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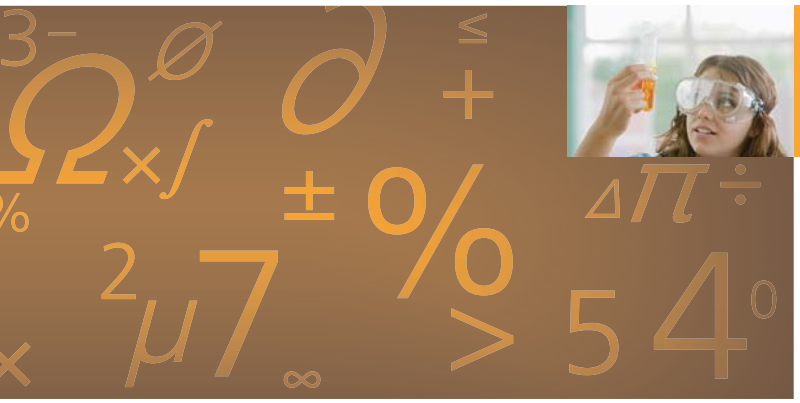

A 'state of the nation' report

2008

Science and mathematics education, 14–19

A 'state of the nation' report on the participation and attainment of 14–19 year olds in science and mathematics in the UK, 1996–2007

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Executive summary

This report examines and evaluates key trends in 14–19 science and mathematics education across the UK from 1996 to 2007. It shows that education in the UK is failing to provide the increases in the numbers of school-leavers with science and mathematics qualifications required by industry, business and the research community to assure the UK's future economic competitiveness.

The proportion of the relevant population cohort taking A-levels in England, Northern Ireland and Wales or Scottish Higher examinations has fallen in chemistry, physics and mathematics between 1996 and 2007. This situation is worrying given (i) the needs of industry and business for STEM skills; (ii) the UK Government's stated desire, in recognition of these needs, to increase the number of STEM graduates; and (iii) the need for more science and mathematics teachers, particularly in England.

The evidence available clearly suggests that the wave of recent educational reform has not yet had the effect of driving up participation to the desired extent. Ongoing educational reform, particularly in England, has made it very hard to discern with certainty the impact of any one initiative.

At a time when the education systems of the UK are becoming increasingly divergent, a common set of challenges faces our policy-makers. These include the need to:

- provide science and mathematics education appropriate for students of all levels of attainment in an environment where more students remain in education post-16;
- give a solid core grounding in science and mathematics to those who will probably not continue studying these subjects post-16;
- create a system with academic and vocational study pathways that are each recognized as valuable and fit for purpose;
- monitor standards without causing distortions in teaching and learning;
- acknowledge the differences between science disciplines in terms of their different demands, traditions and motivational appeals for students.

A different approach to educational reform is needed. Instead of being geared to short-term political ends, educational reform should be driven by carefully considered and well-defined educational rationale, informed by evidence and advanced through a process of consultation, piloting and development.

1 Main findings

1.1 Participation and attainment trends in national science and mathematics examinations, 1996–2007

Participation and attainment up to age 16

There are different patterns in the uptake of GCSE science options in England, Northern Ireland and Wales. The highest proportion of double-award science entrants is in England. In contrast, single-award science has been taken by a much higher percentage of the population in Northern Ireland than in any other country. This may be because non-grammar schools in Northern Ireland often encourage high proportions of students to take single-award science and also because single-award science is sat by students wishing to focus on strengths in other areas of the curriculum. Separate sciences have been taken by the highest percentage of the population in Wales.

The pattern of science participation in Scotland, where the opportunity to specialize becomes possible from age 14, is similar to that evident in the other UK nations post-16, with biology being the most popular and physics the least popular science.

Across England, Northern Ireland and Wales there has been an overall increase in the proportion of entrants in each subject attaining grades A*–C in science (with the exception of single-award science), a measure given particular weight in Government performance tables in England. In contrast, the attainment rates of equivalent qualifications in Scotland, in either Intermediate 2 or Credit level at Standard Grade, have been relatively constant in chemistry, physics and mathematics, only increasing slightly in biology.

