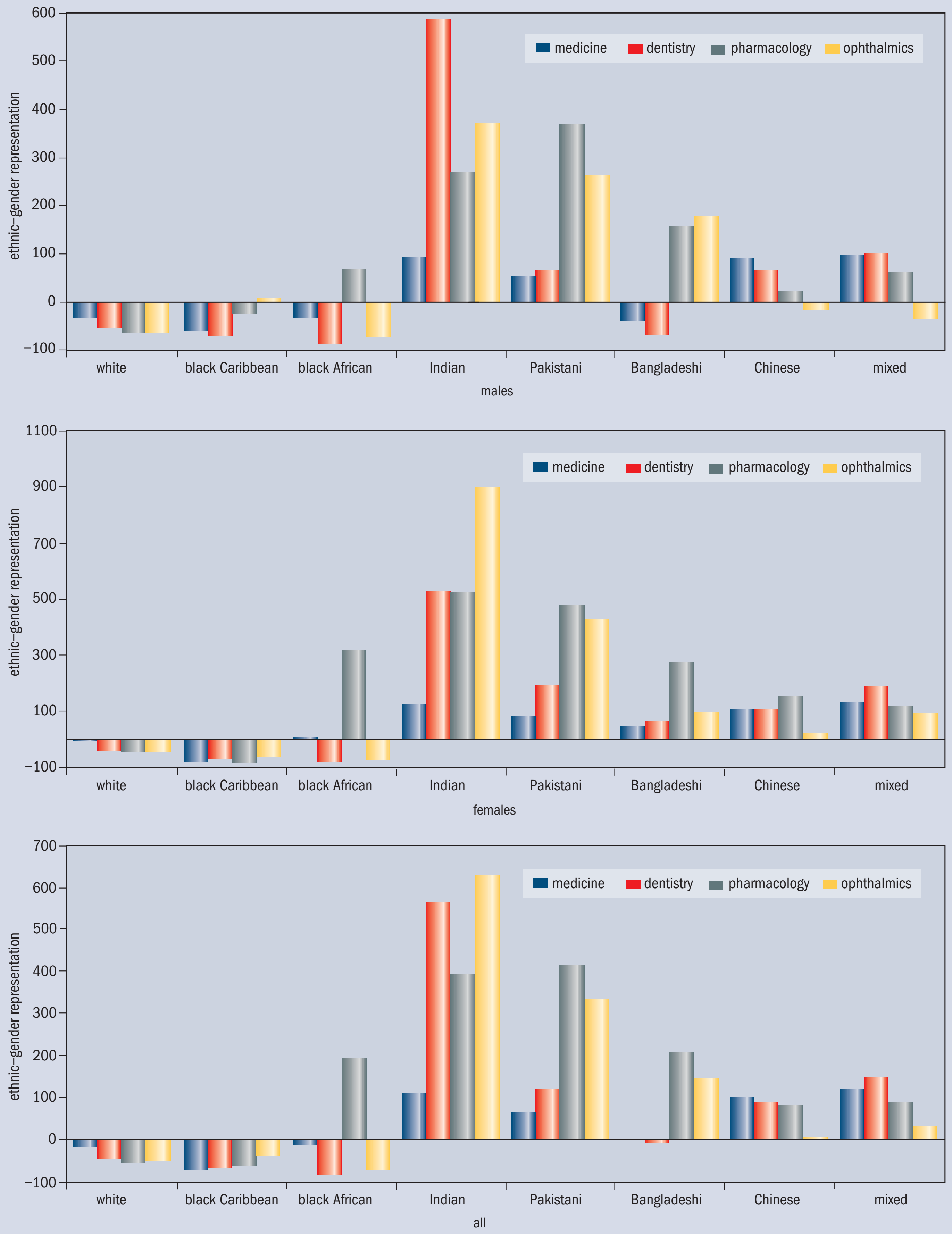


Fig. 19: For caption see p25.

Fig. 20: EGR in law.
Notes:
1. Figures based on undergraduate students only.
2. England- and Wales-domiciled EGR is calculated with respect to the ethnic-gender breakdown of the undergraduate population as a whole.

Source: HESA student data set 2002/2003

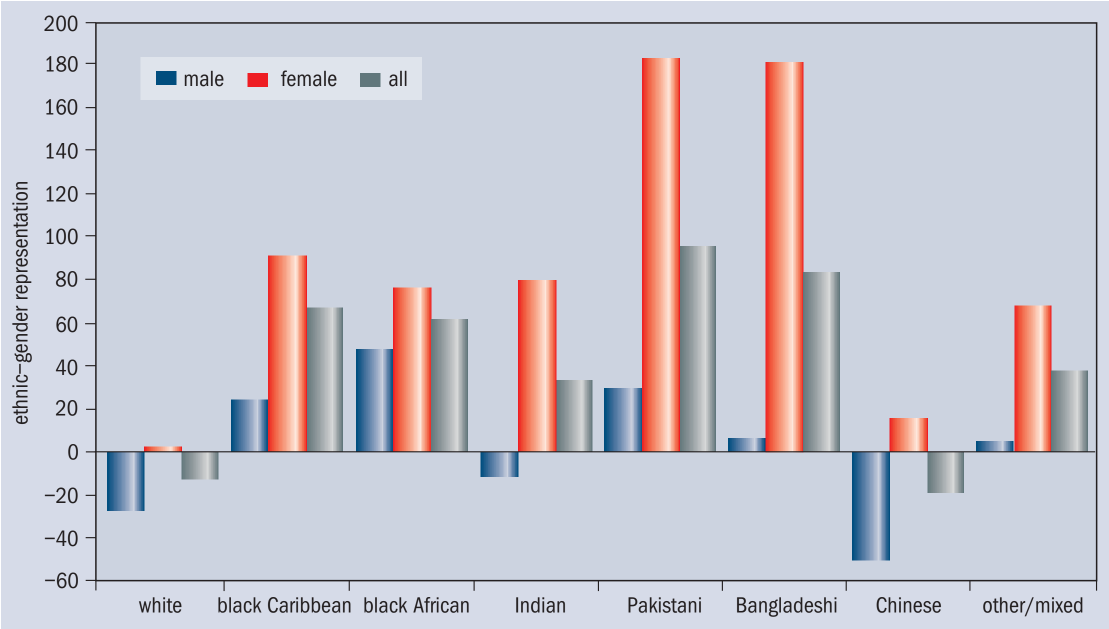


Fig. 21: EGR in business and administration.
Notes:
1. Figures based on undergraduate students only.
2. England- and Wales-domiciled EGR is calculated with respect to the ethnic-gender breakdown of the undergraduate population as a whole.

Source: HESA student data set 2002/2003

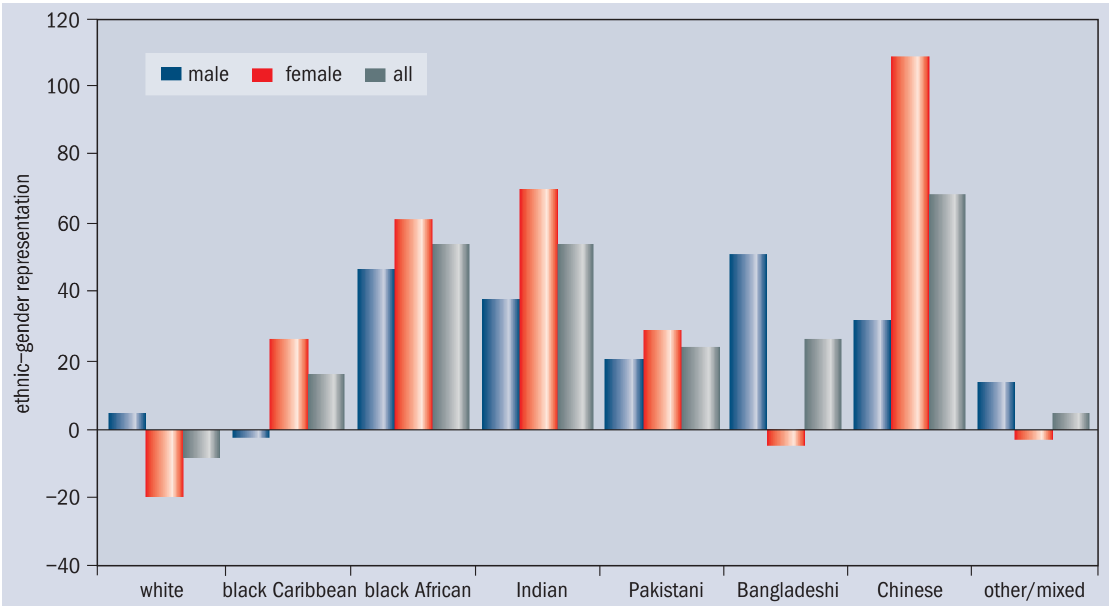


Fig. 19 (previous spread): EGR by medicine and related subjects.
Notes:
1. Figures based on undergraduate students only.
2. England- and Wales-domiciled EGR is calculated with respect to the ethnic-gender breakdown of the undergraduate population as a whole.

