Post-16 maths and university courses: numbers and subject interpretation

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The low take-up of mathematics post-16 and consequences for the traditional STEM (science, technology, engineering, and maths) subjects in higher education are well known. The effect on the newer IT-based subjects, like computing and communications engineering, and the commerce-based subjects, like business and management, economics, and finance is less widely recognised but is at least an equal cause for concern. Most university courses in these subjects are populated with students with no maths beyond GCSE, despite the evident need for better mathematical foundations-perhaps a year of post-16 maths. The scale of this effect and the consequences for these subjects in many university courses are described along with potential implications for the AS-level curriculum.

Introduction: quantitative subjects, courses and professions

My experience during a lifetime in HE doing teaching and research in physics, then in electronics, and then in computer science, and then working in academic management has led me to identify a collection of subjects where students need at least one year of post-16 maths. I call these the quantitative subjects but this does not imply mere familiarity with numerical ways of working: it is intended to mean some degree of general mathematical competence is required. Quantitative courses teach the various quantitative subjects and these courses tend to be gateways to various quantitative professions. In fact the route comprising post-16 maths, then quantitative course and then quantitative profession is so well trodden as to imply that setting students on this path is the main role of post-16 maths. However, many students without post-16 maths also progress to quantitative courses and thence to the quantitative professions.

Quantitative subject groups

The quantitative subjects are separable into groups, as follows:
A. Traditional STEM: Mainly physics based (plus maths of course), includes-
Maths, Stats, Phys, AerEng, CivEng, MechEng, ElecEng, and also Chem, ChemEng;
B. Post-IT revolution: Computer Science and Electronics-Optics technology based, includes-
CS, InfSc, AI, Electronics, Communications Technology;
C. Commerce based: include Economics and Actuarial Sciences (relatively traditional subjects) and others (whose development is heavily indebted to IT) including Accountancy, Finance, Bus&Mgt,
D. Bio-Tec based: Biology in combination with subjects from the other groups, includes-
BioChem, BioEng, BioInf;
M. Miscellaneous: includes Architecture and Medicine.

The allocation of subjects to these groups is not absolutely clear-cut. Thus, there are subjects, besides those in group D, that cross group boundaries. But the above separation into groups, which also corresponds roughly to the temporal sequence A, then B, then C, and then D in which subject groups have developed, albeit with considerable time overlap, is proving helpful when considering the mathematical needs of the various quantitative subjects. However group D is at an early stage of development and so its needs are not discussed.

UCAS data on admissions to quantitative courses

My appreciation of maths requirements for quantitative courses, derived from my own experience and observations and discussions with colleagues, has been greatly extended and quantified by studying the data published by UCAS (UCAS, 2009). In this paper I use 2008 data for national student numbers accepted onto HE courses, and maths requirements for admission in 2010, across a sample of universities, across subject groups A, B, C. The chosen sample universities are ones where I have had some form of inside knowledge and are approximately one per decile of university ranking, where the ranking is according to average UCAS points score as given in The Times Good University Guide for 2010 (The Times, 2009).

The UCAS data, while immensely helpful, is not published in precisely the categories needed for my purpose- for example electronics and electrical engineering courses are lumped together. Also, the courses data is complicated by the existence of combined subject courses. Where these combinations fall within my groups, for example Economics & Management, the overall picture remains clear but where they cross groups, for example Maths & Management, they blur the picture somewhat.

Organisation and presentation of the data

So as to give as clear picture as possible of the maths knowledge universities are requiring for their quantitative courses and how this varies according to university ranking and subject group I have summarised and transcribed the published data. (See Table 1 below).

