Towards universal participation in post-16 mathematics: lessons from high-performing countries

Appendix A

How do general and vocational pathways compare?

Many countries grapple with the challenge of providing upper secondary education pathways that are relevant to the differing needs of students while at the same time responding to the needs of future courses and employers (Noyes et al., 2011). The table below sets out briefly the general, vocational and combined general/vocational mathematics pathways available to upper secondary students in each country in our study. Not all countries adopt the general /vocational education model, although several are attempting to introduce vocational and applied options.

General and vocational upper secondary pathways			
	General	**Vocational**	**Combined**
England	General Certificate of Secondary Education (GCSE) mathematics. Functional Skills Adult Numeracy Qualifications Free-Standing Mathematics Qualification (FSMQ) – Use of Mathematics AS A Level route: 'free choice' of 3 or 4 subjects, AS/A2 options in mathematics and further mathematics. Key Skills (no longer available)	National Vocational Qualifications (NVQs);no mathematics is compulsory. Higher National Certificate (HNC); no mathematics is compulsory. Higher National Diploma (HND); no mathematics is compulsory. BTEC Awards, Certificates, and Diplomas; no stand-alone mathematics qualification but may contain mathematical elements.	Diploma (Levels 1-3) – includes Functional Skills and sector-related learning – only some Diplomas have a mathematical component. Apprenticeships

General and vocational upper secondary pathways			
	General	**Vocational**	**Combined**
Germany (R-P)	Abitur (A Level equivalent) – may include advanced mathematics.	In Germany all vocational courses/options are combined with general education.	Berufsfachschule: occupational and general education including mathematics in some Länder. Fachoberschule: technical and general education (including mathematics). Vocational qualifications • Zeugnis der Fachgebundenen • Hochschulreife • Fachhochschulreife
Hong Kong	Hong Kong Diploma of Secondary Education, mathematics compulsory, elective options in advanced mathematics.	Very few students take vocational qualifications, although these are available.	Applied options are included within general education.
New Zealand	National Certificate of Educational Achievement (NCEA) Levels 1-3; free choice of subjects to build up the credit requirement for each level; achievement of basic (Level 1) mathematics compulsory; options in advanced mathematics with calculus and mathematics with statistics.	Very limited: vocational and technical education generally takes place at post-secondary level as a career/vocational degree.	
Scotland	Core Skills Numeracy Units/Lifeskills mathematics. Standard Grade / National 3/4/5 from 2013 (GCSE equivalent) Mathematics. Highers / Advanced Highers (free choice generally of 5 or 6 subjects). Scottish Baccalaureate (not widely available).	Scottish Vocational Qualifications (Levels 1-5). Higher National Certificates Workplace Core Skill Units	Skills for Work

General and vocational upper secondary pathways			
	General	**Vocational**	**Combined**
Singapore	GCE Advanced Level ('A' Level) route (Higher 1 – Higher 3) but must offer a contrasting subject. International Baccalaureate (IB). National University of Singapore (NUS) High School Diploma.	3-year diploma courses (Polytechnics) may include mathematics. National ITE Certificate (ITE). Higher National ITE Certificate (ITE). 3-year diploma in visual and performing arts.	No combined programmes
USA (MA)	High School Diploma, includes basic mathematics and students may choose advanced courses in Pre-calculus and Advanced Quantitative Reasoning. Advanced Placement Program – additional college-level courses in calculus and statistics.	Very limited: vocational and technical education generally takes place at post-secondary level as a career/vocational degree.	

The options for England are particularly complex, due in part to policy initiatives aimed at increasing participation in upper secondary mathematics, such as the introduction of the AS Use of Mathematics pathway (Noyes et al., 2011). Not all options are available to all students, and choice in the pathways and qualifications offered is constrained by funding regulations, local factors and teacher availability. In practice this results in there being very little choice open to some students. Some qualifications, such as AS Use of Mathematics, have limited value in the eyes of some higher education providers and employers (Kounine et al., 2008), while others such as the Diploma have failed to attract sufficient numbers of students. Other factors may also influence student choice of pathway, such as prior attainment and socio-economic status, both in the general /vocational split (Conlon, 2002) and in options within the general track (Hutcheson et al., 2011). England is not unique in facing constraints to the courses offered. For example, some schools in New Zealand struggle to offer all subjects or courses due to the size of the cohort and the relatively sparse population in some areas (Hipkins & Vaughan, 2002).

