A Report for the Joint Mathematical Council of the United Kingdom

UK Mathematics 14-19: the Gender Jigsaw

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Summary

There is persistent evidence that the UK has an inadequate 'pipeline' to the mathematics needed for personal and societal thriving. Further, participation in that pipeline post-16 is significantly skewed towards males. The JMC has therefore commissioned a short report on participation and attainment in mathematics, age 14-19, including by gender, across the UK. The main findings are:

1. Mathematics education provision in each of the four UK jurisdictions is in a state of flux. Recent changes, and so impact on participation and attainment, have not yet stabilised, and the pandemic from 2020 has led to particular disruption to learning and assessment. Structures in England, Wales and Northern Ireland have much in common, but curricula and assessments have diverged since 2016, each with particular emphases and goals. Scotland's provision supports greater local autonomy of enactment, and often a wider curriculum to at least age 17.

2. Across the UK, girls enter Mathematics GCSE/N5 and additional mathematics qualifications in comparable numbers with boys at age 16, and they perform at least as well as boys in those qualifications. Approaches to assessment during the pandemic have resulted in the award of significantly enhanced grades, especially to girls. Each year, around 180,000 older students retake GCSE, especially in England, but the 'standard pass' rate remains low and the mathematical benefit is often of questionable mathematical benefit to either boys or girls.

3. Significant differential participation in favour of boys is evident in all significant advanced school mathematics qualifications in the UK except Core Maths, though it is less marked in Northern Ireland. Total advanced mathematics entries remaining fairly steady. It is not clear how plummeting AS entries in England have impacted the choices made by students.

4. Key issues in upper secondary UK education are therefore around provision for previously low-attaining students, gender bias within most advanced school mathematics pathways, and under-participation by previously moderate- or high-attaining students.

5. As with GCSE and N5 mathematics qualifications, the approaches used for assessment during the pandemic resulted in improved grades across advanced school mathematics qualifications, and especially so for girls. However, even before then, there is no systematic evidence of boys routinely outperforming girls at this level, except at the highest grades for Mathematics A Level in England. Neither is there clear evidence that any of the recent changes to mathematics curriculum and assessment have impacted (positively or negatively) on (girls' or boys') participation or attainment in advanced school mathematics.

6. All four UK nations have participated in recent PISA assessments of mathematical literacy. England and Wales show an improving trend across successive PISA cycles, while Scotland has declined and Northern Ireland has remained broadly stable. Boys have often, but not always, somewhat outperformed girls, but not to the extent they do across the OECD as a whole. Accompanying surveys of mathematics-related beliefs and experiences show marked

differences by gender, in ways known to be detrimental to girls' future participation, and these differential reports are remarkably persistent across time and UK country. Only England has participated in recent, mathematics curriculum-close, year 9 TIMSS assessments. There has been no significant difference in performance by gender in recent cycles, including, overall, in the recent 'PSI' (problem solving and inquiry) items though again, students' reported affect and experiences are differentially detrimental to girls' continuing participation.

7. International studies show gendered gaps in upper secondary mathematics participation are not inevitable, but they are widespread, and often related to comparatively poor mathematics-related affect or unhelpful stereotypes. Girls are more likely to value, and be influenced by, pedagogic approaches and supportive interactions that are with a range of others. Participation at this level is enhanced by ambitious, connection-making teaching which embraces appropriate challenge and supports students through that. There are also significant gendered issues at the tertiary level and in the workforce, including academia.

8. The evidence shows teaching mathematics for meaning-making and for connections, including to realistic uses of mathematics in across a wide range of contexts, supports the participation of all students, but especially girls. That teaching should also challenge, encourage, support and specifically affirm the mathematical identity and capabilities of all students. It should offer opportunity for working in a range of both collaborative and independent, discursive ways. Developing curricula and pedagogies should also build on gender-specific preferences and interests in harnessing digital tools for mathematical purposes. Other small-scale interventions should target the range of influences on young people's pathways decisions: their peers, their parents and other influential figures, extra-curricular activities, the resources they use and images and roles they encounter, to promote gender-inclusive messaging. Teachers might also consider single-sex activities on occasion.

9. Analysis of data shows post-16 participation in the UK at present remains disappointingly gender-biased, with significant, and likely increasing, implications for individual and for societal thriving. The evidence suggests broad pedagogical, and some smaller-scale, but important, principles that are promising but need to be communicated and enacted; a broader curriculum post-16, and incorporation of mixed, less traditional forms of assessment, also show potential.

Acknowledgements

Particular thanks are due to Julie Harris, Education and Training Inspectorate, Northern Ireland; Dominic Oakes, FMSP Wales; and Sue Pope, SQA, who provided country-specific information and comments for draft documents.

1. Introduction:

In 2011, the UK ACME said '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'. ACME's Mathematical Futures programme takes as a premise that those needs, as well as needs at a lower level, have since expanded considerably. Within the current participation levels, headline figures show girls continue to be significantly under-represented.

Differential participation in advanced mathematics in the UK by gender has remained stubbornly persistent in recent years. For example, girls still represent less than 40% of entry for A Level Mathematics (though up to 45% in Northern Ireland) and under 30% of entry for Further Mathematics A Level in England. The challenge appears similar in Wales or Northern Ireland. Males and females attain at roughly comparable levels at age 16 in these jurisdictions, and that is replicated in recent international studies such as PISA 2018 and TIMSS 2019, yet reported affective factors, as well as A Level and later participation in mathematical sciences, persistently favour boys. The structure of post-compulsory qualifications in Scotland is markedly different, and participation and attainment by gender is more complex. However, the much more gender-equitable participation being achieved for Level 3 Core Maths qualifications in England, even though at comparatively small scale, suggests the issue is not intractable. The issues are therefore around both scale of upper secondary participation in mathematics, and distribution by gender within that.

Partial explanations for gender-related challenges are thought to lie in personal strength profiles, in family, peer, teacher and wider encouragement and stereotypes, and in differential response to the same learning experiences (Noyes, 2009; Smith & Golding, 2018), with some productive approaches to the issue having been identified (e.g. Smith & Golding, 2018). Upper secondary gendered participation patterns evident in England, Wales and Northern Ireland, however, are replicated elsewhere (e.g. in Australia and New Zealand: Kirkham, Chapman & Wildy, 2020; Vale & Bartholomew, 2008), and indeed across much of the globe (World Bank, 2020). In contrast some eastern European and far eastern jurisdictions evidence more gender-equitable participation and progression into mathematics-intensive courses at university (World Bank, 2020), although at the most elevated levels of performance fewer than 10% of Mathematical Olympiad participants from 2000 on have been female.

