Nuffield Foundation

Response to Department for Education consultation on Study Programmes for 16-19 year olds

January 2012

Study Programmes for 16-19 year olds Consultation Closing date: 4 January 2012

Q1) Will the measures listed in the consultation document be sufficient to ensure that the 16-19 study programmes principles are followed?

No. The Consultation document sets out 'a clear expectation that English and maths must be part of a study programme for those students who have not achieved A*-C in GCSE in these subjects'. It rightly states that 'for those who need more intensive support to move towards achieving a C grade GCSE providers are best placed to determine what will meet their needs and enable them to progress. Based on level of rigour, assessment arrangements, skills taught and views of employers, the qualifications that we recommend to providers are: functional skills and free standing maths qualifications' (FSMQs).

But this by itself, and even the removal of support for inadequate qualifications, may be insufficient to ensure that rigorous qualifications such as the FSMQs have desired take-up. The Nuffield Foundation has supported the FSMQs since their inception, and despite the FSMQs being around for over a decade, take-up is extremely limited. In June 2010, 4,113 Foundation and Intermediate FSMQS were taken (http://store.aqa.org.uk/over/stat_pdf/AQA-FSMQ-FND-INT-STATS-JUNE10.PDF & http://store.aqa.org.uk/over/stat_pdf/AQA-FSMQ-LEGACY-STATS-JUNE10.PDF) and student numbers would be even lower, despite a cohort of over 300,000 students not achieving A*-C at GCSE.

Significant demand side issues need to be addressed – understanding and recognition of the FSMQs by employers, universities, parents and students – and some supply side issues

- colleges and schools not making adequate provision for FSMQs
- potential lack of teachers to cope with an increase in the post-16 maths cohort
- recent narrowing of learning and assessment opportunities on the FSMQs due to the removal of coursework/portfolio assessment (coursework was particularly appropriate for students interested in and/or motivated by applications of mathematics). This narrowing has resulted from Ofqual's requirement that a single (FSMQ) module not have more than one type of assessment, an example of mathematically and pedagogically unsound regulation by Ofqual.

This final point has been highlighted by ACME in its December 2011 submission to the Commons Select Committee on Education on 'the administration of examinations for 15 to 19 year olds in England' and ACME also highlights the lack of mathematical expertise and lack of transparency at Ofqual. 'There has been a tendency for a 'one size fits all' approach to the regulation of subjects. By treating subjects generically, little room is left for the vital aspects that distinguish one subject from another. Ofqual's overall approach to regulation and its enforcement stifles innovation in the system. **The regulator should ensure that assessment structures for mathematics harmonise with subject content and the curriculum aims'.**
http://www.publications.parliament.uk/pa/cm201012/cmselect/cmeduc/writev/1671/exb47.htm

The ACME submission also touches on the critical point on raising awareness of the various qualifications for the range of stakeholders.

Q4) ... the Secretary of State has signalled his ambition for the vast majority of 16-19 year olds to be studying maths within 10 years. **In line with this ambition for all to be studying maths post-16 in the next decade, we would be interested to know what you feel could be done to encourage more young people who have already achieved GCSE A*-C to study maths. What would this provision look like?**

Our response to this question is developed through the following 3 points.

1. Evidence on the necessity for students to be studying some mathematics post-16
2. An analysis of student preparedness for post-16 mathematical pathways (a rudimentary mapping of mathematical attainment)
3. A discussion of curricular content, pedagogy and assessment for post-16 mathematical provision and some exemplar pathways (international and national, present and past).

Note that the term mathematics here encompasses the range of quantitative and logical approaches one finds in mathematics, statistics, computing, financial literacy and problem-solving.

1. Our recent report *Is the UK an outlier? An international comparison of upper secondary mathematics education* http://www.nuffieldfoundation.org/uk-outlier-upper-secondary-maths-education demonstrated that among 24 (mainly OECD) comparable countries, the UK has the lowest proportion of students studying mathematics post 16. ACME's *Mathematical Needs* report www.acme-uk.org/media/7624/acme_theme_a_final (2).pdf added further detail to the UK specific picture. '*It is not just a case of students missing out on two years of learning mathematics, serious though that is, but of their arriving at the next stage of their lives having forgotten much of what they did know. ... We estimate that of those entering higher education in any year, some 330,000 would benefit from recent experience of studying some mathematics (including statistics) at a level beyond GCSE, but fewer than 125,000 have done so'.*

The ACME report explores the differing needs across a spectrum of universities/courses and employment sectors. The report echoes the (sadly regular) findings of surveys run by a range of subject bodies – that even where the mathematical content requirements are not much beyond GCSE and/or have been met, undergraduates (even those with A-levels) can lack confidence, fluency, and the capacity to apply their mathematical skills in new/unfamiliar (subject-specific) settings. The situation gets increasingly severe as one moves from the physical sciences to the life sciences and social sciences (see sampling below).

