Transition to STEM Degrees – Further Maths A-level

The rapid pace of change within post-16 mathematics education over the last fifteen years has created both opportunities and challenges for mathematics educators. Since the well-documented damaging outcomes of Curriculum 2000, A-level Mathematics has arguably gained a reputation as a challenging domain, with recent research suggesting that Mathematics and particularly Further Mathematics A-levels are amongst the most demanding A-level subjects [1].

This article gives an overview of topical research and curriculum activity in relation to post-16 mathematics and outlines the utility and incidence of Further Mathematics A-level qualifications in progressing to a wide range of degree courses. Data relating to trends in admissions to STEM courses over the past eight years will be presented, providing evidence of the extent of uptake of the A-level Further Mathematics qualification by those progressing to STEM undergraduate degrees. The role of universities in influencing post-16 mathematics education is also considered.

1 Why study Further Mathematics?

Further Mathematics is a qualification designed to both broaden and deepen a student's mathematical knowledge. Under the current qualification structure Further Mathematics students take three units (AS) or six units (A-level) in addition to those in their AS/A-level Mathematics qualification. This is advantageous for a number of reasons, including:

- An introduction to a number of topics in pure mathematics that are not covered at A-level, but which are beneficial in STEM and associated degree courses, such as complex numbers, matrices, hyperbolic functions and more demanding differential equations;
- Opportunities to study a broader range of applications in mathematics from mechanics, statistics and/or decision mathematics;
- Increased time engaging with mathematics and developing greater fluency;
- Increased confidence and resilience in tackling demanding mathematical problems and applying knowledge and understanding in a wider range of contexts.

A-level Mathematics and Further Mathematics specifications are currently being reformed. Having originally been proposed for first teaching from 2015, evidence from consultations [2] led to the introduction being delayed until 2016 to ensure the changes did not have a negative impact on participation rates.

2 What is the current trend in the uptake?

After a catastrophic drop in the numbers of students sitting A-levels in Mathematics and Further Mathematics post Curriculum 2000, the curriculum was revised in 2004 due in at least part to concerns that the content was too difficult and so discouraged students from progressing with the subject post-16 [3]. Participation in post-16 mathematics is now buoyant (Figure 1), with Further Mathematics in particular still being one of the fastest growing subjects at both AS and A-level [4].

A number of large scale projects [5] have also been implemented during the last decade to promote and support post-16 mathematics, including the work of the Further Mathematics Support Programme (FMSP). The FMSP has played a major role in increasing participation in A-level Further Mathematics from around 5,000 students in 2005 to over 14,000 students in 2014, a 160% increase.

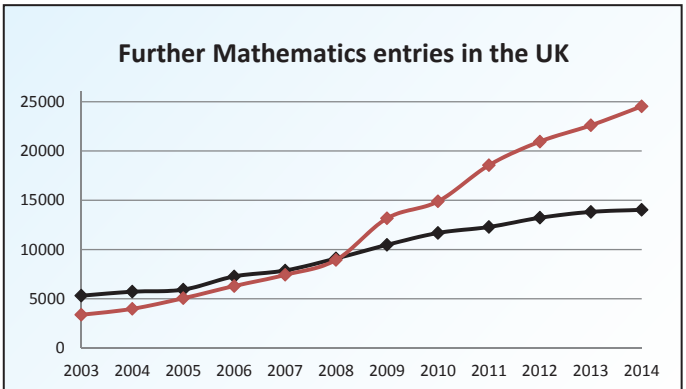

Figure 1: Further Mathematics Entries at AS (red) and A-level (black) [6].

3 What are the key factors in participation?

In 2014 AS/A-level Mathematics became the most studied AS/A-level qualifications (overtaking English) with 161,711 and 88,816 entries respectively. Whilst the proportion of students studying A-level Mathematics and Further Mathematics is increasing the fact that mathematics is not a requirement for many higher education courses, which have a mathematical component, can act as a disincentive to take up. Indeed, evidence shows that in countries where post-16 study of mathematics is optional, the requirement for a qualification in mathematics for entry to higher education is an important factor in increasing uptake post-16 [7].

