The sciences at key stage 4: time for a re-think?

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Why key stage 4 is so important, and why changes are needed

Key stage 4 is a pivotal period of time in a student's school life; it is the point at which they make subject choices that define their future study, as well as their last experience of those subjects that they do not choose to take further. The sciences are core subjects to 16, yet multiple qualifications exist for students of this age. As this discussion paper documents, evidence suggests that rich opportunities in physics, chemistry and biology are currently the preserve of a minority. There is evidence that the existence of multiple routes through key stage 4 disadvantages a large number of students in both their experiences and the choices that are taken away from them. For this reason, the SCORE organisations are proposing that there should be a single route in the sciences for all students up to the age of 16.

SCORE's proposal: a single route in the sciences

SCORE's vision is that opportunities for high-quality study of the sciences are available to all, on an equitable basis, and we believe that this can only be achieved by the creation of a single route at key stage 4. This single route would remove the need for decisions to be made at 14 that could limit students' future choices, and give all students an authentic, exciting and inspiring experience of the sciences, providing them with the skills and knowledge to succeed in their future endeavours, whether or not they decide to pursue the sciences beyond 16. It would also establish the principle that all students should have equitable access to the sciences.

The case for a single route

The sciences, along with English and mathematics, are core subjects, and are therefore compulsory for all students; however, unlike English and mathematics, there are currently multiple routes for students through the sciences at key stage 4.

Many reasons are given for the existence of multiple routes at key stage 4 in the sciences. The sciences are sometimes considered more difficult than other subjects, so different options are needed for students of differing ability. Students can find three separate qualifications too time-consuming and that it unbalances the curriculum. And different routes are needed for those aiming to continue the sciences beyond 16 and those who are not.

However, the same arguments are not made for other subjects; differences in ability are often dealt with through tiering, and there is an acceptance that all students should follow a common curriculum up to 16, regardless of the choices they may make in the future. While the sciences are different from some subjects in having a body of knowledge that can be a pre-requisite for further study, the existence of multiple routes (including several routes intended for the same destination, namely A-levels) means that specific prior knowledge cannot be presumed at A-level, and schools and colleges must adapt their teaching to cover all possibilities.

A single route would also make it easier to ensure coherence between the curricula in the sciences and related subjects such as mathematics and computing. Both of these are integral to the study of the sciences, and students wishing to continue this study beyond the age of 16 will need a solid grounding in mathematical and computational thinking. A single route would also mean that, while they retain their separate identities, the three sciences of biology, chemistry and physics could be taught as three disciplines sharing a common mode of working, based on a set of core principles such as the importance of observation and evidence.[1]

1. See the SCORE Key Stage Four Guidelines for further information (http://www.score-education.org/media/12525/ks4%20guidelines%20final%20version.pdf)

Options currently available at key stage 4

GCSEs	IGCSEs	Other qualifications	Other science subjects offered at GCSE
Biology	Biology	BTEC First in applied science	Computing
Chemistry	Chemistry	Cambridge National in science	Environmental science
Physics	Physics	Cambridge Technical in science	Electronics
Science	Science (double award)		Human health and physiology
Additional science			Environmental and land-based science
Further additional science			Astronomy
Additional applied science			Psychology

The effect on those who progress to A-level and further study

Although many of the options listed in the table do in theory provide progression to A-levels in the three sciences of biology, chemistry and physics, there is evidence that those who take a core and additional GCSE option are disadvantaged compared with those who take the sciences separately.

Research by Cambridge Assessment[2] has shown that students who take separate sciences do better than any other group. In addition, students who take an applied route may find it difficult to progress to A-level at all. Students' confidence and expectations of what they can achieve may also be limited if they take a route perceived as less challenging.