Source: HESA student data set 2002/2003

are particularly prevalent in computer science. Ethnic Asian groups in particular are over-represented in this subject area, with Indian, Pakistani and Bangladeshi males almost three times as likely to study computing as would be expected based on the undergraduate population. There is a strong gender divide in these subjects, with males dominating particularly in physical and mathematical sciences.

Similarly, figure 20 presents the analysis of EGR in medicine and other related subjects (i.e. dentistry, pharmacology and ophthalmics). These subjects are vocational alternatives to science at undergraduate level and thus compete with chemistry and physics for students. The results show a very strong ethnic Asian bias towards these subjects, irrespective of gender. A chi-squared significance test shows that students are not randomly allocated to these subjects by ethnic group.

A strong preference for studying medicine is particularly apparent for Indian students. They account for 27% of all dentistry students, 19% of all pharmacology students and 32% of all ophthalmics students. These figures are remarkably large compared with the numbers that might be expected based on the proportion of Indian students in the undergraduate body. Indian students are 5% of the undergraduate student body and only 2.3% of the population of young people. At the same time, both white and black students are very much under-represented in all of these areas (with the exception of a relatively large number of black African students in pharmacology).

Law and business

It is informative to analyse two other vocational subject areas outside SET and medicine that may be attractive as

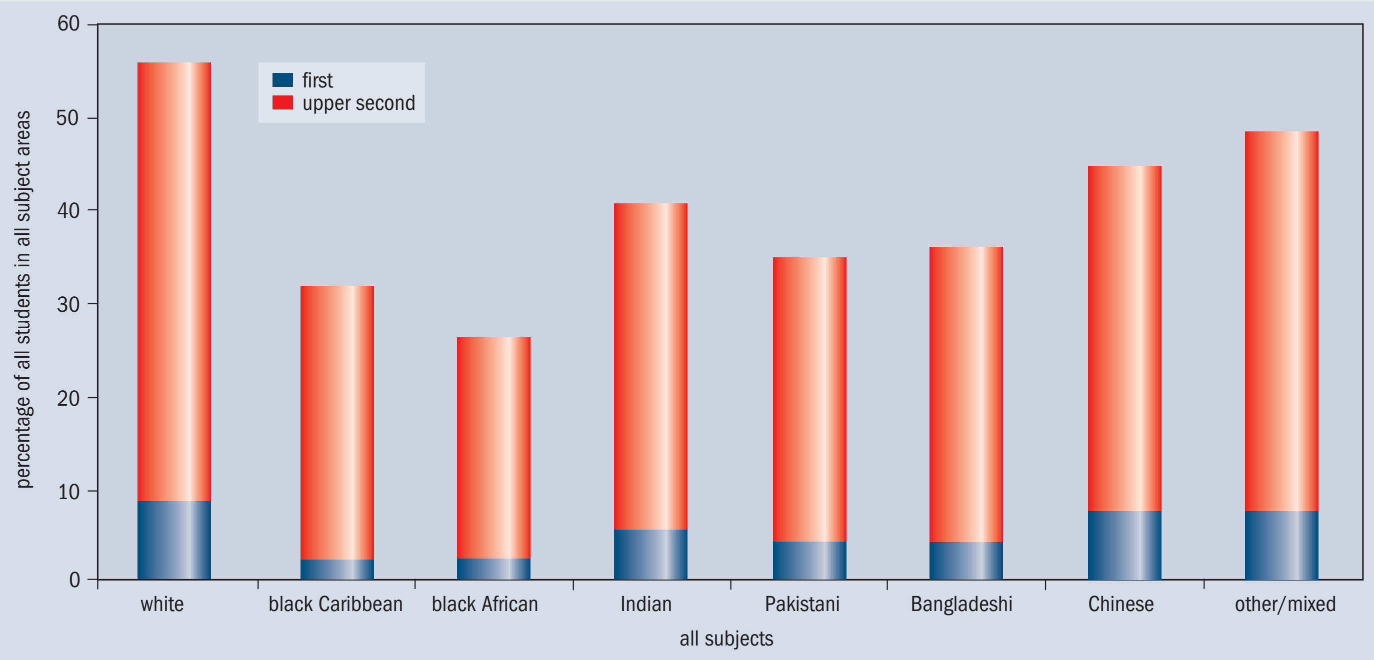


Fig. 22: Proportion of students obtaining first- or upper-second-class degrees in all subjects, by ethnic group.
Notes:
1. England- and Wales-domiciled students only.
2. Percentages exclude those whose ethnicity is not known.

Source: HESA first destination surveys combined cohort 1996/1997–2001/2002

alternative career paths, that is law and business.

EGR in these subject areas is shown in figures 20 and 21. Again, strong ethnicity effects emerge. A chi-squared significance test shows that students are not randomly allocated by ethnic group. Both subjects are successful in attracting ethnic-minority students. Law, in particular, attracts large numbers of ethnic-minority females. Pakistani and Bangladeshi women are almost three times as prevalent in law as would be expected based on undergraduate population numbers.

Similarly, business and administration is successful in attracting ethnic-minority groups; again, especially women. In contrast to SET, the ethnic-minority group over-representation in this area also includes students from black Caribbean and black African backgrounds.

7.3: Achievement in undergraduate chemistry and physics

High achievement in undergraduate chemistry and physics is normally a prerequisite for further study and progressing towards a career in either science. This stage of attainment is not only a key milestone in progress along the educational pipeline, but also provides a benchmark population for comparing numbers of students in postgraduate study in the next section of this report.

The proportions of students obtaining first- or upper-second-class degrees by ethnic group in chemistry, physics and overall are presented in figures 22–24. This analysis uses a merged data set of students completing their studies between 1996/1997 and 2001/2002. The striking feature of the results is that a much higher proportion of white students obtain first- or upper-second-class degrees compared with students from other ethnicities.[28] This applies not only to chemistry and physics but across all subjects. If obtaining a first or upper-second is ranked by ethnicity, rankings in chemistry and physics are remarkably consistent, not only with all subjects (lower panel in the figure) but with a whole range of subjects. The general pattern of white students being the highest achievers, followed by Chinese and Indian, is repeated with remarkable consistency. Evidence of this is shown in appendix 8.

The implication of these findings for chemistry and physics is that the most under-represented ethnic groups in the student body (i.e. black students in chemistry, and in physics all groups other than white and Chinese students) tend to be the ethnic groupings that do the least well in their undergraduate studies. This further restricts the proportions of these groups qualified for postgraduate study in chemistry and physics.

The effect of this is that the higher levels of chemistry and physics are dominated by a small number of ethnic groups. Most severely affected by low achievement in undergraduate studies are black Caribbean and black African students. On average they are only half as likely to get a first or upper-second compared with white students.

Ethnic Asian groups in general fair a little better, especially Indian students, but still students from these groups tend to fair less well than their white counterparts.

A recent study attempts to explain some of the differences in degree performance between white students and non-white groups (Leslie, 2005). It is argued that much of the under-performance can be explained because ethnic-minority students are, on average, less well qualified when they enter, which may be partially explained because far larger numbers apply. A diminution in average quality of applicant would be expected. A second cause is that the ethnic communities tend to specialise in subjects where fewer good degrees are awarded (e.g. medicine).

The study presents a methodology for accounting for the difference in entry qualifications and "subject ease" (which

28. White students are significantly more likely to obtain a first or upper-second in chemistry or physics than all other ethnic-minority groups, individually or taken as a whole, using a two-sample proportions T-test. This strong result can be replicated for most subject groupings (appendix 8).

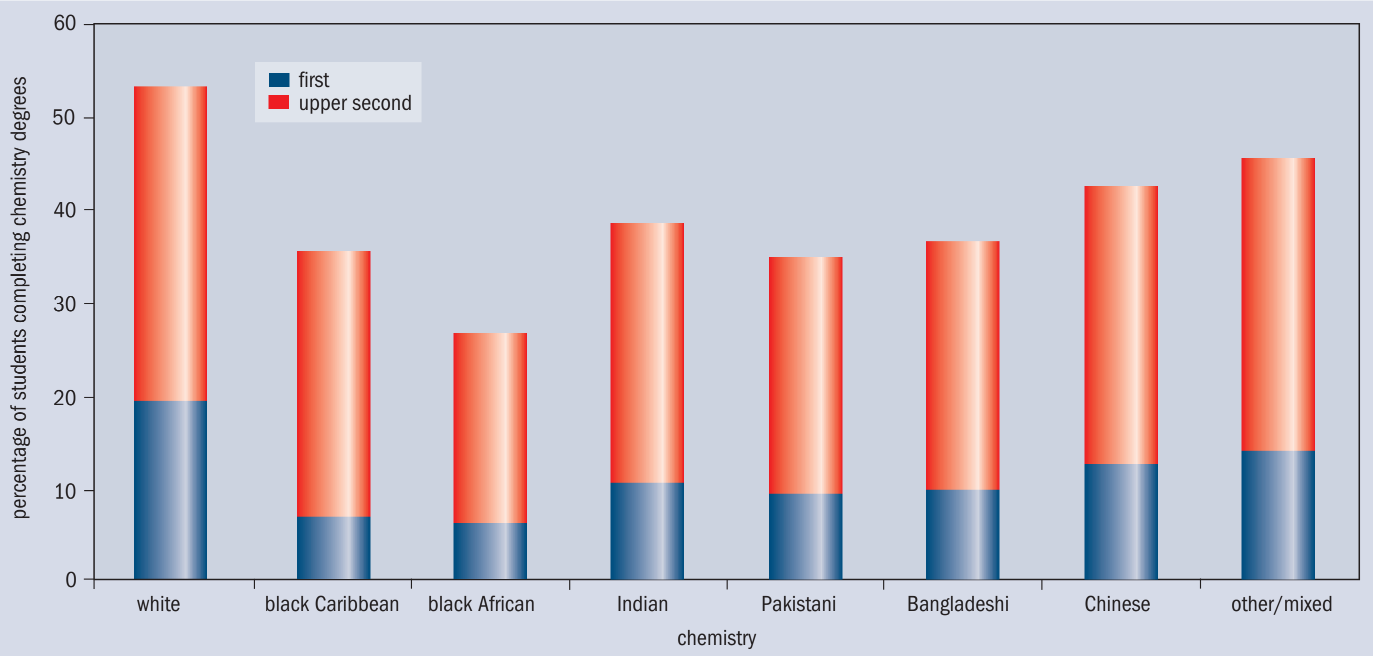


Fig. 23: Proportion of students obtaining first- or upper-second-class degrees in chemistry, by ethnic group.
Notes:
1. England- and Wales-domiciled students only.
2. Percentages exclude those whose ethnicity is not known.