Why does it matter? Relative, as well as absolute, participation and attainment matter because mathematics provides access to careers in the range of STEM and social science fields, and associated personal, economic and social benefits. Women are particularly underrepresented in jobs at the mathematics-intensive technical frontier: in the 20 leading economies, women workers account for 26 percent of workers in data and artificial intelligence, 15 percent of workers in engineering, and 12 percent of workers in cloud computing (WEF 2020). Such concerns underpin recent global focus on participation by gender (e.g. UNESCO 2017, World Bank 2020) but are experienced far from uniformly across the globe. Concerns are reflected in e.g. first year undergraduate numbers in England (Figure 1). However, it is becoming increasingly clear that there is a concern about 'pipelines' into not only the most mathematically demanding courses and

Figure 1: Numbers of first year undergraduates in England 2019-20

and careers, but across a much broader range of mathematical functioning, as mathematical demands increase across a wide spectrum of occupations as well as of personal thriving, especially with the proliferation of easily-accessible data.

Recent curriculum and assessment reforms for mathematics education across all jurisdictions in the UK have specified economic and personal thriving as key drivers. Further changes to assessment have been driven by the coronavirus pandemic in 2020-22, but there is little subject-specific analysis of impact of those changes on high-stakes performance and participation by gender. The aim of this report is to produce a comparative evidence synthesis based on publicly available longitudinal data from the four countries of the UK; to read between available data and then move beyond the data, contextualising them in the wider international and UK-specific evidence base.

The report outlines the policy background to the issue. It summarises recent relevant data by gender across the four home nations, and analyses patterns within those data, relating them to the wider evidence base. It locates that data within wider published global, then UK, evidence. Finally, it draws together some approaches thought to be productive in addressing related some of the issues.

Accounts of gender-related work are challenged by variability of definitions and categories in relation to sex and gender (e.g. Forgasz, 2021). However, in common with much of the research and literature (including UK national mathematics attainment and participation statistics and currently completed international PISA/TIMSS assessment data), this high-level report conflates male/female with girl/boy in a largely binary way, while also recognising that this has limitations.

Throughout, it should be remembered that in the UK, differential attainment and participation in mathematical and other qualifications by socioeconomic status, as well as for some ethnic and other groups, remains a significant issue for both personal and national thriving (e.g. Ofsted, 2014). Furthermore, and although Mathematics is the single most popular A Level subject, upper secondary participation in mathematics remains low compared with other developed countries (Hodgen et al., 2010). There are also complex intersectionality effects. Gender-related issues are therefore only one area of concern – and themselves bring a 'flipside': if girls are under-participating in mathematics in an era of near-universal UK participation in upper secondary education, there are also corresponding areas of relative under-participation by boys. Further, there is a heterogeneity of mathematics-related behaviours, attainment and affect within each gender: although the report evidences a range of overall differences, individual boys and girls show widely overlapping behaviours, attitudes and beliefs. (Note, also, that participation in standard qualification routes, including in Higher Education, is very different from, although related to, mathematical participation as an adult, whether in employment, as a citizen or as an individual: direct measurement of adult participation is fairly intractable.)

Finally, there are at least three key questions that are related to the focus of this report, for 14-19 year olds: What actions (in policy, pedagogy, wider society…) would enhance mathematical *equity* (or equality) of access, participation and attainment by gender? What actions would enhance the *scale* of mathematical participation? Or the *level* of mathematical functioning within and throughout the population? The answers to these three questions might not always be the same.

2. The policy background in the UK

The UK is relatively unusual in expecting most 16-year-olds to take high-stakes examinations: GCSEs in England, Northern Ireland and Wales, and typically, 'National 4/5' at age 15/16 in Scotland. For more academically-inclined students, these are often followed by 'Highers' and 'Advanced Highers' (and maybe further N4/5 qualifications) at ages 17-18 in Scotland, and 'A Levels' at age 18 elsewhere in the UK; in England, 'AS Levels' at age 17 are much less common than previously, following recent education policy changes. A relatively small number of upper secondary students, largely in independent schools, take International Baccalaureate Diplomas, which necessarily include some mathematics, but related participation and performance data are not easily accessible. There are many more students in England than in the Northern Ireland, Wales and Scotland systems catering for approximately 600 000, 20000, 25000 and 50000 students in each year. Data are sometimes difficult to separate, especially from England, Wales and NI. All four jurisdictions have experienced recent changes in curriculum and assessment:

England

England had a new National Curriculum from September 2014, offering a renewed emphasis on mathematical communication, reasoning and problem solving. First assessments for the new GCSE

Mathematics, at two tiers, were in Summer 2017. These involved a new grading scale of 9-1 rather than A*-G, with greater discrimination for strong performance, and all summative assessment at the end of the course. GCSE Mathematics is high stakes for schools because of its weighted role in performance measures. A 'standard or good pass' (grade 4 or 5) is often a 'gatekeeper' qualification for later courses or employment, and 'resitting GCSE Mathematics' after age 16 is widespread.

Students with low prior attainment can study for 'Entry level' or 'Functional Skills' qualifications, and GCSE Statistics and a level 2 'Additional Mathematics' qualification are also available, attracting relatively small entries. A small proportion of 16 year olds, almost all in independent schools, take IGCSEs. New mathematics A Levels (Mathematics, Further Mathematics) followed new GCSEs from September 2017, with first large-scale assessments in Summer 2019. Mathematics A Level has a similar renewed focus on proof and on problem solving, involves the study of both statistics and mechanics as well as pure mathematics, and requires the digitally-supported study of a large data set. The new A Levels reverted to all-examination end-of-course assessment with successful performance reported on an A*-E scale, rather than the modular assessment available previously; AS qualifications have been 'de-coupled' from A Levels (do not contribute to them). There is also a small scale (<1000 entries) Statistics A Level.