Over the last ten years, some University departments offering degrees in STEM subjects have dropped the requirement for entrants to have A-level Mathematics, possibly due to the 20% reduction in the number of students taking A-level Mathematics in 2002. Now that A-level Mathematics and Further Mathematics participation have both recovered to a level exceeding those pre-Curriculum 2000 it is possible that a reluctance remains amongst many admissions tutors who still believe that if they were to make either Mathematics or Further Mathematics a requirement they would be unable to fill their course places.

In addition, not all schools and colleges offering A-levels have the capacity or expertise to offer A-level Further Mathematics. There have, however been 'remarkable achievements in the study of Further Mathematics' in recent years. Whilst in 2005 only around 40% of state institutions offering A-level Mathematics also offered Further Mathematics, there has been a targeted move from a situation where the subject was openly branded as 'elitist' to a situation today where

> almost two-thirds of state schools can offer this vitally important A-level and students in other schools can, and do, take it using the online and face to face provision of the FMSP [8].

Government policy has shown clear indicators in recent years of the perceived importance of mathematics education. In late 2013, the FMSP announced they had been awarded extended and enhanced funding by the Department for Education (DfE) to promote mathematics post-16 and support schools and colleges to work towards all students having access to Further Mathematics within their own institution.

In May 2014, the Your Life campaign (www.yourlife.org.uk), chaired by businesswoman Edwina Dunn and involving 170 leading businesses, was launched. This campaign has an aim to increase the number of students studying each of Mathematics and Physics A-levels by 50% over the next three years [9].

Additionally, the government have recently published new accountability measures for schools and colleges which show the proportions of students in the 2012–13 cohort who studied A-level Mathematics, Further Mathematics and other sciences at an institution and regional basis, including analysis by gender. This data will be published annually [10].

4 Progression Data

Mathematics in Education and Industry (MEI) purchased a dataset from the Universities and Colleges Admissions Service (UCAS) relating to students entering university in 2013–14 and the previous eight cohorts (see Tables 1 and 2). They show the number of students entering G1 undergraduate mathematics degree courses (Table 1) and STEM and other degree courses which may require mathematical skills (Table 2), and the uptake of A-level Further Mathematics amongst these cohorts.

Mathematics degrees

Table 1 shows that the number of students entering mathematics courses with UCAS code G1 has increased from 5,041 in 2005–06 to 7,699 by 2013–14. Within these cohorts, the proportion of students with A-levels who had studied A-level Further Mathematics increased appreciably from 35.6% to 59.6%. There are now more students entering onto Mathematics degrees in absolute terms and a much higher percentage of them have studied an A-level in Further Mathematics. This presents a picture of a widening pool of increasingly well-qualified applicants. Whilst many HEIs do still not insist on Further Mathematics as an entry requirement and admit students without it, more and more are advising students to consider taking it, wherever possible.

Year	Total number of students accepted to G1 Mathematics courses			% accepted to G1 Mathematics with A-levels that had A-level FM
	All	studied A-levels	studied A-level FM	
2005–06	5041	4217	1503	35.6%
2006–07	5349	4465	1756	39.3%
2007–08	5861	4799	1935	40.3%
2008–09	6403	5591	2250	40.2%
2009–10	6916	6096	2454	40.3%
2010–11	7276	6651	2855	42.9%
2011–12	7585	6429	3055	47.5%
2012–13	7311	6002	3006	50.1%
2013–14	7699	6427	3832	59.6%

Table 1

Other degrees

Whilst the proportion of universities who insist on post-16 mathematics as an entry requirement across disciplines such as biology, computing, geography and psychology may be relatively low, the actual qualifications of students can be notably different and are sometimes considerably above the minimum requirement [11].