Source: HESA first destination surveys combined cohort 1996/1997–2001/2002

is defined by the proportion of first and upper-seconds awarded to white students). This shows that, at least in part, the under-achievement of different ethnic groups can be accounted for by lower higher-education entry qualifications and by subject difficulty.

However, even after accounting for entry qualifications and subject choice, the ethnic-minority communities are still somewhat behind in terms of degree result. The study examines broad subject classifications (e.g. physical sciences) rather than individual subjects and does not take socioeconomic factors into account. Consequently, although overall performance of the ethnic-minority cohorts in broad subjects may be to some extent explained by the study, questions still remain at the individual subject level.

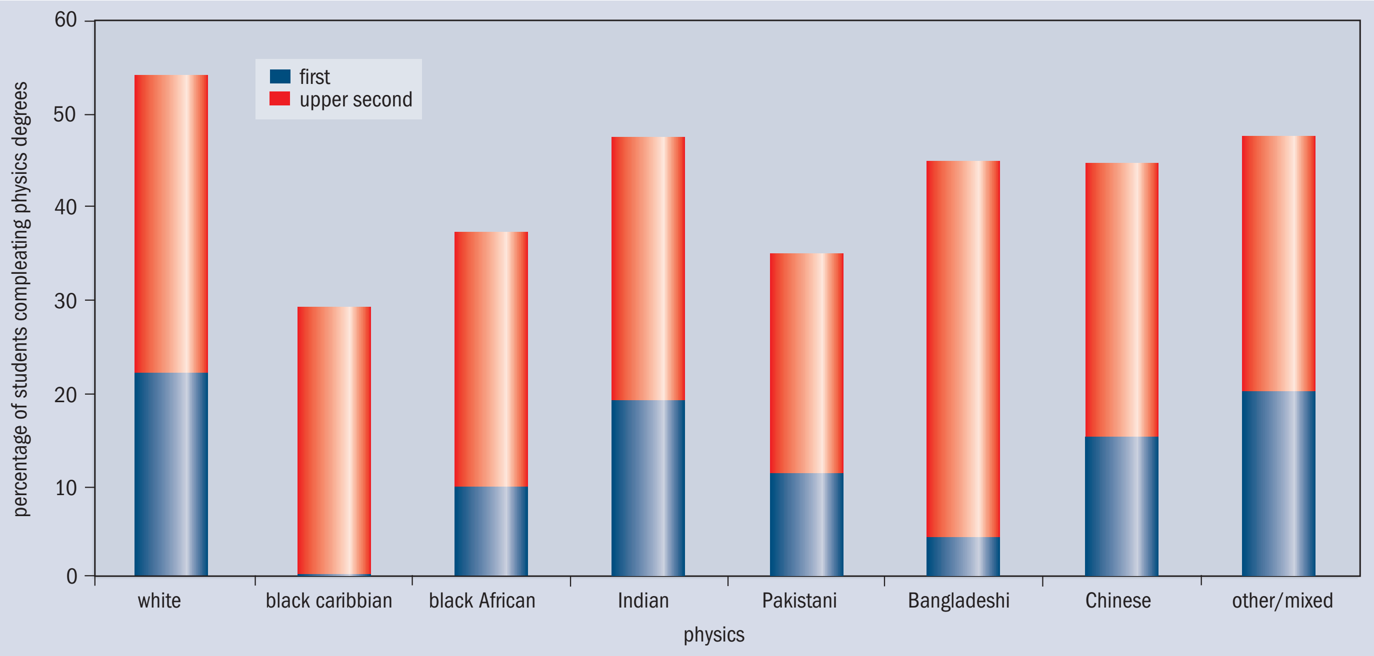


Fig. 24: Proportion of students obtaining first- or upper-second-class degrees in physics, by ethnic group.

Note: 1. England- and Wales-domiciled students only.

2. Percentages exclude those whose ethnicity is not known.

Source: HESA first destination surveys combined cohort 1996/1997–2001/2002

8: Ethnicity and postgraduate studies

"Ethnic-minority students graduating in chemistry and physics are more inclined to study subjects other than chemistry and physics at postgraduate level."

The completion of undergraduate studies is the final bifurcation point in the educational pipeline. At this point, students must make decisions regarding their careers and, in particular, whether or not to study chemistry or physics at postgraduate level; study in an area perhaps more vocationally orientated; or enter the job market. This section examines the extent to which attrition from undergraduate to postgraduate study depends on ethnicity. This is done by analysing EGR among postgraduates in chemistry and physics in a similar manner to that previously described. EGR is measured with reference to a benchmark group of those achieving a first- or upper-second-class degree in chemistry or physics.[29]

Examining the ethnic composition of students studying for postgraduate qualifications in chemistry or physics based on 2002/2003 student data reveals that, in chemistry and physics, the majority of students classed as postgraduate are on doctoral rather than masters programmes. Based on 2002/2003 figures, 79% of postgraduate students in chemistry and 76% of postgraduate students in physics were enrolled on doctorate programmes. Analysis is therefore restricted to the last stage of the pipeline (i.e. those studying on doctorate programmes).

Figure 25 shows the ethnic and gender composition of doctorate chemistry, based on a percentage breakdown of the student body. White males dominate the England- and Wales-domiciled doctorate chemistry student body, in contrast to the less pronounced gender imbalance in undergraduate chemistry, with numbers of ethnic-minority students being very small.

To measure EGR the data are normalised (by subject) with respect to the population that achieves a first or upper-second, as described above. The resulting measures of EGR are shown in figure 26. This confirms white male domination. Using a chi-squared significance test, it is shown that students are not randomly allocated to postgraduate chemistry by ethnic group, based on the population of undergraduates achieving a first- or upper-second-class degree in chemistry.

Data show that white males are over-represented relative to their undergraduate numbers, whereas white females and most non-white groups, particularly ethnic Asian students, are notably under-represented.

Similar patterns are observed for physics. Using a chi-squared significance test, it is shown that students are not randomly allocated to postgraduate physics by ethnic group, based on the population of undergraduates achieving a first or upper-second in the same subject. Figure 27 shows the ethnic and gender composition of the England- and Wales-domiciled doctorate physics student body. Figure 28 shows the EGR for physics relative to numbers achieving a first or upper-second at undergraduate level.

The data show that, even relative to the population achieving first- or upper-second-class degrees at undergraduate level, those outside the white male population (with only minor exceptions) show relatively little inclination to study physics beyond undergraduate level.

Further study in other subjects

The proportion of students going on to further study in general, not necessarily in chemistry or physics, is now examined. Figure 29 shows the percentage of chemistry and physics graduates, by ethnic group, going on to further study (irrespective of subject), based onthe HESA first des-

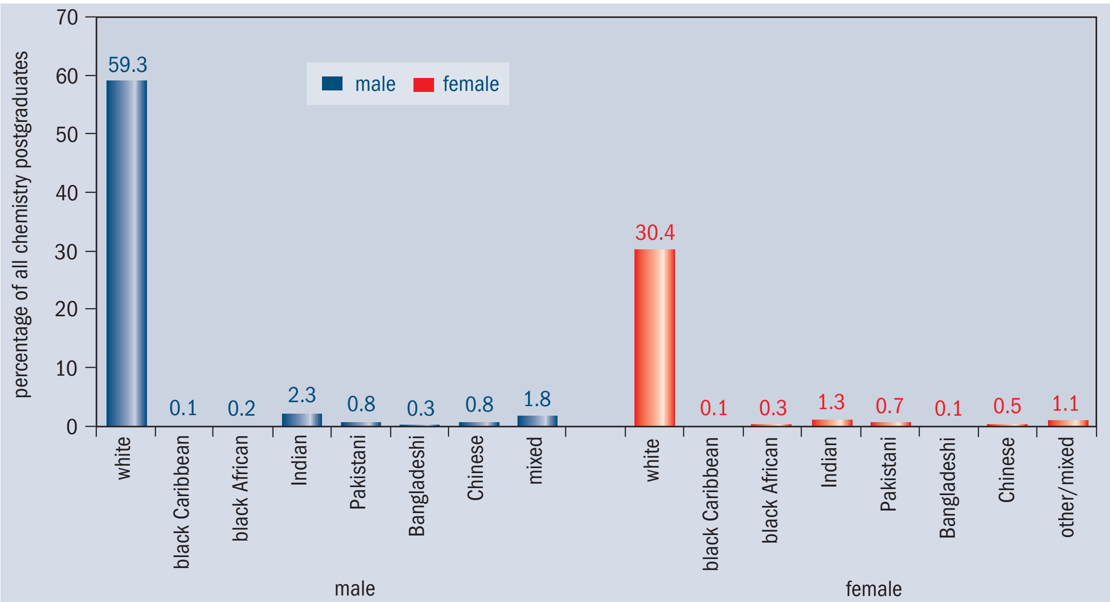


Fig. 25: Ethnic and gender composition of doctorate chemistry.
Notes:
1. The percentages relate to England- and Wales-domiciled students studying for a doctorate.
2. Numbers exclude those whose ethnicity is unknown.