Since 2015, advanced mathematics provision in England has been broadened via six 'Core Maths' qualifications of the size and demand of an AS, but intended to be studied over two years. They are required to contain content which will:

1. Deepen competence in the selection and use of mathematical methods and techniques.
2. Develop confidence in representing and analysing authentic situations mathematically and in applying mathematics to address related questions and issues.
3. Build skills in mathematical reasoning and communication.

(https://qips.ucas.com/qip/core-maths-qualifications-count-towards-dfe-16-19-performance-tables-category).

Post-16 students also have access to a variety of advanced (and lower) 'BTEC' courses and will shortly be able to choose 'T Levels', but none of those has an explicitly mathematics focus.

GCSE, Core Maths and A Level qualifications are assessed via one of four Awarding Organisations (five for Core Maths). The DfE has in recent years made significant investment in the Advanced Mathematics Support Programme and its predecessor programmes, reflecting a concern for participation in advanced school mathematics and beyond.

Northern Ireland

The Northern Ireland Curriculum was launched in 2007 by Council for Curriculum, Examinations and Assessment (CCEA), with a particular emphasis on Numeracy to age 14. At 14-16 schools must offer at least one qualification in mathematics: nearly all schools use CCEA's GCSEs in Mathematics, Statistics, Further Mathematics. They may also use English and Welsh qualifications, at both GCSE and A Level. CCEA GCSEs are from 2019 graded A*-G, with A* aligning with a 9, and a C* additionally introduced to increase discrimination around critical threshold performance levels. GCSE Mathematics is offered at two tiers, each of which is unitised (two units, the second labelled a ‘completion test’, and some resitting permitted). It offers two routes in each tier, more or less aspirational within that tier, and is assessed by written papers. Rather than widespread resitting of GCSE Mathematics by students without a grade C+, learners often go on to complete essential skills through apprenticeship programmes, or similar. GCE A levels in Mathematics and Further Mathematics are also offered by CCEA, with assessment by written examination and successful outcomes reported on an A*-E scale. AS contributes 40% to A Level, and single resitting of units is available. A Level Mathematics consists of four units, the first two comprising AS Mathematics, with study of both mechanics and statistics required for both AS and A Levels. First assessment for each was in Summer 2019. Post-16, students may also retake GCSE mathematics, or add Further Mathematics GCSE.

Scotland

The Curriculum for Excellence was introduced from August 2010, with new qualifications introduced from 2013-2016. The 2010 Curriculum for Excellence (with new qualifications from 2013-2016) has a 2019 ‘Refreshed Narrative’ focusing on fuller enactment and promoting Maths-positivity. At 16, most students gain National 4s (internally assessed) or National 5s (externally). National 5 qualifications are available in Mathematics and Applications of Mathematics (to 2017, ‘Lifeskills Mathematics’), as well as in the cognate subjects of Accounting, Computing Science and Engineering Science. Learner journeys can later include Highers in Mathematics (pure mathematics only) and Applications of Mathematics (2022). The latter requires use of spreadsheets, and R for statistics, mathematical modelling and financial problem solving, as well as a statistics project alongside a terminal exam that needs access to digital technology. There are also Advanced Highers in Mathematics (pure mathematics only), Statistics and Mathematics of Mechanics, plus awards in Statistics and Data Science. Accounting, Computing Science and Engineering Science are also available at Higher and Advanced Higher levels. These qualifications and their assessment (from N5, by end of course examination) are overseen by SQA, and successful assessment reported on an A-C scale, with successful course completion A-D. The post-16 curriculum offered is typically broader than that in England, Northern Ireland and Wales: as well as including a wider range of subjects at least to S5, the penultimate year, students are able to access a wide range of other certifications alongside Highers/Advanced Highers, though they will typically take only up to 3 Advanced Highers. Related qualifications, of a variety of sizes and levels, have continued to develop in recent years.

Wales

The 2008 Skills Curriculum was supplemented by the 2012 National Literacy and Numeracy Framework, which as well as an emphasis on processes and communication, includes a focus on financial literacy. From 2016, there are two GCSEs, *Mathematics* and *Mathematics Numeracy*, with three tiers, each assessed by two written examinations, and performance reported on an A*-G scale. They were first taught from 2015, with revisions for teaching from 2017. At age 16, almost all students take GCSE Mathematics and about 80% take both; only WJEC GCSEs may be taken in state schools. The National/Advanced Welsh Baccalaureate requires C+ in either and includes an Individual Project involving numeracy. WJEC AS and A levels in Mathematics and Further Mathematics are permitted in state schools, with successful assessment reported on an A*-E scale, AS contributing 40% to A Level, and single resitting of units available. A Level/AS Mathematics have a similar structure and assessment to those in Northern Ireland; they require engagement with a large data set, though have no other obvious focus on the use of digital tools for mathematical purposes. The individual project of the post-16 Welsh Baccalaureate Advanced has a numeracy assessment component. Other initiatives have included provision of a Level 3 Certificate in Statistical Problem Solving using Software, and the Curriculum for Wales (CfW) from 2022 for ages 3-16 will demand cross-disciplinary planning.

2020-21 Context

Additionally, it is important to note that Summer 2020 and Summer 2021 GCSE, A Level, N4/5, Higher and Advanced Higher examinations were cancelled because of disruption to usual education due to the coronavirus pandemic, and alternative assessment arrangements put in place. None of the substitute systems has been totally satisfactory (as, indeed, use of externally-set written examinations only has its drawbacks), but over the two series a variety of teacher assessment and of school-internal assessment, of estimation of final performance had usual education been available and of evidenced performance on a reduced curriculum, were used. Such initial awards were usually subject to a national moderation process. Further detail is available from national Education department websites.

> 14-19 mathematics provision in each of the four UK jurisdictions is in a state of flux. Recent changes, and so their implications for participation and attainment, have not yet settled down, and the 2020-2022 pandemic has led to particular disruption to learning and assessment. Structures in England, Wales and Northern Ireland have much in common, but curricula and assessments have diverged since 2016, each with particular emphases and goals. Scotland's provision supports greater local autonomy of enactment, and often a wider curriculum to at least age 17.