Table 1 Maths qualifications for entry to Quantitative Subject HE courses**

		Math	Phys	CivE	MecE	Aero	E&E	Chem	ChE	CompS	Econ	Bus	Mgt	Fin	Accy
Group A:		**Math**	**Phys**	**CivE**	**MecE**	**Aero**	**E&E**	**Chem**	**ChE**						
	UCAS code	*G1*	*F3*	*H2*	*H3*	*H4*	*H6*	*F1*	*H8*						
Group B:										**CompS**					
	UCAS code									G4					
Group C:											**Econ**	**Bus**	**Mgt**	**Fin**	**Accy**
	UCAS code										*L1*	*N1*	*N2*	*N3*	*N4*
*Score**	*University*														
452	**UCL**	A*AFM	(A)	(A)	(B)	-	(B)	GCSE	(B)	A	A*	-	-	-	-
412	**Manch**	A	C	C	C	C	C	GCSE	C	B	GCSE	GCSE	GCSEB	GCSE	GCSE
407	**Soton**	A	A	?	C	C	C	GCSEA	-	B	C	-	GCSEB	-	-
378	**Sussx**	A	C	-	C	-	C	GCSEB	-	GCSE	B	-	-	GCSEB	-
346	**QML**	B	B	-	C	C	C	-	-	GCSE	C	.GCSE.		-	-
316	**City**	B	-	C	B	B	B	-	-	GCSE	GCSEB	GCSEA	GCSEA	GCSEA	-
278	**Br'ton**	C	-	C	C	C	C	-	-	GCSE	-	-	GCSE	.GCSE.	
265	**Hudd**	-	-	-	C	-	C	.GCSE.		GCSE	-	GCSE	-	-	GCSE
236	**K'ston**	C	-	GCSE	C	C	-	GCSE	-	GCSE	GCSE	GCSE	GCSE	-	GCSEB
194	**Middx**	-	-	-	-	-	-	-	-	?	-	?	?	?	-
179	**LSBU**	-	-	GCSE	GCSE	-	GCSE	GCSE	-	GCSE	-	GCSE	GCSE	-	GCSE
National numbers (thousands)															
Subjects		6.4	3.3	4.6	5.6	???	4.8	4.0	1.7	19.8	6.9	11.7	12.5	1.5	6.4
	Totals			**Group A = 29.4K**						**Group B = 19.8K**		**Group C = 39.0K**			

** The data in this table has been transcribed from the UCAS Website by the author who is responsible for any errors.
* The UCAS points score given for each university is the average across all its undergraduate courses- not just those for quantitative courses.
UCAS points are Full A-level Grade A= 120, B= 100, etc and AS-level Grade A= 60 etc.

For clarity the Table is divided into three parts- one for each subject group (A), (B) and (C). The columns divide subject groups into subjects and there is a row for each university in the sample. Table entries are the corresponding maths knowledge level required for entry. The Table is the most recent snapshot.

Student numbers by subject

For most subjects the picture is confused by the many distinct codes for subject variations and course modes. It is apparent that lower ranking universities offer more combined subject courses, for example Maths with Stats and OR, occasionally to the exclusion of a core course, and also subject combinations which cross my subject groups. In my opinion these are generally marketing devices to attract better qualified students. Student numbers given for each subject are summed across all the variations (which may give rise to some double counting).

Maths entry requirements

For clarity, so far as possible, I have focussed on the core code for each subject- single subject, three year full-time course. The requirements shown are minimum entry requirements.

"-" means the subject is not offered.

"?" means a minimum maths knowledge for entry is not specified.

Where a subject is only offered in combination with an adjoining subject in the Table the requirement is shown straddling the two subjects, thus ".GCSE."

For clarity the only maths requirements shown are GCSE and A-level. (Equivalent IB, Scottish Higher, etc, are not mentioned.)

GCSE maths grades: GCSE means Pass at gradeC, higher grades are shown explicitly.

AS-level maths: not present in the Table- presumably because the majority of students go on to full A-level so it is not used as an entry condition.

Full A-level maths: the required grade eg "B" is shown.

Commentary on the Table content

Subject group (B)

The table shows only CS courses in this group. This is a consequence of the way university courses are presented and UCAS data is collated: specifically courses in Electrical Engineering and Electronics are lumped together, and courses focussing on communications are also recorded there or else under CS, rather than as a separate subject. These (CS, Electronics, and Communications) are subjects where the author has first hand teaching experience and is aware that the mathematics needs differ from Electrical Engineering.

Correlation with university rank

Subjects offered. Chemistry and Physics tend to be offered only by high ranking universities and these tend not to offer Business.

Maths needed for particular subjects. Some variation of maths grade is to be expected, but where the same subject, eg Economics or Computer Science, requires A-level grade A at a high ranking university and GCSE grade C at lower ranking universities, then it is remarkable.

Student numbers in the subject groups

The numbers of students in each of the three subject groups are comparable. *The combined numbers in the newer groups (B) and (C) are double the number in the traditional STEM group (A) and this is justification for emphasising the hitherto neglected maths needs of these groups.*

Low maths requirements turn quantitative subjects into qualitative ones

The inevitable consequence of having a low maths hurdle for entry, observed at first hand by the author, is that subjects which are essentially quantitative have to be interpreted qualitatively. (The alternative for universities would be to close most of their groups B and C courses!) This in turn means the quantitative professions are fed graduates who are inappropriately prepared. In the opinion of the author this fact implies a significant downgrading effect on the national skills-base.

Mathematical needs of the quantitative subject groups

The government sponsored STEM initiative (STEM, 2007) has drawn attention to the national importance of the traditional STEM subjects (group A) and the (full) A-level curriculum seems to be associated with the maths needs of this group. In this paper I am more concerned with the maths needs of the newer quantitative subjects, groups B and C, where most of the quantitative student numbers are to be found and where most courses are only viable because they are filled with students without post-16 maths knowledge.