Source: HESA student data set 2002/2003

29. The benchmark population is shown in section 6, based on students completing their undergraduate studies in 2001/2002. The ethnic and gender breakdown of this group in chemistry and physics, which is used for benchmark comparisons, is shown in appendix 8.

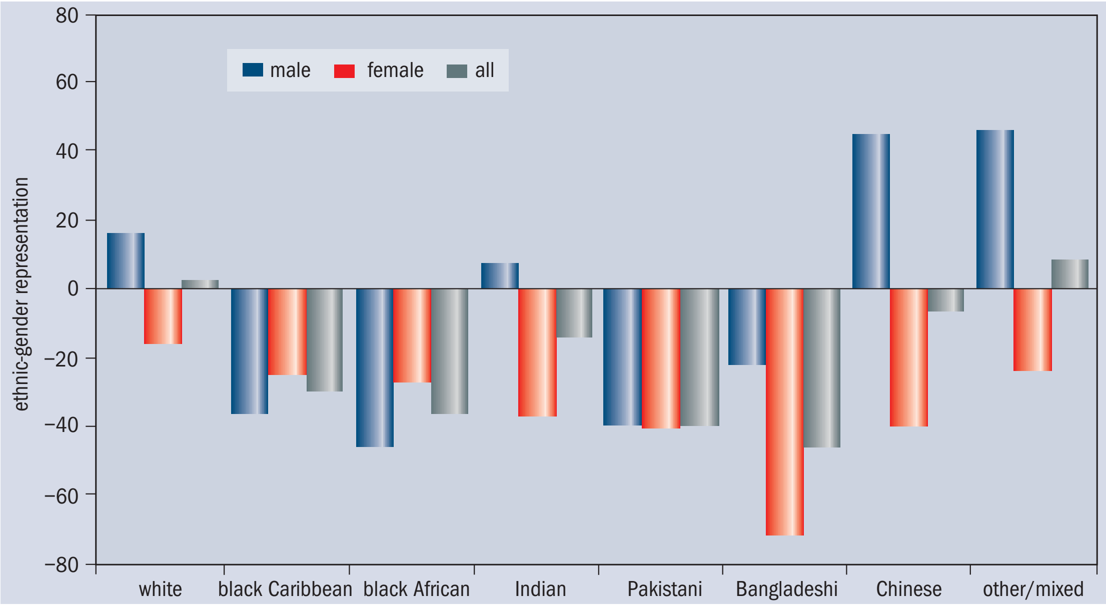


Fig. 26: EGR in doctorate chemistry.
Notes:
1. Figures based on doctoral students.
2. England- and Wales-domiciled EGR is calculated with respect to the ethnic-gender breakdown of the undergraduate population achieving a first- or upper-second-class degree in chemistry.
3. Numbers exclude those whose ethnicity is unknown.

Source: HESA student data set 2002/2003

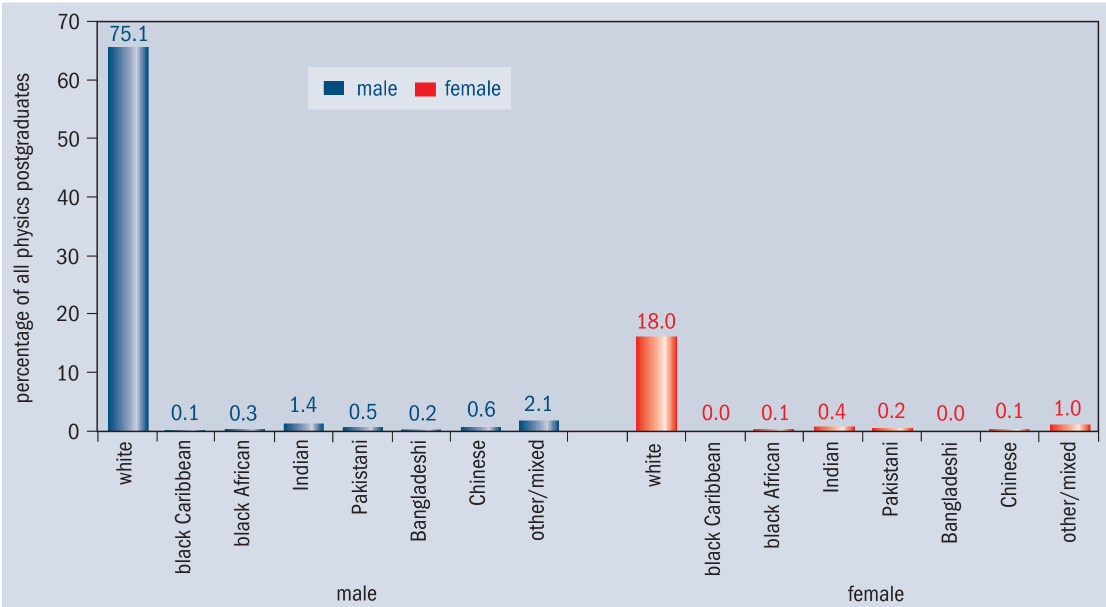


Fig. 27: Ethnic and gender composition of doctorate physics.
Notes:
1. The percentages relate to England- and Wales-domiciled students studying for a doctorate.
2. Numbers exclude those whose ethnicity is unknown.

Source: HESA student data set 2002/2003

tination survey in 2001/2002. The figures show that, while the majority of students do not choose further study (approximately a third of chemistry and physics graduates study at postgraduate level),[30] ethnic-minority students completing chemistry and physics degrees are, in fact, significantly more likely to continue in further study than their white counterparts.[31] It appears, then, that ethnic-minority students graduating in chemistry and physics are more inclined to study subjects other than chemistry and physics at postgraduate level.

What cannot be determined from quantitative census data, however, is whether this is the result of push or pull factors (i.e. whether ethnic-minority students become disillusioned with physical sciences during their undergraduate studies or whether they show a more general preference, say, towards postgraduate programmes that they perceive to be more vocational).

Further qualitative work is recommended to determine the causes, and further quantitative work to determine the nature of the further study.

Fig. 28: EGR in doctorate physics.
Notes:
1. Figures based on doctoral students.
2. England- and Wales-domiciled EGR is calculated with respect to the ethnic-gender breakdown of the undergraduate population achieving a first- or upper-second-class degree in physics.
3. Numbers exclude those whose ethnicity is unknown.

