The maths A-level curriculum from a university viewpoint

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It is proposed that the purpose of mathematics at A-level is to lay down a mathematical foundation for quantitative degree courses. From this viewpoint the consequence for universities of the present modest numbers of students taking maths at A-level is described and options for increasing these numbers are considered. Also from this viewpoint, the ACME and QCA proposals for reforming maths A-level curricula are reviewed. Adoption of a Free Standing Maths Qualification in statistics as an entry qualification for quantitative degree courses unable to demand A-level is identified as a priority.

Keywords: Mathematics; Curriculum; A-level; Free Standing Maths Qualification; Quantitative courses; Student numbers.

Introduction

The author's background is an academic career in physics, electronics, computer science and higher education management- all "quantitative" fields in which some knowledge of maths is essential. The first three are "STEM" (science, technology, engineering and maths) subjects, the last one- management- together with accountancy, architecture, business, economics, finance, medicine, and doubtless others form a second subject group whose mathematical underpinning is also important. These quantitative subjects have university courses devoted to them, aiming to prepare their graduates for careers in what may be termed the quantitative professions. The inclusion of this second non-STEM group is emphasised because of a perceived danger that the context for discussions of maths A-level is sometimes, doubtless unintentionally, restricted to the needs of the STEM group of subjects.

It seems very likely that the great majority of students with maths A-level progress to a degree course in a quantitative subject (or else directly to training for a quantitative profession such as accountancy). Surprisingly the data to quantify this assumption is not available.

The origin of this paper is reflection on information acquired in a series of interviews and discussions held by the author during the academic year 2008-09 with admissions tutors and course directors of quantitative courses in a number of universities of differing types and also with their heads of department and other concerned academics. Collectively these interviews/discussions amount to a small informal survey across the quantitative courses in universities of different kinds (high prestige research intensive, middle ranking with emphasis on preparation for professional careers, former polytechnic with a strong engineering and technology tradition).

University viewpoint

Does it make sense to speak of a university viewpoint on the A-level maths curriculum? Surely it does. The views of individual course directors, heads of department and academics generally, modulate this viewpoint according to their subject, the prestige of their university, and whatever rationalisation of courses their university is currently undertaking, nevertheless a general university viewpoint remains evident. In summary this viewpoint is that *the purpose of maths A-level is, or ought to be, to lay down a mathematical foundation for quantitative degree courses*.

Numbers taking mathematics A-levels

It is generally accepted that 80,000 students took A-level maths in the 1980s, that this number fell of a cliff as a consequence of the Curriculum 2000 changes (Smith 2004), and has been recovering since then at about 7-8% per annum, so that last year the number was 56,000 (STEM 2008) and this year it is 60,000 (Thomas 2009). The government target, announced by the Prime Minister, is to get back to 80,000 by 2014. The number matters because the number of university places on quantitative courses- the total of STEM plus non-STEM- far exceeds even 80,000 and many of these courses are accepting GCSE maths by default.

What factors determine the number taking A-level maths is open to speculation. What is certain is that students *choose* their A-levels. While far more students stay on at school now, after GCSE, than in the 1980s, and far more go on to university, they have more subjects to choose from- maths has to *compete.*

It seems the majority of secondary students have *strong negative perceptions of mathematics: "I'd rather die"* (Brown et al. 2008)) and these have to be overcome if maths A-level numbers are to keep growing. The author proposes there are only three levers that might be pulled:

1. Bribe students to take maths
2. Make the A-level curriculum more obviously interesting and relevant
3. Tackle the problem earlier by radically reforming GCSE.

Crudely, the first option could involve payments of cash rewards for maths success, but more indirectly, if more students were made aware of the lifetime rewards of having a maths A-level they might take the bait. The second option is explored further in this paper. The third option is more long term and the author's own proposal- teaching maths in the context of *reasoning* which itself should be a main GCSE subject is way beyond the scope of this paper.

Effects of maths A-level numbers on university courses

Over the past decade maths A-level numbers, that is to say the supply of students mathematically qualified to enter quantitative courses, have been both historically low and unreliable. The consequences have varied according to both the prestige of the university and the subject of the degree course.

Generally, the most prestigious universities have not been too much affected- that is to say they have generally been able to fill their courses with qualified students, although even at this level there have been difficulties.