The next two sections present an evidence base of participation and attainment data from the four countries of the UK, focused on certification cohorts from recent years (usually 2016 onwards). Section3 addresses participation and attainment at age ~16 (Scottish year groups do not align exactly), and #4 addresses participation and attainment in higher school mathematics, generally after the age of 16. They analyse patterns within England, Northern Ireland and Wales first, since there are broad similarities in the 14-19 education structures across those three jurisdictions, and then corresponding patterns in Scotland, where the education system, does not align quite so easily. They synthesise and represent this data to show patterns over time and, where appropriate, for between-country comparisons.

Where possible, they explore relationships between any changes. For example, is there evidence of whether changes in GCSE grading have impacted A level uptake? Have new level 3 qualifications altered choices between pathways? How do those answers differ by reported gender of the student? And of particular interest at this time, what is the early evidence of the impact of the pandemic on 14-19 year olds' participation and attainment in mathematics?

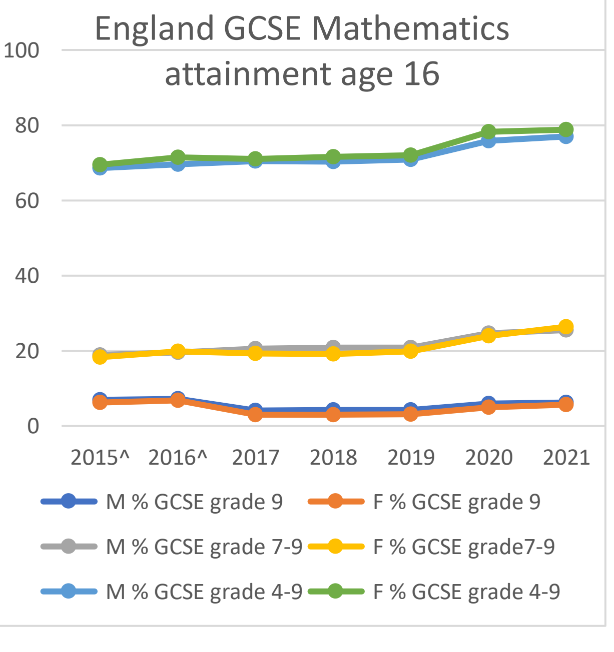
3. Mathematics participation and attainment at age 16 across the UK

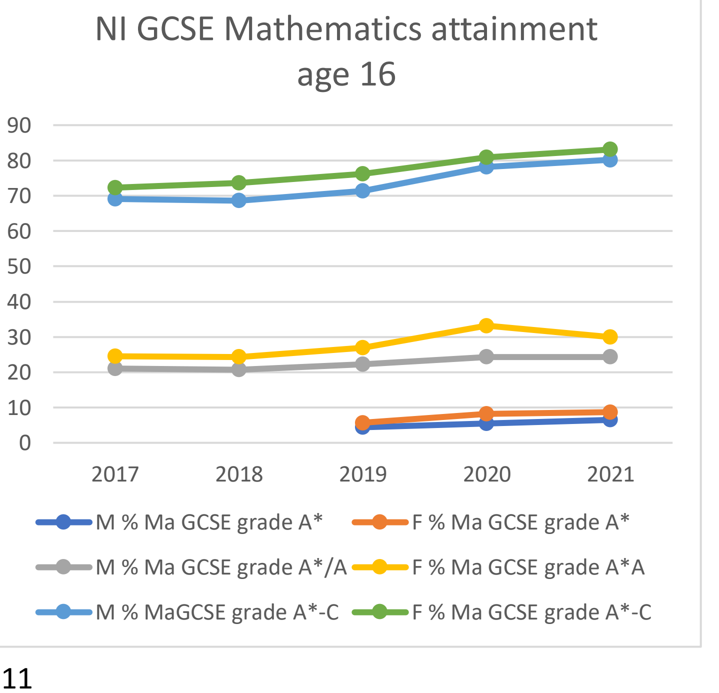
This section and the next draw on the publicly-available participation and performance data from Examination results - JCQ Joint Council for Qualifications for England, Northern Ireland and Wales, and from Statistics and information - SQA for Scotland, though the range of information available is not consistent year on year. Note also that it is not possible to discern from these data where students appear twice, e.g. for both Mathematics and Applications of Mathematics N5s in Scotland. It is usually the case that students taking Further Mathematics (GCSE or A Level) will also take Mathematics at that level, though not always in the same assessment session.

The graphs below show attainment at the top grade (A*/9) and strong performance (A/7+) since those are used both by students and centres as indicators for A Level participation, as well as 'standard pass' level of grade C/4+, often used as a threshold performance for later courses or employment. Prior to 2017, the GCSE systems in England, Northern Ireland and Wales were much more aligned, so for 2016 data are combined under England figures since England entries dominate numbers; for GCSE Mathematics across these jurisdictions, participation by gender was evenly split male/female.

3.1 England

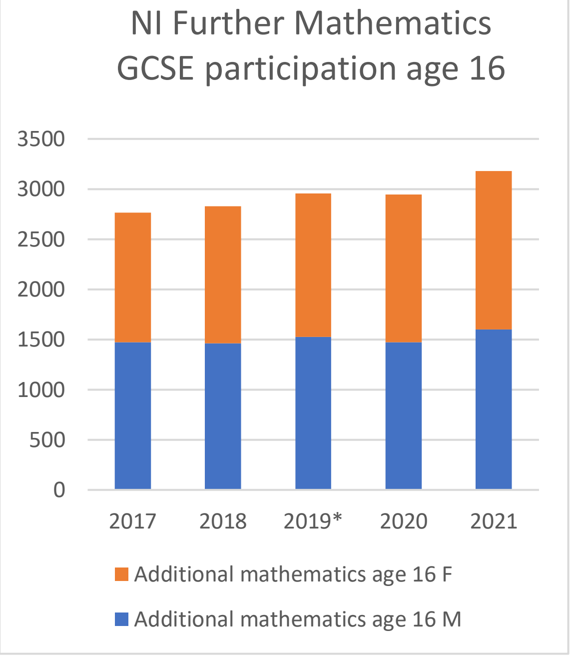
The vast majority of 16 year olds take GCSE Mathematics: about 300,000 of each in each student cohort of over 600,000. (Below, 2015 and 2016 figures are for the whole UK, since specifications had not diverged). One goal of the new grading system from 2017 was to increase the demand of the highest available grade, and that was clearly achieved. It will be seen that attainment rose significantly in 2020 and 2021 with 'centre-assessed' and 'teacher-assessed' grades, and girls benefited disproportionately from that, especially at the grade 4+ level. In general, though, performance by gender can be seen to be comparable, across grades.