Table 2 illustrates the proportions of students entering undergraduate degree courses in a range of subjects (including Economics, Computing and Finance) with the A-level Further Mathematics qualification. The data shows a general upward trend in uptake of Further Mathematics, with particularly noticeable increases having taken place between 2005–06 and 2013–14 in

JACS Subject Classification		Total number of students accepted onto Degree courses in 2013–14			% accepted with A-levels that had A-level Further Mathematics (FM)		
		All	studied A-Levels	studied A-Level FM	2013–14	2010–11	2005–06
G3	Statistics	179	147	91	61.9%	31.7%	34.1%
G1	Mathematics	7699	6427	3832	59.6%	42.9%	35.6%
GG	Combinations within Mathematical Sciences	514	331	188	56.8%	21.4%	17.9%
Y	Combs of phys/math/comp sciences	980	633	268	42.3%	18.8%	22.3%
F3	Physics	4765	3682	1328	36.1%	21.1%	15.7%
H1	General Engineering	3568	2039	528	25.9%	35.4%	8.8%
HH	Combinations within Engineering	667	262	62	23.7%	10.0%	6.6%
H4	Aerospace Engineering	2401	1388	325	23.4%	12.0%	13.7%
F5	Astronomy	172	127	29	22.8%	8.6%	6.9%
H6	Electronic and Electrical Engineering	4472	1684	381	22.6%	9.3%	10.8%
H3	Mechanical Engineering	7156	3949	887	22.5%	11.6%	11.1%
N3	Finance	1683	817	174	21.3%	19.5%	7.3%
Z	Combs of 3 subjects, or other general courses	6439	3832	786	20.5%	N/A	8.9%
H8	Chemical, Process and Energy Engineering	2797	1782	354	19.9%	15.5%	8.7%
H2	Civil Engineering	3871	1881	351	18.7%	10.6%	8.1%
Y	Combs of phys/math sci with social studies/bus/law	3082	1843	337	18.3%	11.8%	5.9%
Y	Combs of sciences with engineering/tech	1332	704	124	17.6%	6.7%	3.7%
L1	Economics	7871	5520	816	14.8%	11.5%	6.2%
Y	Combs of phys/math science with arts/humanities/languages	1840	860	109	12.7%	9.7%	5.5%
I1	Computer Science	12916	5089	588	11.6%	5.5%	3.6%

Table 2

Mathematical Sciences, Physics and a range of Engineering courses. For example, during this eight year period, the proportion of students entering a Physics degree who had studied A-levels and had an A-level Further Mathematics qualification increased from 15.7% to 35.6%. For Economics degrees the equivalent figures were 6.2% to 14.8%, with the proportion in Finance having almost trebled from 7.3% to 21.3%.

Whilst it is difficult to quantify how many students complete AS Further Mathematics each year, due to entry patterns and 'cashing in' rules, it is clear that growth in this qualification has also been dramatic in recent years and it seems reasonable to assume that a high proportion of students go on to do degree courses in related subjects at university with that qualification too.

This data raises a number of questions relating to causation and sustainability. Exactly which factors influenced these students to take Further Mathematics A-level? Was the motivation intrinsic to the subject or a function of the utility of the qualification for future study or career plans? And crucially for HEIs, what is the degree of interplay between trends in the qualifications students are actually presenting on entry to universities with the university entry requirements? These are areas that the FMSP is planning to consider through exploratory meetings with Admissions Tutors and network meetings between school and university representatives.

5 Conclusions and the role of HEIs

The overall picture for A-level Mathematics and Further Mathematics is extremely positive. Promotion of post-16 mathematics is a key driver in current government policy and there is evidence of a strong and sustained candidate base for these qualifications. It is essential in the current period of curriculum reform to maintain and build upon the successes of the last ten years in relation to increasing participation in mathematics post-16. Higher Education Institutions should play a key role in maintaining the current momentum.