Further down the pecking order- in the middle and lower tier universities- the consequences have been much more serious. Most obviously, many STEM courses have been judged non-viable by their institution and have been closed. (A rapid scan across universities offering STEM courses suggests there may now be as few as 60 of these.) Less obviously many STEM courses have adapted their teaching and, inevitably, their degree content, to an intake without A-level maths. (The author is personally familiar with the limitations imposed on computer science course content when students have only GCSE maths.)

Lowering maths entry standards to keep a course running was a natural response of course directors and heads of department following the Curriculum 2000 debacle. But there seems to be a ratchet effect- entry standards lowered in times of shortage are hard to raise again when supply improves- for example, some chemistry courses have not reverted to requiring maths. One reason is student preferences are changing and top-tier universities are finding many of the best mathematicians, who might formerly have been expected to enter STEM courses, are crowding into their actuarial, economics, and finance courses (one example is the university with 3,000 applicants, all predicted to get an A, for the 200 places on its economics course).

Below the top tier, the considerable expansion of non-STEM quantitative course provision has generally been achieved by requiring no more than GCSE maths for entry. These students will mostly have done no maths since their GCSE exams- at least 2.5 years previously. A typical university response is to devote 25% of the first undergraduate year to level 3 maths- similar to the amount of time that study for an AS level at school would occupy. Requiring an AS level for entry would seem more rational- but unfortunately there would not be anything like enough applicants to fill the courses.

Institutional rationalisation of courses, which the author believes is occurring across the HE sector, is another factor affecting numbers, but in a very different way. One driver for this is “prestige ranking” fuelled by league tables compiled, for example, by The Times newspaper. The entry grades for institutions’ courses have come to be regarded as a quality measure for universities and so Vice Chancellors may well feel pressured to maximise these. If an institution decides to maximise UCAS points for entry right across its courses, then the consequence would be closure of some quantitative courses requiring maths A-level. Then, while maths A-level numbers were rising, the number of course places requiring this qualification would be falling. This would be a disastrous situation.

ACME and QCA proposals for reform of the mathematics A-level curriculum with effect from 2012

The proposals in detail as well as the timescale rationale are described on the ACME and ACA websites (ACME 2009), (QCA 2009). The two sets of proposals are pretty consistent. They cover not just A-level Maths (AS and A2) but also Further Maths, A-level Use of Maths, and Free Standing Maths Qualifications (FSMQs).

The main structural changes proposed for Maths are (a) reduction from 6 modules to 4 for both AS and A2- bringing maths into line with most other subjects, (b) elimination of options (c) inclusion of about 40% applied material (both ACME and QCA propose the applied shall consist of Mechanics and Statistics, while QCA proposes also that Decision Mathematics be included in the applied). Further Maths would continue to comprise 6 modules at both parts and include options.

Details of proposed content for the pure maths at AS level are published by QCA. The proposals emphasise the importance of coherent treatment of the subject. Responses to both sets of proposals have been sought over the internet. The questionnaires seem to imply that most respondents will be teachers of some kind. Maybe this is appropriate since what teachers feel able to deliver is a constraint on reform.

ACME and QCA proposals seen from a university viewpoint

The comments which follow relate, in order, to the points in the preceding section and, of course, assume that the primary role of level 3 maths is to lay a mathematical foundation for university courses in the quantitative subjects.

(a) Reduction, from 6 modules to 4, in line with most other subjects, should contribute to making A-level Maths more attractive, which is surely a good thing.

(b) Elimination of options would be welcomed by universities since their intake cohorts would then have a more homogenous maths experience in contrast with the current situation where the mathematical background is heterogeneous and typically requires a first year remedial class to bring the cohort together mathematically.

(c) The applied proposals are more contentious. While there is a good case for including statistics- all professions need an understanding of statistics- mechanics and decision mathematics are not so relevant across the range of quantitative subjects, in fact they are only directly relevant to a minority of quantitative subjects (civil and mechanical engineering, physics, and maths itself for the former). Students will be aware of this and these inclusions will appear to the majority as unnecessary hurdles and so will certainly not help to make maths more attractive to more students. The opinion of the author is that neither mechanics nor decision mathematics (which in any case seems like a token offering to up-to-dateness) can be justified as compulsory components of Maths A-level. However, mechanics has been part of A-level Maths for so long, and is part of the peculiarly British tradition of including theoretical physics within mathematics, that consensus in favour of dropping it is very unlikely.