The effect on choices at 16

Research carried out by King's College London[3] has shown that, while students often enjoy the sciences at school, a large number of them are put off from taking them beyond 16 because they think the subjects are 'not for them'. This attitude is exacerbated by the existence of separate routes, which reinforce perceptions about which routes are suitable for which students. And it is not only those who take a combined or applied route who feel that they are not part of the 'elite' taking separate sciences; often, even those who are in the 'triple science' group doubt their own abilities in the subjects, because they have been given the impression that only the highest achievers should take the sciences separately. This is particularly true for girls, who are often more likely to lack confidence, especially in subjects that have traditionally been associated with boys. The OECD has said that many girls choose not to pursue careers in science, technology, engineering and mathematics because they do not have the confidence in their ability to excel in mathematics, despite having the capacity and skills to do so.[4]

The sciences are not unique in being disliked by some students; in fact, science does not appear to be particularly unpopular at key stage 4. In the Longitudinal Study of Young People in England 2004 – 2010[5], although around 80% of students expressed positive views about their learning, around 20% of students expressed a negative opinion about all subjects, suggesting that there is a cohort of students for whom school is not a positive experience. While measures must certainly be taken to try and engage these students better, it is not clear that providing separate science curricula and qualifications will achieve that aim.

2. Rodeiro, C, Comparing progression routes to post-16 Science qualifications (Cambridge Assessment, 2013)
3. Archer, L *et al*, ASPIRES: Young people's science and career aspirations, age 10 – 14 (Kings College London, 2013)
4. OECD: Are boys and girls equally prepared for life? (2014) http://www.oecd.org/pisa/pisaproducts/PIF-2014-gender-international-version.pdf
5. Longitudinal Study of Young People in England 2004 – 2010 (Department for Education) https://www.education.gov.uk/ilsype/workspaces/public/wiki/Welcome

The illusion of choice

The existence of multiple routes in the sciences has another drawback. Schools are under pressure not only to help each student meet their potential, but also to maximise their institution's performance under accountability measures. This means that, while students may sometimes be able to make choices themselves, decisions on which qualifications are offered are more likely to be made by the school. This leads to inequity of provision; in 2010, E4E published research[6] that demonstrated considerable geographical variation in the provision of separate sciences, despite a large increase nationally. This showed a 16% variation in the proportions of students entered for all three sciences; the highest was Bournemouth, Dorset and Poole with 27.7%, and the lowest, North and North-East Lincolnshire with 11.7%. Access to the separate sciences was also dependent on size and type of school; smaller schools were less likely to offer them (possibly because of the need for specialist teachers), as were mixed schools.

The EISER project[7], being carried out at the University of Leeds, has shown that the range of courses introduced as a result of reform has dramatically altered the choices that schools are making about what science courses to offer to their students. The research suggests that, while flexibility in provision does increase choice, and can mean a better match for individual student needs, it also creates pressure on both schools and students to make the right choice, often without appropriate advice and guidance. Moreover, there is a strong correlation between socio-economic background and the type of course taken at key stage 4, with schools with low levels of deprivation being more likely to offer triple science. This suggests that the opportunities for students, and schools, to make genuine choices about courses are limited.

Students, then, are frequently not in a position to select the course that is most suitable for them, but are compelled to take the option that has been chosen for them by their school. And this has an impact on their progression; in 2014, 90% of entries for A-level physics came from only 50% of schools in England.[8] There are also concerns that changes to the accountability measures could exacerbate this issue, with schools making subject choices based on the change in the rules governing which subjects can count in the science 'slots' within the 'Progress 8' accountability measure. The table below shows the change in entries for year 11 students in summer 2014 relative to 2013, showing a move away from the separate sciences, possibly to capitalise on the 'Progress 8' requirements for two science qualifications.

GCSE entries by subject, summer 2014

Subject	Number of entries	% change from 2013
Biology	129,978	-12%
Chemistry	129,982	-11%
Physics	131,655	-9%
Science (including applied)	152,198	+32%
Additional science	296,896	+18%
Other sciences	7085	+39%

6. Opportunity or ability? Key stage 4 science and mathematics participation and attainment in England in 2010 (Education for Engineering, 2011)
7. Enactment and Impact of Science Education Reform: http://www.education.leeds.ac.uk/research/projects/enactment-and-impact-of-science-education-reform-eiser
8. Data from the National Pupil Database, 2014

Is 14 the best age to be making these decisions?