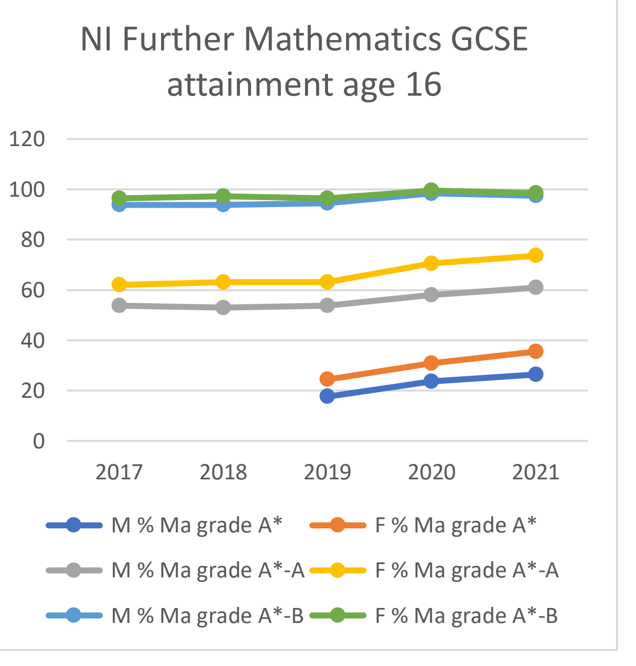




3.2 Northern Ireland

Each year, about 7000-8000 16-year olds of each gender in Northern Ireland, out of a total cohort of about 20,000, take GCSE Mathematics; again, attainment was higher in 2020 and in 2021, although these years are still relatively early for the new GCSEs, so performance levels are no yet established. At each of the grade levels analysed, and across years, girls performed somewhat more highly than boys. Around 3000 16-year-olds (~40% of those taking GCSE Mathematics) also take GCSE Further Mathematics, with gender-equal participation having been recently achieved:

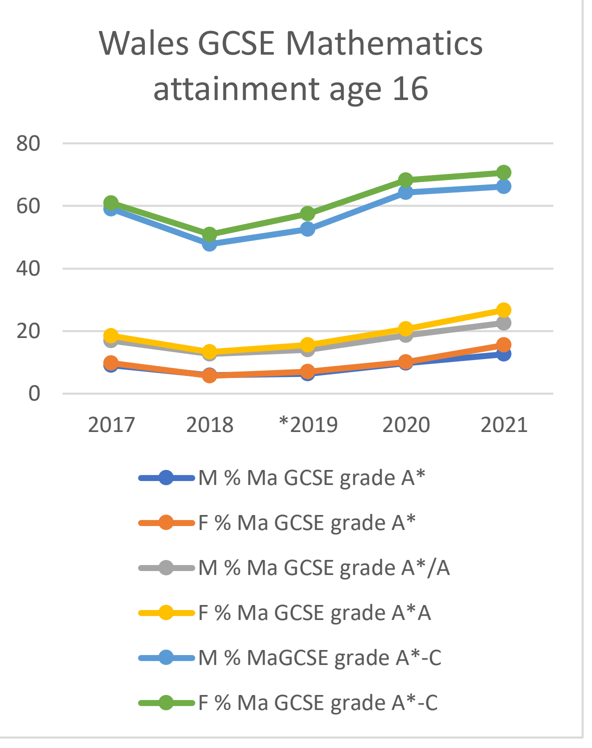


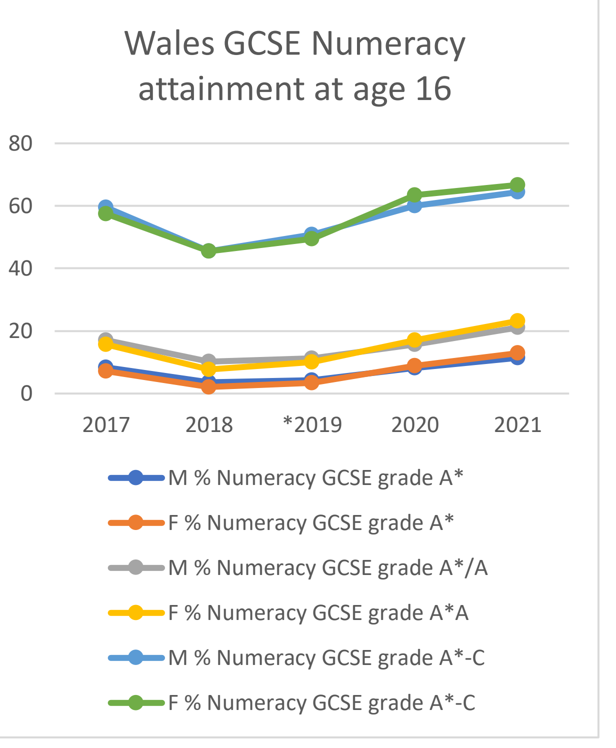


Further Mathematics GCSE is a qualification taken by those already attaining at a good level, so as with Further Mathematics at A Levels, grades awarded are relatively high. Girls also somewhat outperform boys at each grade level here. There has again been a marked improvement in grades awarded in the last two years, and especially so for girls performing at the higher levels.

3.3 Wales

Almost all Welsh students in each cohort take GCSE Mathematics (c. 25,000).