Post-16 participation and attainment

Across all major science subjects throughout the UK, post-16 participation is lowest in physics and highest in biology. Between 1996 and 2007 participation rates expressed as a percentage of the 17-year-old population in England, Northern Ireland and Wales have not exceeded 12% in biology or mathematics, 7% in chemistry and 6% in physics. Furthermore, they have decreased in chemistry, physics and mathematics in each UK nation. The 2007 figures show that physics participation in England, Northern Ireland and Wales is just 3.5%, 4.7% and 2.7%, respectively. This contrasts with the situation in Scotland, where 10% of 16 year olds sat Higher physics in 2007. Overall, post-16 participation in chemistry, physics and mathematics is highest in Scotland relative to other UK nations. This may reflect the fact that young people in Scotland have the opportunity to specialize in the separate sciences from age 14 and that Scotland has a healthier number and supply of teachers who are specialists in these subjects.

The percentage of 17 year olds attaining good grades at A-level has varied less than might be expected in England, Northern Ireland and Wales given the considerable changes that have occurred in the education systems of these countries. In biology and chemistry the percentages attaining grades A–C have increased very slightly, while they have decreased very slightly in physics and been generally constant in mathematics. The percentage of 16 year olds attaining grades A–C in Scottish Highers decreased between 1996 and 2007 in all science subjects (except human biology), with the largest decrease being in physics.

1.2 Inequalities in participation and attainment in science and mathematics subjects in the UK

Many factors influence participation and attainment in science and mathematics 14–19, some of which are more quantifiable than others. We have examined the available evidence concerning the impact of gender, socioeconomic status and ethnicity.

Gender

More female students participate in biology and fewer take physics and mathematics post-16. Participation in chemistry is comparatively balanced. There is no evidence that this variation stems from differences in ability; in fact, slightly more girls than boys attain 'good' grades at age 16 in mathematics and compulsory science subjects.

Research into attitudes towards science subjects and mathematics supports the argument that gendered participation is the result of broader patterns of subject preference and career aspirations due, at least in part, to societal assumptions about what is appropriate, respectively, for young women and young men.

Socioeconomic status

Subject-specific data for socioeconomic status in the UK are not published systematically. The available data, primarily from England, confirm a link between economic status and attainment differences in GCSE and A-level results in science and mathematics. Of those who attain highly at GCSE, students' progression to A-level physics and mathematics occurs at much the same rate in these subjects, regardless of economic status.

Ethnicity and other factors

Clear patterns in both attainment and progression for different ethnic groupings emerge. In England, Chinese and Indian students attain higher proportions of A*–C grades in science and mathematics GCSEs and A-levels, while Caribbean students attain at much lower rates.

Of students with top GCSE sciences and mathematics grades, fewer Caribbean and White students progress to take chemistry and mathematics A-levels than other ethnic groups. Chinese students with top GCSE grades have the highest rates of progression to physics and mathematics, while Pakistani and Indian students also have high rates of progression in chemistry and mathematics.

Other factors linked to post-16 participation

Prior attainment is the single biggest predictor of progression to post-16 study in science and mathematics (although extensive research appears to have only been conducted in England). Such progression is linked to students' attitudes and perceptions of their own ability and the extent to which their choices are constrained by their schools' provision and their grades. There is some evidence that, other factors being equal, the study of separate sciences prior to 16 results in an increased likelihood of progressing in those subjects taken.

1.3 Inequity in the education system

The range of qualifications on the education market is growing. This widening provision appears to offer more choice and flexibility, but the availability of these qualifications is dependent on whether schools and colleges choose to embrace them. Inevitably, a patchwork of provision is developing.

This increasing range of qualifications available for a given level in the qualification system, quite apart from traditional 'equity' issues of differentiation in participation and/or attainment with respect to gender, socioeconomic status and ethnicity, opens up a whole new area of potential inequity that requires research in its own right.