Key stages 3 and 4 represent a time of enormous change for students; they must cope with the pressures of adolescence at the same time as they are being asked to make decisions that could have long-term implications for their future. Recent research in neuroscience[9] has shown that at the age of 14, brains are still plastic and adaptable, and students' interests, preferences and choices might well be different from those of their later lives. As a result, there is a risk of placing adult expectations on students by requiring them to make potentially life-changing decisions at 14.

Maintaining a common curriculum in the sciences for all students until the age of 16 would lessen this pressure, and provide a firm foundation for a wider choice of options at this later stage, by which point students may be better able to identify their own strengths and aspirations. It would also reinforce the importance of science as an intrinsic part of social, cultural and individual development.

Principles for a better solution

Core principles

- Science is core until the age of 16, therefore an equitable solution must be found that works for as many students as possible
- The sciences should be balanced until the age of 16: this means that any course(s) they take should include biology, chemistry and physics, as well as appropriate content in mathematics and computing
- Each of the sciences should be taught by specialist teachers

From the evidence

- Having multiple routes leads to inequity of provision
- Students are disadvantaged at A-level if they take a combined science route
- Choices are often made by schools, not students
- The existence of multiple routes leads to students feeling the sciences are 'not for them'

Recommendations

- A single route at key stage 4 for all students
- Separate identities for biology, chemistry and physics

9. Giedd JN, Rapoport JL. Structural MRI of pediatric brain development: what have we learned and where are we going? Neuron. 2010 Sep 9;67(5):728-34. doi: 10.1016/j.neuron.2010.08.040.
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How has SCORE reached its conclusions?

The SCORE organisations have been focused on the sciences at key stage 4 for a number of years. In 2013, SCORE published guidelines for the content of key stage 4 qualifications; while these were originally intended to help awarding organisations to develop appropriate specifications and assessments in the sciences, they also formed a starting point for SCORE to think about how the sciences are organised at this level.

In January 2014, SCORE held a seminar with a number of leading education researchers to examine the issue in more detail. Summaries of their research can be found on the following pages of this document. This seminar presented the SCORE organisations with compelling evidence of the drawbacks of having multiple routes in the sciences at key stage 4.

In February 2014, the SCORE annual conference was on the theme of curriculum choices at 14. Through panel debate, expert input and delegate workshops, those attending considered a variety of aspects of curriculum choice, and whether it was appropriate in the sciences at the age of 14. While there wasn't a clear consensus in any direction, it was clear that this is a significant area of discussion for all those involved in science education.

Next steps

The present document represents SCORE's attempts to define both the problem and a possible solution. We are, however, aware that no solution to this question will be perfect, so we hope it will act as a spur for further discussion.

We are aware that our proposals would be difficult to implement within current qualification structures, and that they could be interpreted as prescribing triple science for all students. This is not the case; we believe it would be possible to design a curriculum that includes sufficient content in the three sciences to provide a solid foundation for further study, while also leaving enough space in the timetable for a broad and balanced programme of other subjects. However, while there would be a common curriculum, teachers would have the freedom to use their professional judgement to teach content in a way that was appropriate for their students, and assessment would need to be designed to allow for a range of abilities, possibly with tiered question papers.

Further research is needed to explore how these proposals could work in practice; SCORE would welcome discussions with other organisations and individuals about how best to proceed. We also recognise that, after a period of intensive reform, many working in education would favour a period of stability rather than further change. We will therefore be arguing that our proposals should be considered for the next round of qualifications and curriculum reform, and will work with those responsible for determining policy to ensure they are aware of our proposals.

Comparing progression routes to post-16 Science qualifications

Carmen Vidal Rodeiro, Cambridge Assessment

At present, awarding bodies in England provide schools and students with a wide choice of level 2 (aimed to 14 – 16 year olds) science qualifications designed to ensure that pupils study science that is relevant and up-to-date. However, it has recently been argued that some courses may not be good preparation for the study of science at a higher level. Consequently some students may decide not to pursue a science subject post-16 or, if they do so, they may drop it or not fulfil their potential.