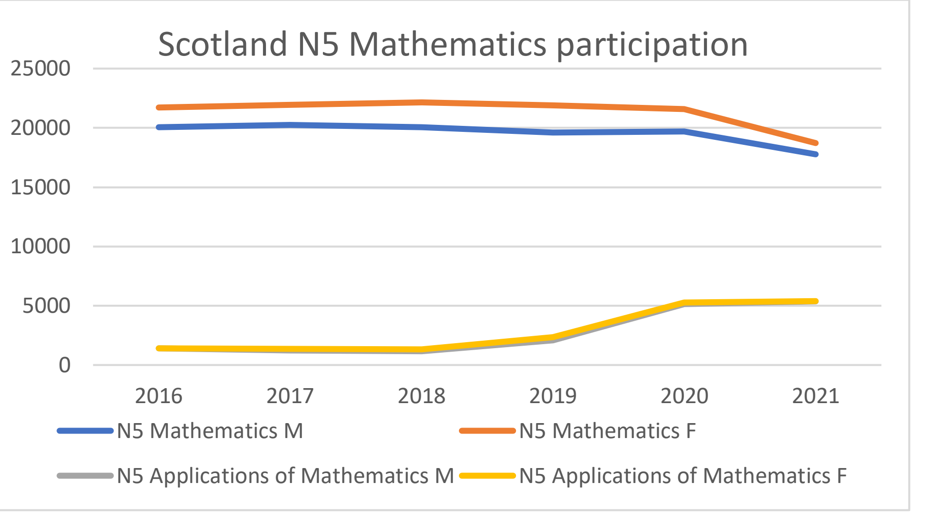


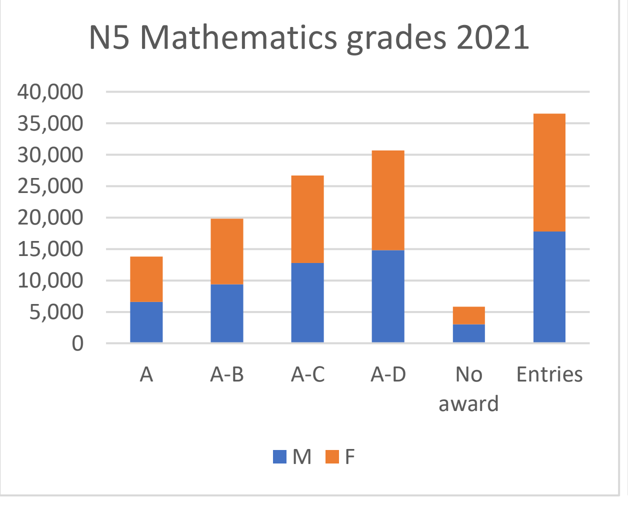
In recent years girls have consistently outperformed boys at the grade C+ level. Since the introduction of new specifications (2017 included examinations on legacy qualifications), awarded grades have risen for both genders especially over the last two years, with girls benefiting in 2021 in particular. Most (~80% of students) also take GCSE Numeracy, a minority at age 15 rather than 16. Overall awarded grades for that are slightly lower than for GCSE Mathematics, but with similar patterns of attainment by time and by gender.

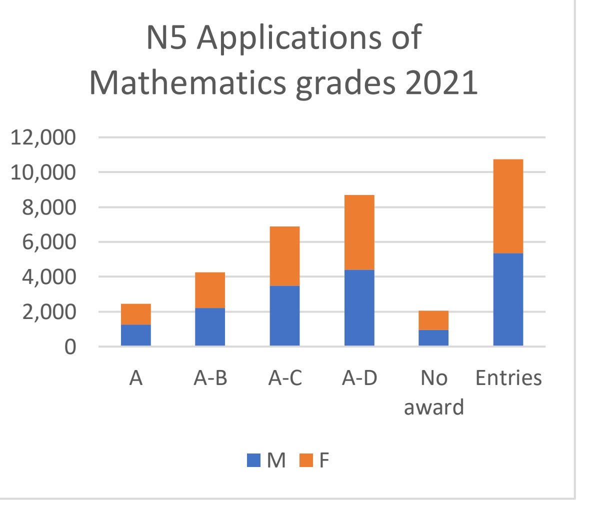
There is some effort to establish near-equivalence of GCSE grade across all Awarding Bodies in the three jurisdictions. It will be seen that the % of GCSE Mathematics entries at age 16 gaining a grade a C/4+ is highest in England, with Northern Ireland entries somewhat more selective, and Wales attainment levels somewhat lower. This might well reflect the high stakes nature of GCSE performance measures in schools in England.

3.4 Scotland

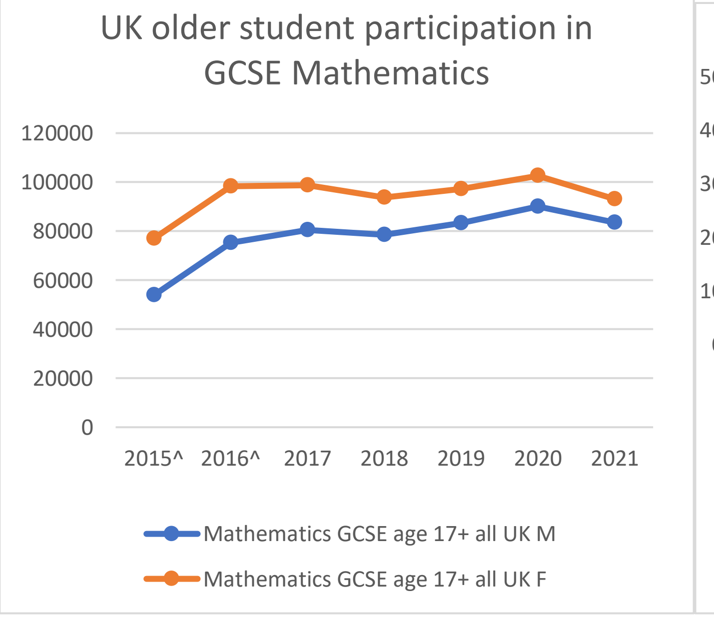
As analysed, national assessments in Scotland have a very different structure, with local interpretation of the Curriculum for Excellence and a generally broader provision post-16. Participation is not easily disaggregated by age, but with a typical cohort of about 50,000 students, N5 Mathematics is taken by about 45,000 students, some of whom might be in S5 rather than S4. Rather more girls than boys enter, but that is true across most Scottish qualifications, and broadly, there remains concern that girls continue to outperform boys in formal school examinations, particularly at the highest levels (Corry, 2017). Entries for N5 Mathematics dwarf those for N5 Applications of Mathematics. Performance by gender on both, and at all levels, is fairly comparable.