Physics: *Mind the gap - Mathematics and the transition from A-levels to physics and engineering degrees*, EdComs, Institute of Physics report (2011) www.iop.org/publications/iop/2011/file_51933.pdf

Biosciences: *A survey of the mathematics landscape within bioscience undergraduate and postgraduate UK higher education,* J. Koenig, HE Academy UK Centre for Bioscience (2011) www.bioscience.heacademy.ac.uk/ftp/reports/biomaths_landscape.pdf

Psychology: *Assessing numeracy and other mathematical skills in psychology students as a basis for learning statistics*, HE Academy Psychology Network, G. Mulhern and J. Wylie (2005) http://pnarchive.org/docs/pdf/p2007509_Assessing_numeracy.pdf

Thus not only is there a case for wider post-16 mathematics provision but also to improve the 'application' skills for traditional A-level students.

2. There are two headline statements in this section.
2a. That the traditional A-level in mathematics is not the recommended route for most students achieving a B or C at GCSE mathematics;
2b. Offering an alternative pathway for students achieving a B or C at GCSE mathematics is a meaningful option and will not diminish student numbers for the traditional A-level.

The evidence for 2a looks at attainment on A-level mathematics in terms of prior attainment at GCSE and compares this with some other subjects (English and History). The data (some from the DfE/DCSF, some from UCAS and the STEM Advisory Forum) has some uncertainty but what is presented here is representative and possibly more encouraging than the situation on the ground.

The numbers of students achieving the higher grades at GCSE mathematics (2011) are as follows:
A*: 40,000
A: 88,000
B: 120,000
C: 208,000

Fewer than 10% of students achieving a grade B progress to A/AS level and virtually none with a grade C. The numbers progressing in other core subjects (for example English) are much higher.

B and C grade GCSE students who progress to A level do less well in mathematics than in other subjects. For students with a grade B in GCSE mathematics, 20% get a grade E and 8% fail. The comparable figures for English are 3.5% and 0% and for History 8% and 1%. (2008/9 figures, DfE data)

For students with a Grade C at GCSE, the A level figures are:
Mathematics: 23% Grade E, 18% Fail
English: 18% Grade E, 1% Fail
History: 22% Grade E, 3% Fail.

The picture is clear: if you are a B/C GCSE student taking mathematics at AS/A-level you are unlikely to do well and you have a good chance of failing. If you choose a different subject the chances are you will do better. Given that you can choose only 3 or 4 subjects it is an entirely rational decision to drop mathematics and follow subjects in which you have a significantly better chance of doing well. It is a common story that many schools actively discourage 'B at

GCSE maths' students from pursuing an A-level, and in some cases will not allow them. Colleges tend to take a more inclusive line, but the main pattern is the same. No doubt there are perverse consequences for some students, but it is hard to argue against the general trend. On the whole students with the lower grades are better off not attempting the traditional A/AS in mathematics.

Moreover, the evidence of the ACME "Needs" report and the other reports cited above suggests that the desirable attributes are confidence, fluency, and capacity to model and problem-solve. Subjects outside the physical sciences, engineering and of course mathematics per se (for example biology, business studies, economics, geography, psychology and sociology) do not require much content beyond the GCSE other than statistical methods. For students following these subjects the traditional A-level is arguably not the right fit in any case.

This brings us to 2b, offering an alternative pathway for students achieving a B or C at GCSE. The *Evaluating Mathematics Pathways* (EMP) project https://www.education.gov.uk/publications/eOrderingDownload/DFE-RR143.pdf showed that the *Use of Mathematics* qualifications (albeit small numbers) provide an empowering pathway, especially for students who may either have a B or C at GCSE mathematics or those who (despite an A*/A on GCSE mathematics) do not need or are not disposed to the traditional A-level. The EMP project studied developments that had been put in place in response to the 2004 Smith Report www.mathsinquiry.org.uk/report/MathsInquiryFinalReport.pdf recommendations that "a highly flexible set of interlinking pathways that provide motivation, challenge and worthwhile attainment across the whole spectrum of abilities and motivations" be developed.