Source: HESA student data set 2002/2003

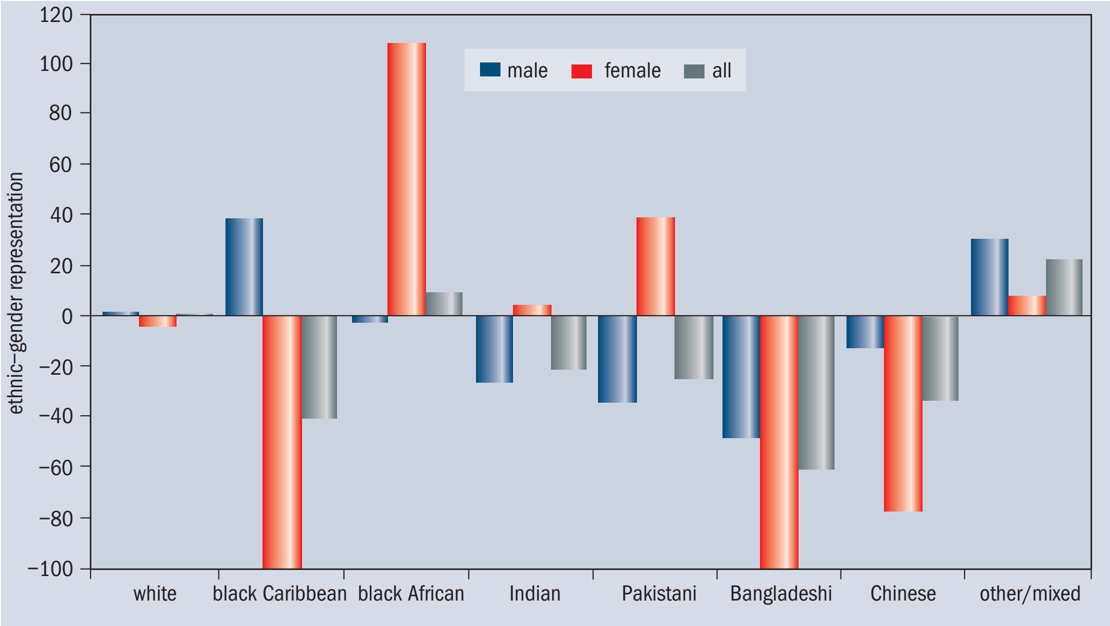
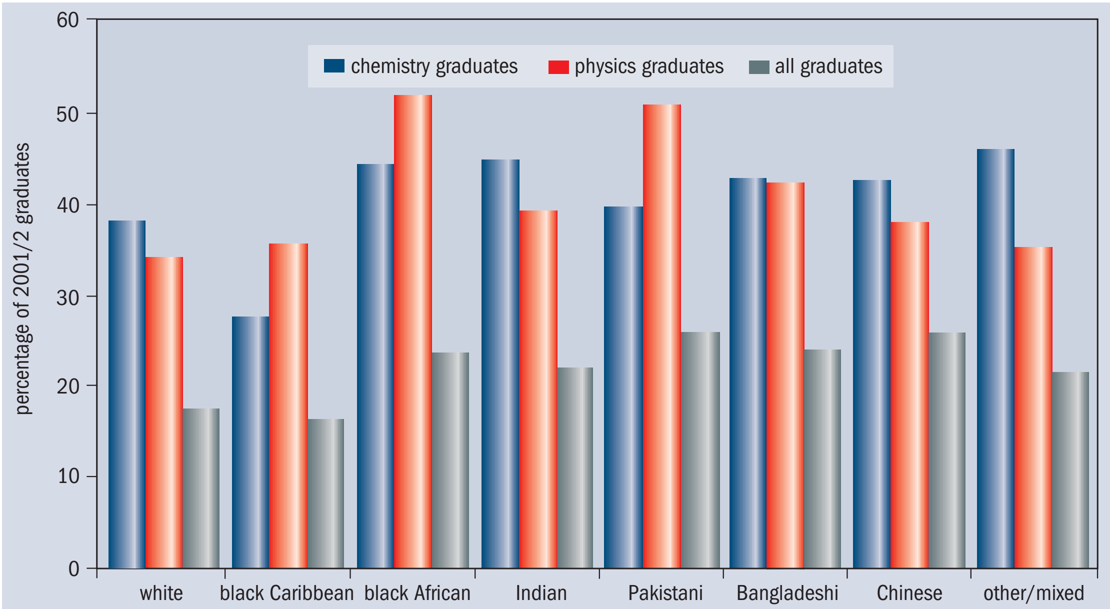


Fig. 29: Proportion of students going on to further study, by ethnic group.
Notes:
1. England- and Wales-domiciled students only.
2. Percentages exclude those whose ethnicity is unknown.

Source: HESA first destination surveys combined cohort 1996/1997 – 2001/2002



30. The percentage of students going on to further study from chemistry and physics is notably higher than the average for all subject areas.
31. Based on a two-sample proportions T-test.

9: Conclusions and recommendations

The metaphor of the educational pipeline helps us to visualise progression through a career in chemistry and physics. Chemistry and physics are white and male dominated at doctorate level (based on numbers of England- and Wales-domiciled students), and the pipeline helps us to understand how, and at what stage, different ethnic groups tend to leave chemistry and physics.

Attrition is complex. Rates of attrition vary by ethnic group and gender at each stage. However, patterns emerge relating to ethnic-minority groups. Based on subject choices at A-level, only black Caribbean students show a strong preference against studying science subjects, relative to the white population.

At undergraduate level, relative to the overall or to the undergraduate population, ethnic-minority groups generally tend not to study physics, resulting in a very strong white (and male) dominance in the subject. However, relative to those qualified to read physics ("potential undergraduate physicists"), ethnic-minority groups' preference to read physics is variable. Only Pakistani students are more likely than white students to transfer from being potential undergraduate physicists to become undergraduate physicists. However, overall, relative to the number of young people in the population, only Chinese students are more likely to read undergraduate physics than white students. In fact, Chinese students are twice as likely as white students to read undergraduate physics.

In undergraduate chemistry, only black Caribbean students are very much under-represented relative to the overall numbers in the population. In contrast, Indian and Chinese students are more likely to read undergraduate chemistry than white students: Indian students are twice as likely, and Chinese students are three times as likely. Interestingly, overall, Pakistani students are one-and-a-half times as likely as white students to read undergraduate chemistry.

Greater attrition of ethnic minorities

The strongest evidence of a greater attrition rate of ethnic-minority students relative to white students applies to the stages once students have begun their undergraduate studies. In common with other subjects, white students in chemistry and physics have far higher rates of achieving a first or upper-second degree than their ethnic-minority counterparts. However, the relative under-achievement of ethnic-minority groups may be partly explained because they are more likely to enter higher education and thus might, on average, be expected to do less well than the white majority.

Taking into account different groups' achievement of a first or upper second, white students are more inclined towards further study in chemistry and physics at postgraduate level. Evidence suggests that ethnic-minority students are not averse to postgraduate study, but they tend to study in other subject areas. This leads to the suspicion that there are different factors affecting the decision making of ethnic-minority group students compared with white students.

The under-representation of some ethnic-minority groups in chemistry and physics (notably young people of black Caribbean, Pakistani and Bangladeshi backgrounds) is largely the result of small numbers of students from these groups achieving at school or staying on for further study post-16. The result of this is attrition of these cohorts before patterns of study and revealed preferences for subject areas become clear. Unfortunately, this is in some sense exogenous to the science community because the causes of poor educational achievement among these groups lie outside science education and are possibly rooted in socioeconomic circumstances, as well as parental and peer-group influences. Groups' self-fulfilling expectations may also play a part (Harrison *et al*. 2003).

It must also be noted that, for all ethnic groups, socioeconomic factors may play a significant role in educational achievement, in subject choices and in influencing decisions as to whether or not to undertake further study in chemistry and physics. It is beyond the scope of this present study to examine the socioeconomic influences. Having noted that, it is known that some ethnic groups are, on average, characterised as belonging to lower socioeconomic classes than the average for the UK's white population (Owen *et al.* 2003). This factor alone will adversely affect educational achievement.

On the other hand, some of the observations highlighted in this report cannot be explained solely by socioeconomic factors (e.g. the significantly higher proportion of Indian students who attend university relative to the white population, and the subject choices of some ethnic groups). Clearly, much detailed work could be carried out to disaggregate the effects of ethnicity and socioeconomic class on educational achievement.

One other issue is the clear preference among some ethnic groups for medicine-related subjects. Students in all ethnic-minority groups except black Caribbean students are more likely to achieve a chemistry A-level than white students. This is probably because A-level chemistry is required to study medicine in higher education. Similarly, students in all ethnic-minority groups except the black Caribbean group are more likely to be a potential undergraduate chemist than white students.

At the culmination of the chemistry and physics educational pipeline, qualified chemists and physicists make choices regarding occupation, including the choice of whether or not to seek employment in academic chemistry and physics, in university departments as well as schools and colleges.[32] A lack of British non-white role models for

"The under-representation of some ethnic-minority groups is largely the result of low numbers of students from these groups achieving at school or staying on for further study post-16."

non-white students to aspire to, or to offer guidance and support, as an end-effect of the attrition of ethnic-minority groups documented, may in part contribute to non-white groups' relative reluctance to study chemistry and physics.

A detailed examination of the occupations of chemistry and physics leavers from higher education is not possible because populations are too small for statistically significant conclusions to be drawn. Similarly, chemists and physicists from ethnic-minority groups are too scarce in LFS data to allow any firm conclusions to be drawn about the occupations of different ethnic groups.

To obtain information about the career paths of chemists and physicists from different ethnic groups, a longitudinal study would probably be the best approach. However, there will not be enough graduates from some ethnic groups for even this approach to yield statistically significant data.

Some information about the ethnicity of academic staff in chemistry and physics is given in appendix 9.

Based on the findings in this report, the following recommendations are made:

- Work should be undertaken to disaggregate the effects of socioeconomic class and ethnicity in respect of educational achievement and subject choices.
- A study should be undertaken to examine factors affecting undergraduate subject choice by ethnic group, especially concentrating on those studying A-level combinations that are likely to qualify them as potential undergraduate chemists and physicists.
- Work should be undertaken to examine different ethnic groups' experiences of higher education in chemistry and physics, to explore in more detail why ethnic-minority groups on average do less well than the majority white population at university; and why these groups are also less likely than the white population to choose postgraduate study in chemistry and physics, even when qualified to do so.
- Related to the recommendation above, work should be undertaken to examine what courses of further study students, especially ethnic minority-groups, do undertake and the reasons for their choices.

32. Employment choices are not analysed in this report.

References

Connor H, Tyers C, Davis S and Tackay, N D 2003 Minority ethnic students in higher education: interim report, Institute for Employment Studies, DfES Research Report **448**.