This work aimed to collect detailed information about the students who obtained different level 2 science qualifications and investigate their progression to post-16 courses. Key questions addressed in the research were:

1. What are the characteristics of the students taking the different level 2 science qualifications?
2. What post-16 science qualifications do students with different level 2 science qualifications progress to?
3. What is the performance in post-16 qualifications of students progressing from different level 2 science qualifications?

Data on uptake of and performance in science were analysed through descriptive statistics and multilevel logistic regression methods. The data were obtained from the National Pupil Database, a longitudinal database compiled by the Department for Education which holds pupil and school characteristics matched to pupil level attainment data.

The outcomes of the research showed that:

- there were clear differences in the background (prior attainment / academic ability, level of deprivation and school attended) of the students pursuing the different science routes at level 2;
- the level 2 science route with the highest progression rate was the triple science (GCSEs in biology, chemistry and physics), with around 46% of the students progressing to a post-16 science qualification. Only around 26% of the students from the double science route (GCSEs in science and additional science) and fewer than 5% of the students following an applied route at level 2, including vocational-related qualifications such as BTECs or OCR Nationals, progressed to science at a higher level;
- performance in post-16 science subjects was better for pupils progressing from the triple science route than for pupils progressing from any other routes, even after overall attainment at level 2 and some individual and school characteristics were accounted for.

The findings from this research might suggest that student choices at level 2 determine post-16 trajectories and therefore further study or employment opportunities. In particular, applied routes in science did not offer much progression to post-16 'academic' qualifications/subjects and therefore they could restrict progression to higher education.

Further information

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Vidal Rodeiro, C.L. (2013). Comparing progression routes to post-16 Science qualifications. *Research Matters: A Cambridge Assessment Publication*, 16, 15 – 23 (Available at: http://www.cambridgeassessment.org.uk/Images/142074-research-matters-16-june-2013.pdf)

EISER: The Enactment and Impact of Science Education Reform

Jim Ryder, University of Leeds

Research Aims

Schools in England have been responding to major changes in the science curriculum for 14 – 16 year olds. A wider variety of science courses are available with more emphasis on applied science and teaching about socio-scientific issues and the nature of science. The EISER study is examining school responses to this major curriculum reform using the National Pupil Database (NPD/PLASC) and in-depth school-based case studies over three years.

Key Findings

Multiple aims and associated values
The stakeholders involved in the activities leading to the development of the revised KS4 science curriculum had different aims for the reform. These aims reflect the differing values of these stakeholders. Thus, multiple aims are identifiable within the documentation associated with the science curriculum reform.

Enactment within specific workplace contexts
Teachers' responses to the curriculum reforms were guided by: personal goals, biography and professional identity; internal features of their workplace such as departmental collegiality, student background and school ethos; and external features such as educational policies outside of science (e.g. personalisation of the school curriculum) and national accountability measures (e.g. attainment league tables). Policy makers need to recognise that meaningful teacher change takes time and that teachers do not respond to a curriculum reform in isolation from other education policies.

Science course provision: Diversification and stratification
Since the introduction of the 2006 reforms, science participation at KS4 has become increasingly diverse. Many teachers report that this flexibility has enabled them to respond effectively to the differing needs of their students. This diversification is accompanied by an ongoing stratification by gender and socioeconomic status. For example, students claiming free school meals are heavily under-represented within GCSE Triple Award Science, and this stratification has remained largely unchanged. Student prior attainment in science is the principal determinant of stratification by socioeconomic status within KS4 and KS5 science.

Further information

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ASPIRES: Young people's science and career aspirations, age 10 – 14

Louise Archer, King's College London

Research Aims

There is widespread concern that not enough young people are choosing to study science, technology, engineering and mathematics (STEM) subjects after the age of 16, and that the profile of those who do is too narrow, with women, working class and some minority ethnic groups particularly under-represented. With some STEM sectors already experiencing recruitment difficulties, and a need to improve scientific literacy across all societal groups, the ASPIRES study sought to investigate how young people's aspirations develop between the ages of 10 and 14, and what in particular influences the likelihood of aspiring to a science-related career.