Across countries, GCSE Mathematics entries by students aged 17+ are not always available by jurisdiction, but are dominated by entries from England, where student funding is linked to a 'resit policy'. However, large participation, especially by girls, is accompanied by poor attainment:



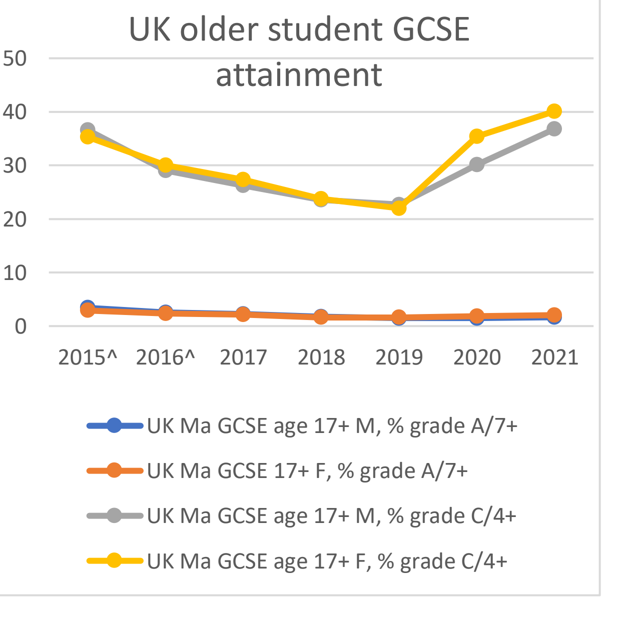


Figure 2 a,b: UK participation and attainment in GCSE Mathematics, age 17+

Such poor levels of accredited progress raise questions about the benefit or appropriateness of such routes, and must inevitably result in widespread poor attitudes to mathematical activity. An overview of needs in this area is reported in ACME (2021). Northern Ireland and Scotland have rather different provision for older students with prior lower attainment, though the participation of older students in Scottish N4/5 and other small or low-level qualifications is difficult to determine from the available data.

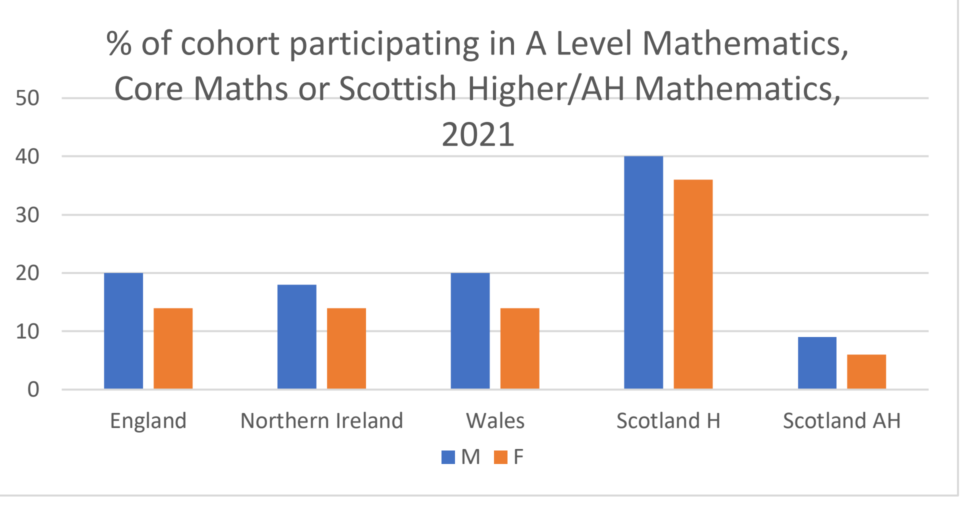
> Across the UK, girls enter Mathematics GCSE/N5 and additional mathematics qualifications in comparable numbers with boys at age 16, and they perform at least as well as boys in those qualifications. Approaches to assessment during the pandemic have resulted in the award of significantly enhanced grades, especially to girls. Participation in GCSE by older students is at large scale but often of questionable mathematical benefit to either boys or girls.

4. Participation and attainment in advanced mathematics across the UK

The qualifications discussed above are usually both prerequisites and foundations for study of advanced school mathematics, and so impact both participation and attainment at a higher level. It is helpful at this level to consider each of participation and attainment. in the four jurisdictions of the UK

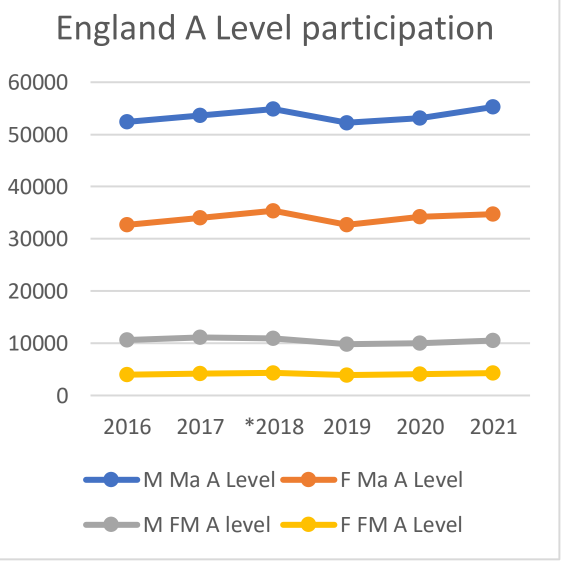
4.1 Participation

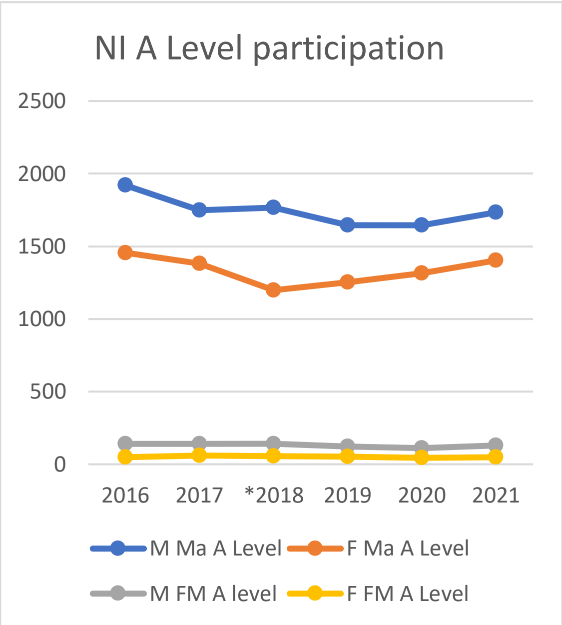
Course accreditation is used as a proxy for participation, without considering attrition through a course. Participation in advanced school mathematics is first considered as a proportion of cohort size: behaviours in relation to GCSE/N5 and other foundational qualifications entry/re-entry vary across jurisdictions, so there are no easy comparisons with entry size. Other approaches, such as that used in the study by Noyes & Adkins (2016), are possible, but prohibitive for a report of the current scale.