1.4 International studies of student attainment

Large-scale international (comparative) studies indicate that the UK's performance is comparable to that of other industrialized nations. The OECD's Programme for International Student Assessment (PISA) 2006 suggests that the UK's performance in science education is above the mean for OECD countries. The results of PISA 2006 also suggest that the UK's performance is not significantly below the OECD mean in mathematics, but that there are relatively low proportions of students attaining at higher levels, a finding reinforced by the 2003 Trends in International Mathematics and Science Study (TIMSS).

These studies offer a certain independent measure of UK performance, although for reasons of design, focus and international cultural differences, it is not possible to use them to make well-grounded comparisons over time.

1.5 The evidence on attitudes towards science and mathematics for 14–19 year olds

Research indicates that attitudes to science and mathematics are less positive at the end of the compulsory years of secondary schooling than earlier and that this may influence the subject and career choices students make post-16. Although science is perceived as important, careers in science generally lack appeal, providing additional disincentive to the further study of science. The higher relative difficulty of physics, chemistry, biology and mathematics A-levels is also likely to have some impact on decision making.

The majority of this body of research fails to consider the link between students' stated attitudes and their eventual actions. For this reason, findings must be treated with caution.

2 Overarching recommendations

2.1 Strengthening and using the evidence base

i. **There should be greater collaboration between the education authorities in England, Northern Ireland and Wales to ensure that comparative data are collected and presented more consistently and coherently,** in order to facilitate evaluation of participation and performance in public examinations.

ii. **Across the UK, published annual education statistics should include much greater detail about patterns of socioeconomic and ethnic participation and attainment in science and mathematics.**

iii. **All commercial organizations with responsibility for administering 14–19 examinations should be obliged to make available specific subject-based data on examination participation and performance,** which need not compromise their commercial viability.

iv. **The provision of alternative 14–19 qualifications** (eg the International Baccalaureate), **beyond those that are most widely available, should be closely monitored** so that the true choice available to young people in different localities, and the value of the extent of this choice, may be assessed and evaluated.

v. **The UK Government should routinely draw on the evidence base it oversees, in consultation with its STEM partners,** before committing to educational reform that could have unintentional effects on science and mathematics uptake and progression.

2.2 Overseeing and monitoring the education system

i. **There should be a fully independent body responsible for curriculum reform in each of the UK nations.**

ii. **Each of the relevant agencies across the UK should have robust systems in place to monitor standards over time at key levels in its qualifications framework.**

iii. **The mapping of individual nations' qualifications frameworks should continue to be updated and maintained, identifying comparable levels and the standards of attainment that are associated with those levels.**

iv. **The impact, in England, on progression to science post-16 of the 'entitlement' for certain students to study separate science GCSEs from 2008 should be monitored.**

v. **The impact, in England, of the move to two mathematics GCSEs on progression to mathematics qualifications post-16 should be monitored once these are introduced.**

3 Research needs

Research is needed into:

i. the drop in science and mathematics participation post-16, with a particular focus on students' decision-making and actions, and this should be conducted in a coordinated way across the UK.

ii. patterns of socioeconomic and ethnic participation and attainment, making use of large-scale national datasets.

iii. the comparatively higher rates of attainment in science and mathematics by GCSE students in Northern Ireland, in order to explore potential lessons that may be learned by other UK nations.

iv. the greater participation in the separate sciences in Scotland, in order to explore potential lessons that may be learned by other UK nations.

v. the differences between UK nations revealed in PISA 2006, in order to explore whether differences may be accounted for by socioeconomic status or whether other factors are involved.

vi. the lower proportion of 15-year-old UK students attaining at the upper levels of difficulty in mathematics, as identified in PISA 2006 and TIMSS 2003, and what might be done to achieve a level comparable to other industrialized countries.

vii. schools with relatively high take-up of mathematics and science subjects post-16, using a sufficient number to take account of variation in the student population, particularly in prior attainment, and the variation in school circumstances.

viii. variation in schools' policies concerning entry requirements to A-level sciences and mathematics and their equivalents in Scotland, and in particular the options that are made available to pupils awarded B and C grades in their GCSEs who wish to continue studies in these subjects post-16.