Methodology

The ASPIRES project is a five-year study funded by the ESRC as part of its Targeted Initiative on Science and Mathematics Education (TISME). The study combines quantitative online surveys and repeat interviews with a selected sub-sample of students and their parents. Survey and interview data were collected at three time-points: the end of primary school (age 10/11, year 6), the second year of secondary school (age 12/13, year 8) and the third year of secondary school (age 13/14, year 9). In total, over 19,000 surveys were completed across these three groups; in addition, 83 students and 65 of their parents took part in interviews across the age range (10 to 14).

Key Findings

Most young people have high aspirations – just not for science
The research found that on the whole, most young people in this age group have relatively high aspirations for professional, managerial and technical careers, and they are supported by parents who value education. However, only around 15% aspire to become a scientist, and this aspiration remained consistently low across the age range. This was lower than many other aspirations, and appeared disproportionately low compared to students' reported interest in science. STEM-related careers, such as medicine, are more popular.

Negative views of school science and scientists are not the problem
While those expressing the most positive views of school science are also the most likely to aspire to science careers, student attitudes to school science do not fully explain their aspirations. Most young people report liking school science from year 6 (at primary school) through to year 9 (the end of key stage 3 at secondary school). 42% of students are interested in studying more science in the future, and they report positive views of scientists and report that their parents think it is important for them to study science. However, this does not often translate into an aspiration to be a scientist.

Family 'science capital' is key

The research found that families exert a considerable influence on students' aspirations, chiefly in the form of 'science capital'. This term is used to describe science-related qualifications, understanding, knowledge (about science and how it works), interest and social contacts. It is unevenly spread across societal groups; those with higher science capital tend to be middle class, but this is not always the case, and not all middle class families possess high levels of science capital. Students who come from families with medium or high science capital were more likely to aspire to science or STEM-related careers, and to plan to study science post-16. Those who have low science capital who do not express STEM-related aspirations at the age of 10 are unlikely to change their view by the age of 14.

Most students and families are not aware of where science can lead

Most young people and their parents appear to have a narrow view of where science can lead, with many believing that science qualifications lead primarily to a career as a scientist, a science teacher, or a doctor. This leads many students to believe that studying the sciences post-16 is 'not for them'. Those young people who are aware of the transferability of science qualifications are more likely to aspire to a STEM-related career and plan to study these subjects post-16.

The 'brainy' image of scientists and science careers puts many young people off

Over 80% of the students who took part in the survey agreed that 'scientists are brainy'. This association means that those who did not perceive themselves to be among the 'brainiest' in their class did not believe they would be able to succeed in science careers, even if they find science interesting and attain well in the subject.

The (white) male, middle-class image of science careers remains a problem

From the surveys, a student is most likely to express science aspirations if he is male, Asian, has high/very high levels of science capital, is in the top set for science and has a family member who works in science or a science-related job. Those least likely to do so are female, white, have low/very low science capital, are in the bottom set and don't have family members who use science in their job. The gender divide is evident from a young age, with girls being less likely than boys to aspire to science careers, even though more girls than boys rate science as their favourite subject. This polarisation is more pronounced among girls who define themselves as 'girly'; even if these girls aspire to science careers at age 10/11, they tend to drop or change them over time. Girls who do aspire to science and STEM-related careers tend to be very academic and describe themselves as 'not girly'.

The factors that hinder students from developing science aspirations are amplified in the case of black students, meaning that their science aspirations are particularly precarious.

Further information

The ASPIRES research team is Professor Louise Archer (Director), Professor Jonathan Osborne (Co-investigator), Dr Jennifer DeWitt (ASPIRES research fellow), Professor Justin Dillon (ASPIRES Intervention), Dr Billy Wong (ASPIRES studentship) and Mrs Beatrice Willis (ASPIRES Administrative Officer).

For further information, visit the website at **www.kcl.ac.uk/aspires**

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