The Royal Academy of Engineering's (2011) analysis of FE and Skill sector STEM data suggests that "some learners may be taking qualifications below the level they have already achieved whilst others are taking no mathematics or numeracy beyond 16" (p. 37). In addition, the number of qualifications fluctuates very significantly from year to year suggesting that this provision is particularly responsive to institutional factors other than student demand or need (e.g. funding, targets or league tables), which may exacerbate the problem.

New Zealand and Massachusetts have experimented with vocational options (such as the Youth Guarantee in New Zealand) and innovations within general education. Hong Kong has integrated applied options within its general mathematics programme. New Zealand provides a pathway – mathematics with statistics – that is focused on the application of mathematics, does not involve calculus, and is seen to be less abstract than more traditional qualifications while being relevant to students and respected by employers and higher education. It has attracted a critical mass of students and is widely available. Participation in the option of mathematics with calculus has fallen, but remains above participation levels in England.

In all countries, vocational education appears to have a lower status than general education pathways and there is evidence of an 'earnings penalty' for some vocational routes (Conlon, 2002, p. 28). However, Singapore and Germany do appear to have managed to make vocational education an attractive and respected option, albeit one with slightly lower status than the general route. On the other hand, it is clear from the vocational innovations currently being trialled in New Zealand and Massachusetts that it is difficult to design a wholly general education system that is appropriate for all students. It remains to be seen whether Hong Kong's provision of applied pathways can address the needs of all students.

Where advanced mathematics is offered, even in countries with successful vocational pathways like Germany, this tends to be through courses within general education taken alongside vocational education. German students in vocational education pathways who wish to progress to university must complete the same examination as those students following the solely general education pathway (the Abitur). In both England and Germany, there have been calls for stronger links between general and vocational mathematics courses with greater course flexibility (e.g. Brockmann et al., 2008; Wolf, 2011), and research has shown that embedding mathematics in vocational teaching may result in higher successful completion rates (Casey et al., 2006).

Do multiple pathways increase social stratification?

There is considerable evidence that educational attainment is socially stratified at all levels of education (Gorard et al., 2012; Nash, 2000), although most countries were unable to provide us with information on this issue. Studies examining stratification by gender and socio-economic status in upper secondary generally find that, although considerable stratification is evident, inequity does not increase at upper secondary (e.g. Sullivan et al., 2011). One study in Germany shows a small increase in stratification by socio-economic status as students progress into upper secondary (Schneider & Tieben, 2011).

In New Zealand, where data were available, there was no evidence to suggest that social stratification increased across the two mathematics pathways after prior attainment was accounted for. In higher education, students who had taken mathematics with statistics performed on a par with those who had taken mathematics with calculus (Engler, 2010). Similarly, in Scotland, there was no evidence to indicate that participation in advanced (Higher) mathematics varied with deprivation after overall prior attainment had been accounted for. Evidence from England indicates that the diversification of Key Stage 4 science qualifications at secondary since 2006 is associated with reduced inequity in stratification of participation by gender, although there is no change to inequities in stratification by socio-economic status (Homer et al., 2011).

Appendix B

The assessment of different qualifications

The table in appendix B shows the general mathematics qualifications available to students in upper secondary education and the assessment methods used. The assessments/qualifications tend to serve one of two broad functions: either they act as entrance examinations to university (such as the German Abitur) or they provide recognition of the completion of upper secondary education (such as the US High School Diploma) (Ofqual, 2012). The complexity in the available assessments in England has implications for students in terms of the higher education choices they make, and the potential to block options through taking the wrong pathway.

The level of teacher assessment does not appear to be strongly associated with participation levels. Some qualifications appear to maintain quality and respect while having a high degree of coursework or teacher assessment.

Post-16 qualifications and assessment methods in mathematics		
	General Education Qualification	**Assessment Methods**
England	GCSE	Written external examination set by examination boards and available at two levels: Higher and Intermediate. Other subjects at GCSE feature coursework, but mathematics does not.
	Use of Mathematics (FSMQs, AS and pilot A level)	Examinations (with pre-released data sheets) and coursework (at level 3).
	FSMQs (non Use of Mathematics)	Written examination
	GCE AS & A Level (common route)	Modular external written examinations set by examination boards. Other subjects at AS and A level feature coursework, but mathematics does not.
Scotland	Standard Grade	Unit assessments set and marked by teachers and external written examination.
	Highers / Advanced Highers	Unit assessments set and marked by teachers and external written examination.
	Scottish Baccalaureate	As above for Highers / Advanced Highers plus an interdisciplinary project (practical assignment).
Singapore	GCE A Level	Modular external written examinations set by examination boards.
	IB	Teacher-assessed moderated tasks and external written examinations.