In addition to the EMP report there is a growing body of evidence from education researchers (e.g. Volume 13 Number 2 (2011) of *Research in Mathematics Education,* http://www.tandfonline.com/doi/abs/10.1080/14794802.2011.585822 a special issue on *deepening engagement in mathematics in pre-university education*) and data from colleges piloting the *Use of Mathematics* A-level (e.g. enrolment numbers at Colchester Sixth Form College, available from the College or from the Nuffield Foundation) that the Use of Mathematics qualifications are opening up mathematics post-16 for a cohort who would otherwise not have done mathematics, without diminishing numbers of those taking the traditional A-level. The evidence suggests that Use of Mathematics qualifications are supporting greater 'self-efficacy' and a positive disposition towards mathematics for these students.

This final point is an important one. As evidenced by the current National Curriculum Review, high performing jurisdictions such as Hong Kong and Singapore explicitly stress the role of developing positive attitudes. 'Whilst promoting a positive attitude towards mathematics is implicit in all curricula, Hong Kong and Singapore provide more detail on attitudes in their aims, including defining this as a separate domain about the fostering of appreciation, interest, confidence and perseverance in mathematics'.
https://www.education.gov.uk/publications/eOrderingDownload/DFE-RR178.pdf

This brings us to possible models for expanded/alternate post-16 mathematics provision.

3. Prior to the AS denoting Advanced Subsidiary Level (Curriculum 2000), an AS denoted an Advanced Supplementary Level, a course spread over 2 years, with the same rigour as an A-level but half the content. One could devise such an AS, which would be a '*mathematics for ...*' course, for subjects such as biological sciences, social sciences, business (and even one for prospective primary teachers), with a common core of algebra and use of graphs, and subject-specific options, say for the second year, focused on more practical and experiential approaches such as mathematical modelling and problem solving, using project work and/or coursework. The algebraic and graphical literacy could be situated in contexts of interest, as it is already done for *Use of Mathematics* FSMQs www.fsmq.org .

Further elements such a course could include would be mathematical comprehension, already part of the *Use of Mathematics* qualifications and of the MEI (OCR-run) mathematics A-level, and statistical methods and statistical modelling.

There is the concern as to where we would find the teaching capacity for additional mathematics cohorts. Such an AS could mitigate that, as the modelling and more contextual/practical elements could be taught by other-subject teachers and/or team taught by mathematics and other-subject teachers. SCORE (Science Community Representing Education) is conducting a study looking at the extent, type and complexity of mathematics in biology, chemistry and physics A level assessments www.score-education.org/policy/qualifications-and-assessment/mathematics-in-science . The Nuffield Foundation is complementing this study and considering the mathematics in business studies, computing, economics, geography, psychology and sociology A level assessments. Both studies will be reporting in April 2012 and preliminary results indicate that there are sufficiently rich and diverse opportunities for mathematical learning within these subject areas. Whether these opportunities be made more explicit, formalised or better supported within these subject areas, or be supported by new mathematics course offerings, these other-subject teachers can play a critical role in the necessary teaching. There is a need for joint/coordinated CPD on this front, with mathematics and other-subject teachers working together. The STEM NRICH project at the University of Cambridge has been explicitly working on this.

These ideas are not new, in fact we are in the favourable position where we can look at past, present, national and international experiments and choose appropriately. In addition to the FSMQs that have been mentioned, Nuffield had developed an A-level in mathematics in the 1990s, *Nuffield Advanced Mathematics*, www.nationalstemcentre.org.uk/elibrary/collection/57/nuffield-advanced-mathematics which had a History and Mathematics module, an Art, Music and Mathematics module, and included a 'reader' and comprehension and communication exercises.

Mathematical modelling (and applications) has matured as a strand within mathematics education in the past two decades and has an internationally coordinated community - The International Community of Teachers of Mathematical Modelling www.ictma.net/ . There is a related study group that is part of the International Commission on Mathematical Instruction (ICMI) and publications such as *Modelling and Applications in Mathematics Education*

The 14th ICMI Study http://springerlink3.metapress.com/content/978-0-387-29820-7/#section=295138&page=1 provide a wealth of information around modelling as a tool, as a means of learning mathematical competencies, related pedagogy, implementation and assessment.