Demack S, Drew D and Grimsley M 2002 Minding the gap: ethnic, gender and social class differences in attainment at 16. *Race, Ethnicity and Education* **3**(**2)** 118–143.

DfES 2004 National Curriculum Assessment and GCSE and GNVQ Attainment by Pupil Characteristics in England.

Elias P, McKnight A, Pitcher J, Purcell K, and Simm C 1999 *Moving on: Graduate Careers Three Years after Graduation* (CSU, Manchester).

Gilborn D and Mirza H 2000 Educational inequality: mapping race, class and gender, report for OfSTED, HMSO.

Harrison B, Mannion K, Bevins S C and Jordan J 2003 Ethnicity and underachievement in science and mathematics education, report for the Royal Society, Centre for Science Education, Sheffield Hallam University.

Jones P and Elias P 2004 Science, engineering and technology and the UK's ethnic minority population, report for the Royal Society.

Leslie D 2005 Why people from the UK's minority ethnic communities achieve weaker degree results than whites *Applied Economics* **37** 619–632.

Leslie D and Drinkwater S 1999 Staying on in full-time education: reasons for higher participation rates among ethnic minority males and females *Economica* London School of Economics and Political Science **66 (127)** 63–77.

Modood T 1997 *Ethnic Minorities in Britain: Diversity and Disadvantage* (Policy Studies Institute, London).

Owen D, Green A, Pitcher J and Maguire M 2003 Minority ethnic participation and achievements in education, training and the labour market, DfES research report 225.

Appendix 1a: Estimated numbers of students at each stage in chemistry based on a school-leaving cohort (all ethnic groups combined)

	Stage description	Estimated numbers	Percentage of cohorts
Youth Cohort Study			
(LFS estimate)	year group cohort of 16/17-year-olds	665 000	100.0
1	obtaining five or more GCSEs at grades A*–C	325 900	49.0
2	obtaining an A-level in chemistry	36 000	5.4
3	potential undergraduate chemist: suitably qualified at A-level to study chemistry at university	23 300	3.5
	studying on a degree course at 18/19	144 600	21.7
HESA data			
	undergraduate degree students – all years*	717 600	100.0
	first-year undergraduate students – all subjects*	241 600	33.7
4	studying undergraduate degree in chemistry – all years*	8800	1.2
5	achieving a first or upper second in chemistry†	4600	0.6

*Figure includes undergraduates of any age domiciled in England and Wales.
†Figure based on percentage of those studying undergraduate degree in chemistry.

Notes:
1. The size of the school-leaving cohort is estimated based on estimates from the LFS (spring 2004).
2. Proportions in the YCS are based on merged data 1996–2004. Numbers are inferred based on these percentages of the school-leaving cohort.
3. Potential scientists at A-level are identified using the UCAS18 definition described in section 6.2.
4. Student numbers on degree programmes are based on HESA data from 2002/2003.
5. Degree classification is based on the HESA first-destination data from 2001/2002.
6. Estimates are rounded to the nearest hundred.

Appendix 1b: Estimated numbers of students at each stage in physics based on a school-leaving cohort (all ethnic groups combined)

	Stage description	Estimated numbers	Percentage of cohorts
Youth Cohort Study			
(LFS estimate)	year group cohort of 16/17-year-olds	665 000	100.0
1	obtaining five or more GCSEs at grades A*–C	325 900	49.0
2	obtaining an A-level in physics	31 500	4.7
3	potential undergraduate physicist: suitably qualified at A-level to study physics at university	16 600	2.5
	studying on a degree course at 18/19	144 600	21.7
HESA data			
	undergraduate degree students – all years*	717 600	100.0
	first-year undergraduate students – all subjects*	241 600	33.7
4	studying undergraduate degree in physics – all years*	6600	0.9
5	achieving a first or upper second in physics†	3800	0.6

*Figure includes undergraduates of any age domiciled in England and Wales.
†Figure based on percentage of those studying undergraduate degree in physics.

Notes:
1. The size of the school-leaving cohort is estimated based on estimates from the LFS (spring 2004).
2. Proportions in the YCS are based on merged data 1996–2004. Numbers are inferred based on these percentages of the school-leaving cohort.
3. Potential scientists at A-level are identified using the UCAS18 definition described in section 6.2.
4. Student numbers on degree programmes are based on HESA data from 2002/2003.
5. Degree classification is based on the HESA first-destination data from 2001/2002.
6. Estimates are rounded to the nearest hundred.

Appendix 2: Science A-levels in the YCS with DfES coding

001 101 Biology
002 103 Biology: human
003 105 Biology: social
004 106 Biology: human and social
005 111 Chemistry
006 121 Physics
007 131 Science: Single Award
008 133 Science: Dual Award (1st grade)
009 135 Science: Dual Award (2nd grade)
010 137 Science: Double Award (1st grade)
011 139 Science: Double Award (2nd grade)
012 141 Science: biology and chemistry
013 145 Science: biology and physics
014 147 Science: chemistry and physics
015 163 Aeronautics
016 165 Science: agriculture
017 167 Science: applied
018 169 Science: astronomy
019 171 Botany
020 173 Science: electronics
021 175 Science: environmental
022 177 Science: geology
023 179 Science: horticulture
024 181 Science: physical
026 185 Robotics
027 187 Science: rural
028 191 Science in society
029 193 Science: technology
030 197 Science: zoology
031 199 Science: meteorology
032 201 Engineering science
033 203 Science: other
034 221 Mathematics
035 223 Mathematics (pure)
036 224 Decision/discrete mathematics
037 225 Mathematics (applied)
038 227 Mathematics (pure and applied)
039 228 Pure and decision mathematics
040 229 Mathematics (pure and statistics)
041 230 Statistics and decision mathematics
042 231 Mathematics (pure and mechanics)
043 233 Mathematics (further)
044 234 Additional mathematics
045 235 Mathematical studies
046 251 Statistics

Note: First column is the National Centre for Social Research code. Second column is the DfES code.
Source: Office of National Statistics

Appendix 3: A-level chemistry and potential undergraduate chemists

Ethnic group males	A-level chemistry	plus 1 science, including maths	potential undergraduate chemist (UCAS12)	potential undergraduate chemist (UCAS18)	potential undergraduate chemist (UCAS24)	YCS sample
white	5.31 (0.21)	4.82 (0.20)	3.47 (0.17)	3.30 (0.17)	2.39 (0.14)	12 104
black Caribbean	2.92 (3.25)	2.92 (3.12)	0.76 (2.67)	0.76 (2.61)	0.00 (2.23)	50
black African	5.47 (3.39)	5.47 (3.25)	4.28 (2.79)	3.26 (2.72)	1.09 (2.32)	46
Indian	12.51 (1.17)	11.91 (1.12)	8.70 (0.96)	8.38 (0.94)	6.77 (0.80)	386
Pakistani	5.21 (1.56)	5.21 (1.49)	3.89 (1.28)	3.37 (1.25)	1.14 (1.07)	218
Bangladeshi	7.52 (2.24)	7.52 (2.15)	5.63 (1.85)	5.06 (1.80)	2.16 (1.54)	105
Chinese	14.17 (2.42)	14.17 (2.33)	12.53 (1.99)	11.53 (1.94)	10.64 (1.66)	90
mixed	7.14 (2.45)	6.60 (2.35)	4.82 (2.02)	4.82 (1.97)	3.22 (1.68)	88
Ethnic group females	**A-level chemistry**	**plus 1 science, including maths**	**potential undergraduate chemist (UCAS12)**	**potential undergraduate chemist (UCAS18)**	**potential undergraduate chemist (UCAS24)**	**YCS sample**
white	4.89 (0.17)	4.44 (0.16)	3.46 (0.15)	3.31 (0.14)	2.30 (0.12)	16 600
black Caribbean	0.63 (2.34)	0.63 (2.23)	0.63 (1.98)	0.63 (1.94)	0.63 (1.61)	90
black African	9.87 (2.67)	8.71 (2.55)	7.37 (2.26)	7.37 (2.21)	3.43 (1.84)	69
Indian	11.40 (1.00)	10.34 (0.96)	7.64 (0.85)	7.09 (0.83)	4.90 (0.69)	488
Pakistani	6.49 (1.21)	5.56 (1.17)	4.35 (1.04)	4.18 (1.01)	2.77 (0.85)	328
Bangladeshi	5.86 (1.19)	3.71 (1.90)	2.73 (1.69)	2.37 (1.65)	1.37 (1.38)	124
Chinese	15.05 (2.23)	14.40 (2.13)	12.24 (1.89)	12.24 (1.85)	5.99 (1.54)	99
mixed	8.48 (1.75)	7.99 (1.67)	6.49 (1.48)	5.77 (1.45)	3.76 (1.21)	61

Notes: These proportions are based on (weighted) means in the population. Standard errors are shown in parentheses.
Source: Youth Cohort Study, 1996 – 2002