Further maths allows universities to identify the minority of students with strong mathematical ability and perhaps having a range of options allows teachers to play to their own strengths. The case for retaining 6 modules for Further Maths is less convincing.

Perhaps elimination of options should be interpreted more widely. A-level Uses of Maths is an alternative to Maths and considered by some to give students a better maths education, perhaps because of the way it is assessed. The author is not competent to pass judgement. But the case for eliminating options (above) seems to imply that Maths and Uses of Maths should be merged in such a way as to retain the strengths of each.

As to coherence- the A-level Maths curriculum is mediated through a high stakes, high-volume, low-cost examination process. It is hard to maintain coherence through such a process and the exams are effectively the curriculum. A common university view is that the exam process should take a large portion of the blame for students' poor mathematical knowledge.

Quantitative courses admitting students without A-level maths

This is the elephant in the room. The author has not been able to quantify the problem but it seems clear that the majority of students admitted to quantitative degree courses have no maths beyond GCSE. These courses are in both non-STEM subjects like Business and Management and also in STEM subjects including Computing and Electronics. The problem is severe in middle tier universities and the former polytechnics, but top tier universities are not immune. How relevant to this situation are the proposed level-3 maths reforms?

The large numbers of students flocking into quantitative courses with only GCSE maths, and that taken 2.5 years previously, are not adequately prepared mathematically for the study of their chosen subjects. Their universities can respond in only two ways- remedial level-3 maths in the first year of the degree and some compromise of degree course content.

This is clearly a bad situation and one remedy would be for students to take an FSMQ appropriate to their chosen subject before going to university. This is less than ideal: it is not very much maths (60 hours of guided study), but it would at least keep mathematical work going. FSMQs are specialised, and the generic case across all quantitative courses for statistics has already been made. Alternative FSMQs are less desirable than statistics since they imply an early choice of degree subject and are contrary to the principle that decisions about specialisation should be delayed as long as possible (in the author's view the British education system is rightly criticised for too early specialisation).

From the university side the situation is difficult. Admissions tutors would like a post-GCSE maths qualification as an entry condition, and would particularly like to require that the qualification be common across the cohort, but they are under pressure to fill their places with students with maximum UCAS scores and this tends to have the highest priority.

It seems to be a chicken and egg situation- if FSMQs were being taken in large numbers then admissions tutors would demand them and students would take them in large numbers, but if FSMQs are only taken in small numbers then they cannot be demanded and so the incentive for more students to take them is small. A single FSMQ is not much maths, but it would be a great improvement on doing no maths work for two years.

A more distant target would be to require FSMQ statistics at A2 as well as at AS-level for entry. But for now, demanding FSMQ statistics at level AS as a minimum condition for entry to quantitative courses, will be tough enough. This is an important goal- it needs to be a good course!

Data collection

It will be helpful to those concerned with keeping track of developments if annual numbers of students gaining AS level and full A-level maths continue to be recorded and are made public. The same applies to FSMQs. It is also desirable that numbers of places and their take-up for quantitative university courses- distinguishing those requiring full A-level from AS level and from GCSE maths- and any requiring FSMQs should be recorded annually and made public. This data should be obtainable from UCAS.

Conclusions

1. In both the national interest and the interests of individual students, maths must become more attractive to more students. In the short term, making students aware of the lifetime return on maths A-level would help. In the longer term radical action is needed throughout secondary education to tackle negative perceptions of maths.

2. The primary purpose of A-level maths is to provide a mathematical foundation for quantitative degree courses. The implications of this viewpoint are-

(a) A single maths A-level should be created by merging Maths with those aspects of Uses of Maths which are believed to develop deeper knowledge of the subject. This maths A-level would not include options or applied maths- except for statistics. Options, including applied options, would be contained within Further Maths.

(b) A concerted effort to develop FSMQ Statistics as a recognised entry qualification for those quantitative courses at present accepting students with GCSE maths is a highly desirable step.

3. It is possible that there will soon not be enough places on quantitative degree courses requiring A-level maths for the increasing numbers of students gaining maths A-level. This would be very disheartening and HEFCE should be alerted.

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