The table shows that in quantitative subject groups B and C most of the students are on courses that require no more than GCSE grade C maths. From direct experience of teaching group B courses and discussion with colleagues who teach group C courses it is clear that these students need 1 year of post-16 maths to engage effectively with their subject. (This contrasts with the group A courses which generally require 2 years of post-16 maths.)

Remedial/foundational maths classes during the first year of the university course are not very successful. This can be attributed to two factors: (a) the students had their last (GCSE) maths class more than two years previously, so any mathematical knowledge and thinking habits they may have acquired are very rusty, (b) these students typically disliked maths at school and resent being given a dose of it at university when they really want to be getting on with learning their major (which no-one told them is a quantitative subject!)

The remedial/foundational maths typically occupies about 25% of the first year of the university course. 25% of one year is about the time that would be allocated to an AS level at school. But it is noticeable that the maths being taught is rather different from the A-level curriculum. It s also noticeable that the maths taught in group B courses is different from the group C maths.

The following two questions emerge. *(a) Can an AS-level maths curriculum be devised that meets the one-year of post-16 maths requirements of groups B and C and also the first year of the two-year maths requirement of group A? (b) Can this AS-level, somehow become a requirement for entry to quantitative courses?*

The bigger picture

The information in the Table is a snapshot taken during a particular year. But quite big changes in quantitative subjects are occurring over time: there seems to be a pattern whereby new subject groups develop and demand for courses in older ones declines relatively. The timescale for significant change seems to be about a decade.

Thus, Traditional STEM subject have been haemorrhaging numbers since the 1970s evidenced, for example, by closure of Chemistry and Physics departments at City and more recently Chemistry at QML, as well as closure of many engineering departments. The students who might otherwise have populated these departments appear to have migrated over time in the direction left to right across the table: from group A to group B to group C. .

The first group B courses demanded A-level maths. But, as is well known, the number of student with post-16 maths has not increased in step with the general expansion of HE and hence much of the growth of group B and then group C numbers, except at the higher ranking universities, has depended on students with GCSE maths only, as the Table shows. From their inception most group C courses generally expected no more than GCSE maths from their students- presumably because the large cohorts of students wanting admission to these courses had no more maths to offer. If, as seems plausible, the currently emerging group D grows rapidly during the next decade- following the growth pattern of the earlier groups B and C- then presumably this will be at the expense of all three older groups and presumably, unless there are dramatic changes in take-up of post-16 maths, these courses too will mostly be populated with students having GCSE maths only.

Besides the development of new disciplines, which may be more attractive to students than established ones, there are other mechanisms governing the changes in quantitative subject provision. Universities are now conscious of being in a league table- ranked according to the average (across all courses) UCAS score of their undergraduate intake. Universities can optimise their scores by allocating students numbers to courses according to the UCAS points they can attract, leading to closure of some courses and departments. (Courses with small intakes have always been at risk of pruning, but the league table provides a spur and a metric.)

University departments then market their courses to attract students with maximum UCAS points- points scored becoming more significant than subjects studied- which can be rationalised by treating UCAS points as a measure of ability. This in turn implies a more foundational role for the first year of university courses.

In their turn secondary students will come to recognise this situation and since they are free to choose the subjects they study post-16 and, since they are likely to perform best in the subjects they enjoy most, this state of affairs seems purely benevolent. But what of mathematics, which is not generally well liked (Brown, 2008) and maybe harder (Smith, 2004) than most subjects? The above scenario suggests fewer students will study maths post-16- unless something changes so that more they find they like doing it!

Conclusion

The government sponsored STEM initiative has drawn attention to the number of students gaining full A-level maths and recent improvement in this number, emphasising its importance for the future of STEM subjects and the national skills-base. In this paper I have attempted to shift the spotlight towards the newer quantitative subjects (groups B and C) where the student numbers are greater than in traditional STEM (group A) - twice as many in fact- and where most courses are only viable because they are filled with students without post-16 maths knowledge.

Students acquire a dislike of maths at school and so generally don't study it post-16. Schools then pass the problem up to the universities to deal with. For their part universities fail to clarify the importance of post-16 maths knowledge for studying quantitative subjects. Lack of mathematical preparation weakens the courses so that students enter the quantitative professions with only qualitative understanding of their subject. The problem would be eased if courses in these newer subjects required their intakes to have one year of post-16 maths

(AS level). But of course they won't be able to do this until large numbers of students choose to take AS level maths- which seems unlikely until it becomes a course requirement: chicken and egg!

Perhaps the way to improve take-up of AS-level maths is by devising an AS-level curriculum that meets the one-year of post-16 maths needs of groups B and C and can also serve as the first year of the two-year maths requirement of group A.

References

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