Appendix 4: A-level physics and potential undergraduate physicists

Ethnic group males	A-level physics	plus maths A-level	potential undergraduate physicist (UCAS12)	potential undergraduate physicist (UCAS18)	potential undergraduate physicist (UCAS24)	YCS sample
white	7.10 (0.24)	5.56 (0.21)	4.05 (0.18)	3.8 (0.17)	2.77 (0.15)	12 104
black Caribbean	1.70 (3.67)	0.94 (3.27)	0.94 (2.80)	0.94 (2.72)	0.94 (2.33)	50
black African	5.64 (3.82)	5.64 (3.41)	3.08 (2.92)	3.08 (2.84)	0.94(2.42)	46
Indian	12.24 (1.32)	9.94 (1.18)	6.18 (1.01)	5.82 (0.98)	3.86 (0.84)	386
Pakistani	3.79 (1.76)	2.05 (1.57)	1.05 (1.34)	0.77 (1.30)	0.48 (1.11)	218
Bangladeshi	6.35 (2.53)	5.44 (2.26)	3.51 (1.94)	3.51 (1.88)	1.44 (1.60)	105
Chinese	19.17 (2.73)	16.21 (2.44)	13.67 (2,09)	12.78 (2.03)	9.80 (1.73)	90
mixed	6.06 (2.76)	4.15 (2.47)	2.96 (2.11)	2.96 (2.05)	1.59 (1.75)	88
Ethnic group females	**A-level physics**	**plus maths A-level**	**potential undergraduate physicist (UCAS12)**	**potential undergraduate physicist (UCAS18)**	**potential undergraduate physicist (UCAS24)**	**YCS sample**
white	2.29 (0.12)	1.54 (0.10)	1.24 (0.09)	1.18 (0.08)	0.90 (0.07)	16 600
black Caribbean	0.00 (1.57)	0.00 (1.29)	0.00 (1.16)	0.00 (1.13)	0.00 (0.98)	90
black African	1.76 (1.80)	0.74 (1.48)	0.00 (1.32)	0.00 (1.29)	0.00 (1.12)	69
Indian	3.22 (0.68)	2.35 (0.56)	1.72 (0.50)	1.72 (0.49)	1.25 (0.42)	488
Pakistani	0.78 (0.82)	0.30 (0.68)	0.30 (0.61)	0.30 (0.59)	0.30 (0.51)	328
Bangladeshi	0.49 (1.34)	0.49 (1.10)	0.00 (0.99)	0.00 (0.96)	0.00 (0.84)	124
Chinese	5.72 (1.54)	2.78 (1.23)	2.78 (1.10)	2.78 (1.08)	0.00 (0.94)	99
mixed	1.79 (1.18)	1.47 (0.97)	1.03 (0.87)	1.03 (0.85)	0.33 (0.73)	161

Note: These proportions are based on (weighted) means in the population. Standard errors are shown in parentheses.
Source: Youth Cohort Study, 1996 – 2002

Appendix 5: Ethnic composition of the England- and Wales-domiciled undergraduate population

Ethnic group	% or undergraduates			% in population 18–25			ratio undergraduates:population		
	male	female	all	male	female	all	male	female	all
white	37.20	43.90	81.00	43.60	44.40	87.90	0.85	0.99	0.92
black Caribbean	0.50	1.00	1.50	0.40	0.50	0.90	1.39	1.79	1.63
black African	1.40	1.40	2.70	0.60	0.70	1.30	2.30	1.93	2.10
Indian	2.60	2.50	5.10	1.30	1.00	2.30	2.05	2.54	2.27
Pakistani	1.60	1.30	2.90	1.00	1.00	2.00	1.68	1.24	1.45
Bangladeshi	0.50	0.40	0.80	0.60	0.40	0.90	0.81	0.99	0.88
Chinese	0.60	0.60	1.20	0.50	0.50	1.00	1.21	1.25	1.23
other/mixed	2.20	2.40	4.70	1.70	1.90	3.70	1.28	1.26	1.27
population (1000s)	390.30	448.50	839.00	2870.00	2914.00	5783.00	–	–	–

Notes:

1. The percentages relate to England- and Wales-domiciled students in the first year of study for a first or enhanced first degree.
2. Population numbers are estimates based on demographic information from the LFS, March–May 2004.

Source: HESA student data set, 2002–2003

Appendix 6: Ethnic and gender percentages in the population of chemistry and physics students achieving a first or upper second degree classification

Ethnic group	% chemistry			% physics		
	male	female	all	male	female	all
white	51.20	36.30	87.50	73.70	18.70	92.50
black Caribbean	0.10	0.20	0.30	0.10	0.10	0.10
black African	0.30	0.40	0.70	0.30	0.00	0.30
Indian	2.10	2.00	4.20	2.00	0.40	2.30
Pakistani	1.30	1.20	2.50	0.70	0.10	0.80
Bangladeshi	0.40	0.30	0.70	0.30	0.10	0.40
Chinese	0.50	0.80	1.40	0.70	0.30	1.00
other/mixed	1.20	1.40	2.70	1.60	0.90	2.50

Note: England- and Wales-domiciled students only.

Source: HESA first-definition data set, 2001–2002

Appendix 7: Undergraduate subject groups ranked by ethnic group participation

Subject group	white	rank	black Caribbean	rank	black African	rank	Indian	rank
	Percentage ethnic group composition of student body by subject group							
medicine and dentistry	62.00	18	0.3	17	1.8	9	14.4	1
subjects allied to medicine	75.50	15	1.4	7	3.6	3	5.8	6
biological sciences	84.20	8	1.1	10	1.3	12	3.2	10
veterinary science	95.00	1	0.1	19	0.1	19	0.4	19
agriculture and related subjects	93.10	2	0.2	18	0.4	17	0.8	18
physical sciences	87.60	5	0.4	14	0.8	15	2.5	13
mathematical sciences	79.40	11	0.3	16	1.0	13	7.6	4
computer science	57.50	19	1.5	6	4.5	1	13.1	2
engineering and technology	75.90	14	0.9	12	3.1	4	5.0	7
architecture, building and planning	80.40	10	1.4	8	2.3	6	2.7	12
social, economic and political studies	79.20	12	1.7	4	2.1	8	4.3	8
law	69.10	17	2.1	2	4.1	2	7.0	5
business and administrative studies	73.60	16	1.5	5	3.1	5	7.6	3
librarianship and information science	81.50	9	2.3	1	2.2	7	3.1	11
languages	89.20	4	0.6	13	0.5	16	1.3	16
humanities	90.30	3	0.4	14	0.4	17	1.0	17
creative arts and design	86.30	6	1.2	9	0.9	14	1.9	14
education	84.50	7	1.9	3	1.5	10	1.5	15
combined	79.20	13	1.0	11	1.5	10	4.2	9

Note: The percentages relate to England- and Wales-domiciled students in the first year of study for a first or enhanced first degree.
Source: HESA first-definition data set 2002/2003

Appendix 8: Proportion of students awarded first or upper-second degrees, by ethnicity and subject group

Subject area	medicine and dentistry	subjects allied to medicine	biological sciences	agriculture and related subjects	physical sciences	mathematical sciences	computer sciences	engineering and technology
	Percentage ethnic group receiving a first- or upper-second-class degree							
white	18.4	58.7	60.0	49.4	52.4	55.4	50.7	51.9
black Caribbean	16.1	32.5	37.3	26.3	33.9	30.3	30.9	29.7
black African	16.7	32.0	31.3	10.3	27.1	26.8	24.8	25.7
Indian	17.0	54.4	46.4	35.3	39.6	47.4	39.6	39.6
Pakistani	10.7	48.1	40.1	38.1	35.0	41.0	33.2	31.1
Bangladeshi	18.5	47.2	40.2	33.3	37.9	39.5	34.3	33.7
Chinese	24.2	59.6	49.7	50.0	42.3	51.2	38.5	42.1
other/mixed	17.4	52.6	51.3	38.5	48.4	47.5	39.6	38.2

Ranked by ethnicity	medicine and dentistry	subjects allied to medicine	biological sciences	agriculture and related subjects	physical sciences	mathematical sciences	computer sciences	engineering and technology
white	3	2	1	2	1	1	1	1
black Caribbean	7	7	7	7	7	7	7	7
black African	6	8	8	8	8	8	8	8
Indian	5	3	4	5	4	4	3	3
Pakistani	8	5	6	4	6	5	6	6
Bangladeshi	2	6	5	6	5	6	5	5
Chinese	1	1	3	1	3	2	4	2
other/mixed	4	4	2	3	2	3	2	4

*Percentages are calculated including unclassified degrees. The percentages of each ethnic group receiving a first- or upper-second-class degree in medicine and dentistry appear low because of the large percentage of unclassified degrees awarded in these subjects.
Note: The percentages relate to England- and Wales-domiciled students in the first year of study for a first or enhanced first degree.
Source: HESA first-definition data sets 1996/1997–2001/2002

Appendix 7: continued

Pakistani	rank	Bangladeshi	rank	Chinese	rank
4.9	3	1.2	3	2.1	3
3.0	5	0.7	8	0.7	11
1.7	10	0.5	10	0.7	12
0.0	19	0.0	19	0.1	19
0.6	16	0.1	18	0.4	16
1.5	12	0.4	13	0.9	10
1.9	9	1.0	4	2.4	1
8.2	1	1.9	1	2.2	2
2.9	6	0.8	7	2.0	4
1.3	13	0.4	14	1.7	5
2.1	8	0.9	5	0.9	9
5.2	2	1.4	2	0.9	8
3.1	4	0.8	6	1.6	6
1.1	14	0.6	9	0.5	14
0.7	15	0.3	15	0.4	15
0.5	18	0.2	16	0.2	17
0.5	17	0.2	16	1.0	7
1.5	11	0.5	11	0.2	18
2.8	7	0.5	12	0.6	13