In a 2010 review of qualifications, Sir Richard Sykes stated:

> All higher and further education institutions should publish clear and specific information on the qualifications they accept and prefer [12],

and that Universities should work together to make their requirements transparent and accessible for 15 and 16 year olds, to inform their A-level choices.

Hillman agrees, advising that there should be:

> clear signalling to the pre-university sector about the nature and extent of mathematical and statistical knowledge and skills needed in undergraduate degree programmes… [including] recommending the benefits of continuing with mathematical/statistical study beyond the age of 16 [13].

Whilst being conscious of the need to ensure no negative impact on degree course recruitment, universities might adopt carefully and appropriately worded admissions criteria (see www.furthermaths.org.uk/encouraging-maths), which emphasise the utility of mathematics within the degree course and provide a clear and precise position statement to reliably inform student choice. Against a background of increasing participation in mathematics post-16, such statements might feasibly be used to differentiate between candidates or to indicate the importance of sound mathematical skills in accessing the degree course content.

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References

1 Coe, R., Searle, J., Barmby, P., Jones, K. and Higgins, S. (2008) *Relative Difficulty of Examinations in Different Subjects*, www.cem.org/attachments/SCORE2008report.pdf (accessed 03/09/2014).

2 Smith, M. (2013) *Independent Chair's Report on the Review of Current GCE Specification Content Within Subject Criteria: A Report to Ofqual*, http://tinyurl.com/SmithOfqual (accessed 03/09/2014).

3 Porkess, R. (2007), More mathematically competent undergraduates, *MSOR Connections*, vol. 7, no. 4.

4 Joint Council for Qualifications (2014), *GCE Trends 2014*, www.jcq.org.uk/media-centre/news-releases/gce-trends-2014 (accessed 03/09/2014).

5 Lee, S. and Lord, K. (2012), *Student progression to STEM degrees – who has studied A-level Further Mathematics?* Proceedings of the Higher Education Academy STEM Conference, Birmingham, UK. http://journals.heacademy.ac.uk/doi/pdf/10.11120/stem.hea.2013.0016 (accessed 03/09/2014).

6 Further Mathematics Support Programme (2013), *Further Mathematics Briefing for Higher Education*, www.furthermaths.org.uk/docs/Further_maths_briefing_HE_Oct13.pdf (accessed 03/09/2014).

7 Hodgen, J., Pepper, D., Sturman, L. and Ruddock, G. (Nuffield Foundation 2010), *Is the UK an Outlier? An International Comparison of Upper Secondary Mathematics Education*, http://tinyurl.com/UKOutlier (accessed 03/09/2014).

8 Vorderman, C., Porkess, R., Budd, C., Dunne, R. and Rahman-Hart, P. (2011), *A World Class Mathematics Education for All Our Young People*, http://issuu.com/conservatives/docs/vorderman_maths_report (accessed 03/09/2014), p. 9.

9 Truss, E. (2014), *Elizabeth Truss on support for maths and science teaching*, http://tinyurl.com/Truss2014 (accessed 03/09/2014).

10 Department for Education (2014), *A-level and other level 3 results: academic year 2012 to 2013* (revised) http://tinyurl.com/Level-3Results (accessed 03/09/2014).

11 Hodgson, J., McAlinden, M. and Tomei, A. (2014), *Mathematical transitions: a report on the mathematical and statistical needs of students undertaking undergraduate studies in various disciplines*, http://tinyurl.com/Hodgson2014 (accessed 03/09/2014).

12 Sykes, R. (2010) *The Sir Richard Sykes Review*, http://tinyurl.com/SykesReview (accessed 02/07/2014), p. 18.

13 Hillman, J. (Nuffield Foundation 2014), *Mathematics after 16: the state of play, challenges and ways ahead*, http://tinyurl.com/Hillman2014 (accessed 03/09/2014).