Post-16 qualifications and assessment methods in mathematics		
	General Education Qualification	**Assessment Methods**
USA (MA)	High School Diploma	State dependent: may include coursework and standardised tests.
	Advanced Placement	Written examination: multiple choice and free response.

NOTE: this table refers to mathematics. Assessment may be different for other subjects.

Appendix C

How are teachers trained?

The table in appendix C outlines each country's approach to teacher training. In all countries, teaching is a graduate profession, although in New Zealand, this has only been a requirement since 2003, meaning that there are still some non-graduate teachers. Initial teacher education in England is complex. Many different university-based and school-based options are available and each offers differing levels of engagement with educational theory through higher education. In contrast, Singapore, albeit a much smaller country, has only one training provider and one route into teaching, which appears to result in greater consistency in trainees' experiences. The balance between higher education and the school-based practicum is also different with student teachers in Singapore spending more time in higher education.

Singapore and Germany are the only countries in the study that offer specialist training at the initial teacher training stage for teachers in the upper secondary years. Others, including England, offer general secondary mathematics training and teachers learn any specialist requirements for the upper secondary stage 'on the job' or through professional development programmes. Concern has been raised in England over the relatively high proportion of non-specialist mathematics teachers and those who have transferred from other subjects (Johnston-Wilder et al., 2003; Smith, 2004; Vorderman et al., 2011). Countries which offer and have slightly higher participation rates in vocational education also provide specialist training for vocational teaching, either as an initial teacher training course (in Germany and Singapore) or as a further diploma/certificate (in England and Scotland). However, there are potential differences in how general and vocational teachers are viewed, possibly reflecting the status of vocational education more broadly. Vocational training is a lower status course in Germany, and in England it has been suggested that further education teachers are considered low status in comparison to school teachers (Molyneux-Hodgson & Sutherland, 2002).

Professional development is very different across the countries, ranging from no compulsory programmes (as in England and Germany) to entitled professional development time (Scotland and Singapore), or a requirement to engage in professional development (Massachusetts). In England, it has been recommended that professional development should focus on upper secondary mathematics teachers both in schools and colleges (Wolf, 2011). While most countries demonstrate a concern with professional development, Singapore is notable in the high level of its expenditure here; teachers are entitled to 100 hours a year of professional development and there are also scholarship and study-leave opportunities to pursue Masters and PhD postgraduate qualifications. This reflects the high status given to teaching as a career in Singapore, with trainees drawn from the top third of the cohort. Singapore does not face any teacher shortage. This is also true of Scotland which is pushing teaching as a respected profession. In contrast, there are concerns in England and across the USA about teacher shortages – in particular reflected through teachers teaching out of subject – and inequalities, particularly for low attaining students and those of low SES in access to qualified mathematics teachers (Akiba et al., 2007).

How are teachers trained?			
	Training Routes	**Specialist Upper Secondary Teacher Training?**	**Specialist Vocational Teacher Training?**
England	University-based: Subject-focused secondary Postgraduate Certificate of Education (PGCE) – one year. Undergraduate Initial Teacher Training (three years, but not widely available for secondary mathematics). Subject knowledge enhancement courses available for non-subject specialists. School based: Four different routes: Graduate Teacher Programme, School-Centred Initial Teacher Training (SCITT), School Direct and Teach First.	No	Training not widely available. Diploma in Teaching in the Lifelong Learning Sector (DTLLS) – one year. Skills for Life teachers (i.e. Numeracy) have specialist subject qualifications in addition to DTLLS.
Germany (R-P)	University-based: training routes reflect different age-ranges and types of school.	Yes	Yes
Hong Kong	University- or Institute of Education-based: Five- year undergraduate programme (B.Ed) or one year Postgraduate Diploma of Education (PGDE).	No	
New Zealand	University-based: Undergraduate B.Ed / B.Teaching degree or postgraduate Diploma of Teaching (Secondary).	No	Not applicable
Scotland	University-based: Undergraduate B.Ed or Postgraduate Diploma of Education (PGDE).	No	School based teacher training, followed by a Teaching Qualification in Further Education (TQFE).
Singapore	One-year Postgraduate Diploma in Education (Secondary)	Yes	Institution-based
USA (MA)	Undergraduate, postgraduate and internship options available	No, but trainee teachers must pass a mathematics subject knowledge test	Not applicable