Appendix 8: continued

architecture building and planning	social, economic and political studies	law	business and admin studies	librarianship and information science	languages	humanities	creative arts and design	education	combined
48.3	57.3	59.7	50.1	59.2	69.0	68.2	57.7	50.7	51.8
27.8	32.8	27.6	26.1	40.6	43.9	32.8	36.0	28.7	29.0
17.3	28.9	24.3	20.9	29.4	44.9	38.0	32.7	16.1	23.2
38.9	44.9	40.5	36.9	43.4	57.3	53.6	39.5	37.8	38.3
30.0	37.3	33.2	29.1	37.1	54.8	49.4	34.8	39.0	33.6
22.4	37.8	36.0	28.3	16.9	58.9	50.5	37.1	35.2	32.4
37.0	48.8	50.4	38.0	58.8	59.9	67.0	45.1	45.9	45.0
38.0	52.5	46.2	40.0	52.4	65.9	64.7	50.1	44.3	49.0

architecture building and planning	social, economic and political studies	law	business and admin studies	librarianship and information science	languages	humanities	creative arts and design	education	combined
1	1	1	1	1	1	1	1	1	1
6	7	7	7	5	8	8	6	7	7
8	8	8	8	7	7	7	8	8	8
2	4	4	4	4	5	4	4	5	4
5	6	6	5	6	6	6	7	4	5
7	5	5	6	8	4	5	5	6	6
4	3	2	3	2	3	2	3	2	3
3	2	3	2	3	2	3	2	3	2

Appendix 9: Ethnicity of academic staff in chemistry and physics

Fig. 30: Academic staff in chemistry, by ethnic group.

Note: The analysis excludes staff whose ethnic group is not known. Source: HESA data sets 2001/2002

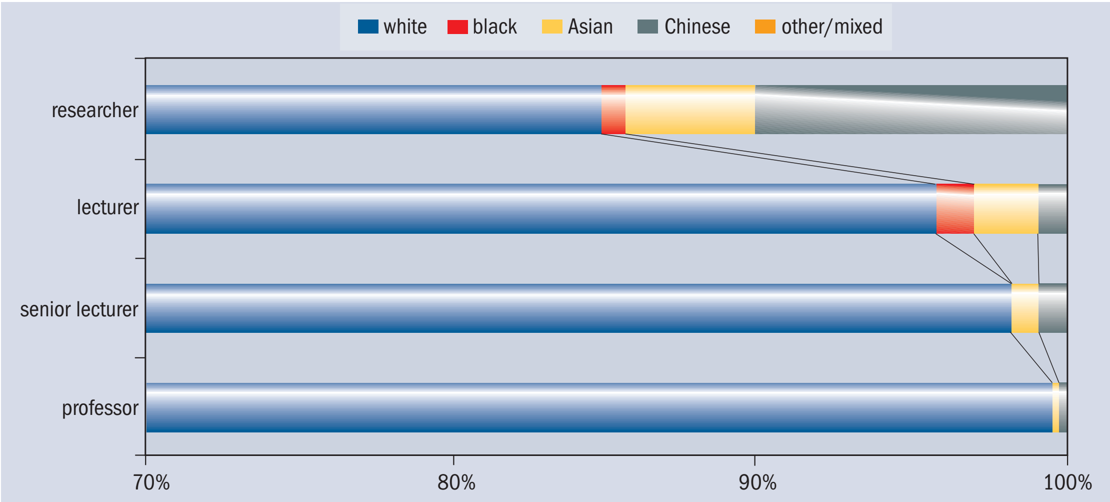
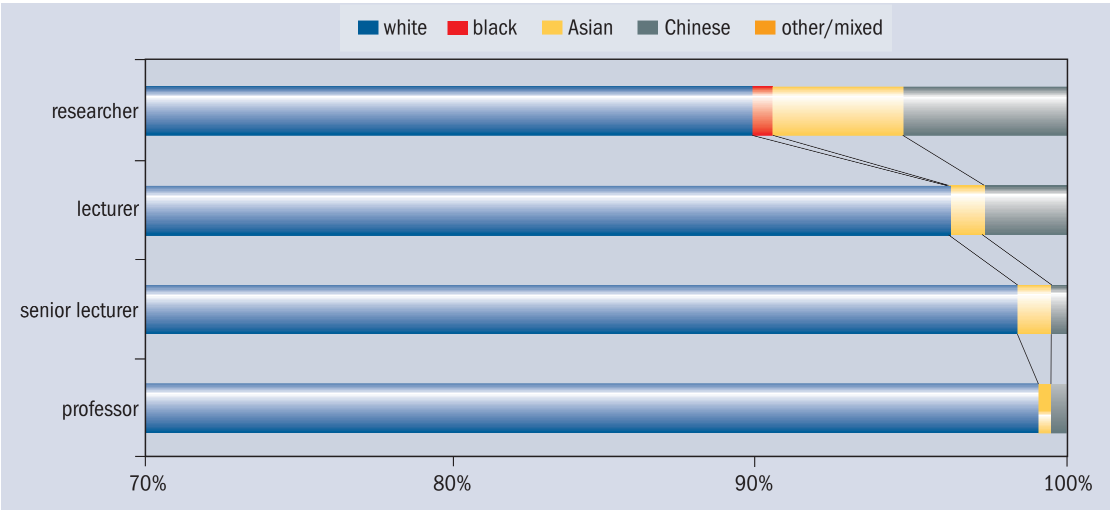


Fig. 31: Academic staff in physics, by ethnic group.

Note: The analysis excludes staff whose ethnic group is not known. Source: HESA data sets 2001/2002



HESA provides an annual census on academic staff by grade. This offers full coverage of academic staff and is therefore comprehensive. The main drawback is the relatively high incidence of "missing" data about ethnicity. Approximately 12% of ethnicity responses are returned as "not known", where individuals prefer not to provide details. Information is not available about whether or not this introduces a systematic bias into the data. That is, members of some ethnic minority groups might be more reluctant to answer this question than others.

An additional consideration when using these data is that not all members of staff are born in the UK. The numbers cannot therefore be compared meaningfully, for example, to student numbers, where the analysis is based on those who are England and Wales domiciled. Finally, staff data will also contain "cohort effects", which are important when considering ethnicity. That is, for example, the data on ethnicity of professors cannot be compared with that of junior academics and researchers on the grounds that these cohorts have been drawn from very different ethnic distributions in the population, based on their age group.

Appendix 10: Statistical inference

This report considers differences in participation between ethnic groups either with respect to studying chemistry or physics at various academic levels (A-level, undergraduate, etc) or with respect to achieving required levels of competences (e.g. minimum GCSE and A-level requirements or based on degree classification). Throughout the study, reference is made to "statistically significant" patterns of study or differences, such as when compared to the majority white population.

Statistical significance, in the simplest terms, purports that the pattern or difference observed, in this instance with respect to study by ethnic groups, is unlikely to have occurred by chance. More precisely, statistical significance means that we are able to infer with a certain degree of error that the patterns or differences did not occur randomly based on a test against a null hypothesis that the pattern or difference is random. Throughout this report, tests of statistical significance are based (following standard practice) on the use of a 5% error level when rejecting the null hypothesis.

In this study, two types of test are used to test for statistical significance. First, direct comparisons between ethnic groups (e.g. percentage of white versus ethnic-minority students studying chemistry at A-level) are done based on a series of two-sample T-tests. In short this test measures the difference in values or proportions (for the main part) in relation to the standard error associated with the two-sample estimates. A sufficient large difference between the two values (relative to combined standard error) results in a T value that we would not expect to observe based on a normal distribution. In this case differences are statistically significant.

Second, for analysis of patterns of study based on a contingency table of sample numbers (e.g. numbers of undergraduate chemistry students by ethnic group and gender), statistically significant effects are observed based on a Chi-squared test, which compares the frequencies to what we would have anticipated based on the "neutral" assumption that students were randomly allocated to subjects by ethnic group and gender. A sufficiently large discrepancy between the observed and neutral pattern generates a Chi-squared statistic that is significant based on a normal distribution of outcomes.

Finally, throughout the study we have been careful to combine ethnic groups and/or restrict dimensions of analysis when sample numbers would be too small to permit statistical inference.

A report prepared for the Royal Society of Chemistry and the Institute of Physics

Representation of Ethnic Groups in Chemistry and Physics

For further information about the report, please contact:

Sean McWhinnie
Royal Society of Chemistry
Burlington House
Piccadilly
London W1J 0BA
UK
Tel: +44 (0) 20 7440 3309
Fax: +44 (0) 20 7734 1227
E-mail: mcwhinnies@rsc.org
Web: **www.rsc.org**
Registered charity no. 207890

Tajinder Panesor
Institute of Physics
76 Portland Place
London W1B 1NT
UK
Tel: +44 (0) 20 7470 4800
Fax: +44 (0) 20 7470 4848
E-mail: tajinder.panesor@iop.org
Web: **www.iop.org**
Registered charity no. 293851