In terms of international experience, parts of Germany and Australia (Queensland) have significant experience of modelling based pathways. New Zealand has recently introduced a highly flexible approach for its post-16 curriculum that enables schools and teachers to 'make their own decisions about planning and designing learning programmes to meet the diverse needs of their students' http://seniorsecondary.tki.org.nz/Mathematics-and-statistics/Learning-programme-design . There is a core of mathematical literacy and then a range of interlinked options allow for a mathematically and statistically rich curriculum to be taught (a conscious decision has been taken to call the subject 'mathematics and statistics' and statistics includes content areas as well as carrying out investigations following a *statistical enquiry cycle*, a cycle that consists of five stages: Problem, Plan, Data, Analysis, Conclusion).

One needs to bear in mind that the content and pedagogy go hand in hand with assessment. The New Zealand curriculum allows for a mix of assessment methods (diagnostic, formative and summative, internal and external) http://seniorsecondary.tki.org.nz/Mathematics-and-statistics/Assessment . Again, there is ample experience of diversified assessment portfolios within past UK/Nuffield work and there are promising new approaches such as *Adaptive Comparative Judgments* http://mec.lboro.ac.uk/mcg/GCSEmaths/ which allow complex pieces of work such as design projects in art/media departments to be assessed with high reliability and validity and are proving applicable for assessing more open-ended mathematics tasks.

Furthermore, these pedagogical and assessment approaches are ideal for use with computing and would allow the realisation of many of the aims of *Computer Based Mathematics* www.computerbasedmath.org/ .

Our comments so far refer only to the supply side. The demand side is equally important. If employers and HE admissions tutors do not signal that they value or, better still require higher levels of mathematical fluency and confidence then there will be little reason for students to change their behaviour and continue their mathematical studies. We hear frequent tales of HE departments that in effect conceal the mathematical demands of their subjects for fear of frightening away prospective students. As long as that continues nothing will change.

We leave the final word to the 1982 Cockroft Report, *Mathematics Counts* http://www.educationengland.org.uk/documents/cockcroft/cockcroft11.html . In some ways it is dispiriting to acknowledge that nothing much has changed since Cockroft reported. On the other hand we are encouraged by the consistency between our arguments and those so eloquently expressed by Cockroft some thirty years ago. The evidence from other countries suggests strongly that the pathways of the kind we describe exist and are desirable. Given the will we believe it would be perfectly possible to create something similar for the UK and to meet the Secretary of State's challenge.

“Since our Committee was set up, the government have published proposals for the development of free-standing intermediate examinations (I Levels)* as a means of broadening the studies undertaken by some of those who currently take full A Level courses. An I Level course would last two years and occupy about half the time normally given to a full A Level course.

We support the suggestion that a course of this kind should be available for students who are not studying mathematics as a full A Level subject. We do not, however, believe it will necessarily be easy to design a suitable course and we expect that considerable development work will be required. In our view an I Level course should not be envisaged merely as a replacement for the 'service' courses which are at present provided in some sixth forms, though it would serve some of the purposes of these courses. ...We believe that the aim of an I Level course should be to develop mathematical ideas and extend previous knowledge without setting ambitious targets in terms of manipulative competence. For example, although calculus would be included, students should not be expected to spend time acquiring facility in the differentiation and integration of complicated functions. The course should illustrate the many ways in which mathematics can be applied and also include some study of the ways in which the subject has developed. We are not aware of any existing course which would be suitable, though we believe that use could be made of some of the ideas which are contained in the *Mathematics Applicable*** course and in the N Level study entitled *Mathematical Awareness*. **An I Level course of the type we would wish to see would require skilled teaching and this would have staffing implications for schools and for in-service education.**

We believe that there would also be a place for an I Level course in statistics. Such a course could serve the needs of many students, especially those who are studying A Level courses such as biology, geography, sociology or economics, in which there is an increasing emphasis on the critical examination and analysis of numerical data. In evidence to us the Royal Statistical Society and the Institute of Statisticians have stressed that statistics is not merely a collection of techniques but is a practical subject devoted to obtaining and processing data; and that the study of statistics should not become separated from the origins of that data. They have also pointed out that statistics in schools frequently ignores the practical situation and concentrates on formal manipulation. Within such an I Level course as we propose there should be time and opportunity to adopt a practical approach and to place emphasis on the application of statistical techniques to data which the students themselves have collected in the course of their own laboratory and field work. In this way it would be possible to demonstrate clearly the application of statistics to the analysis of data arising from study in several different areas of the curriculum and to develop a course which did not concentrate mainly on techniques. We believe that in many sixth forms it might be preferable to provide an I Level course rather than a full A Level course in statistics, since such a course would serve the needs of a much greater number of students.”

**Examinations 16-18* A consultative paper. DES and Welsh Office 1980.

**Schools Council Project MA 1601.