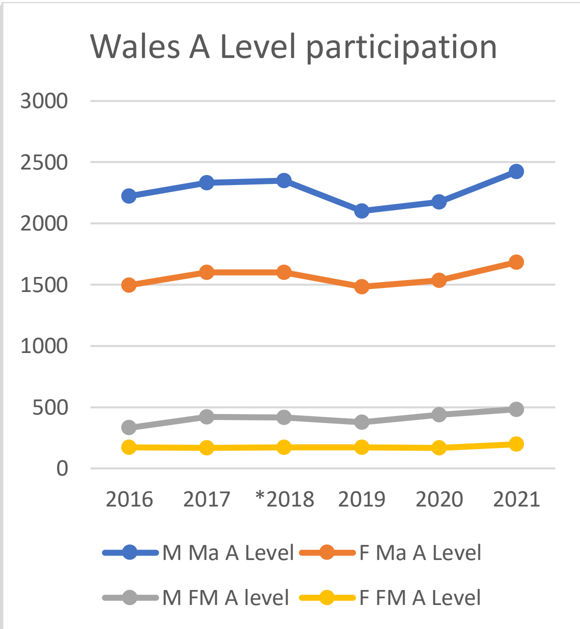


Beyond age 16, students studying advanced school mathematics in England, Northern Ireland or Wales will be preparing for A Level Mathematics (and possibly also AS or A Level Further Mathematics) or in England, Core Mathematics. In Scotland, they might take N4/5 qualifications, Higher Mathematics or, in S6, one (or more) of a variety of Advanced Higher mathematical qualifications dominated in entry by AH Mathematics. Choices available have a clear effect on advanced mathematics participation as a proportion of a whole cohort, though below, some H participation might be in S6 – redistribution across two cohorts would still show positive impact on particiaption of the Scottish system. In England, Core Maths entries are beginning to improve the overall gender balance, but there is still a considerable advanced mathematics gender participation skew across each home nation. (Cohort data taken from https://explore-education-statistics.service.gov.uk/find-statistics/education-and-training-statistics-for-the-uk/2020)

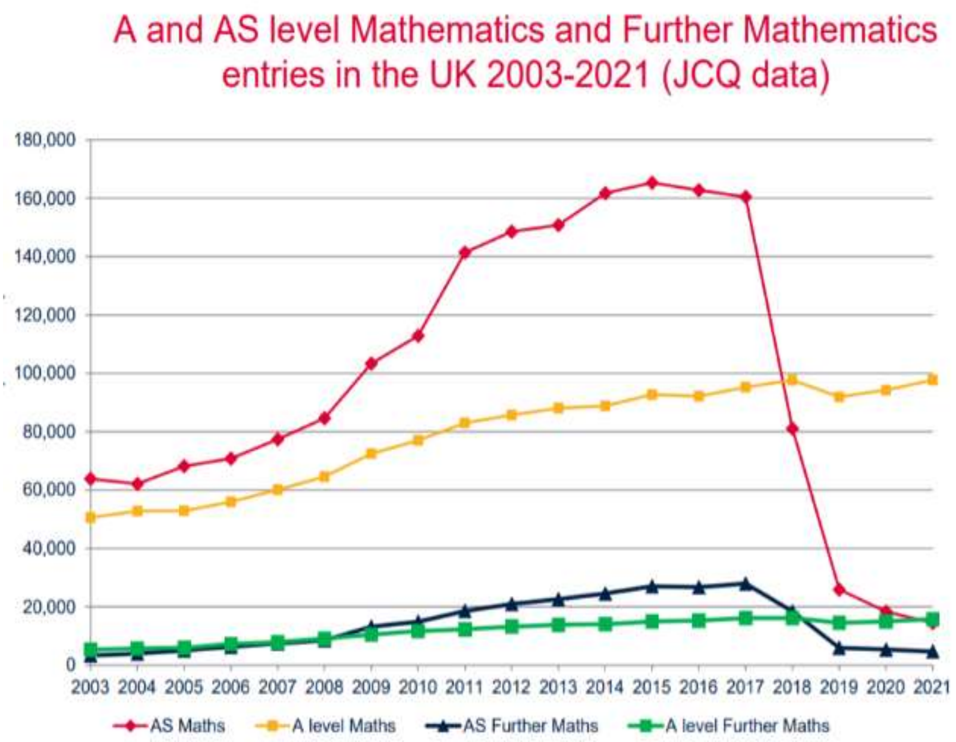
In **England, Northern Ireland and Wales**, those taking AS/A Level Further Mathematics are in general a subset of those who take A Level Mathematics. Girls comprise about 40% of A Level Mathematics entries in England and Wales, and typically a little more in Northern Ireland. In England, about 20% of boys and 12% of girls taking Mathematics A Level also take Further Mathematics A Level, so the participation gap widens. Proportions are similar in Wales, and a bit lower for both boys and girls in Northern Ireland, though Further Mathematics A Level numbers in these last two are quite low, so the relationships is probably quite volatile. In each of these jurisdictions, new Mathematics specifications were first examined in 2018, though the first large scale entries, and first Further Mathematics entries, were in 2019. Those built on re-envisaged GCSEs. As yet there is no sign of a significant impact of new specifications (at GCSE or A Level) on entries, or on participation by gender, other than some disruption over the period of first implementation. Similarly, new funding formulae for post-16 students in England have not yet had a large impact on Further Mathematics A Level, though AS Further Mathematics entries have reduced significantly.







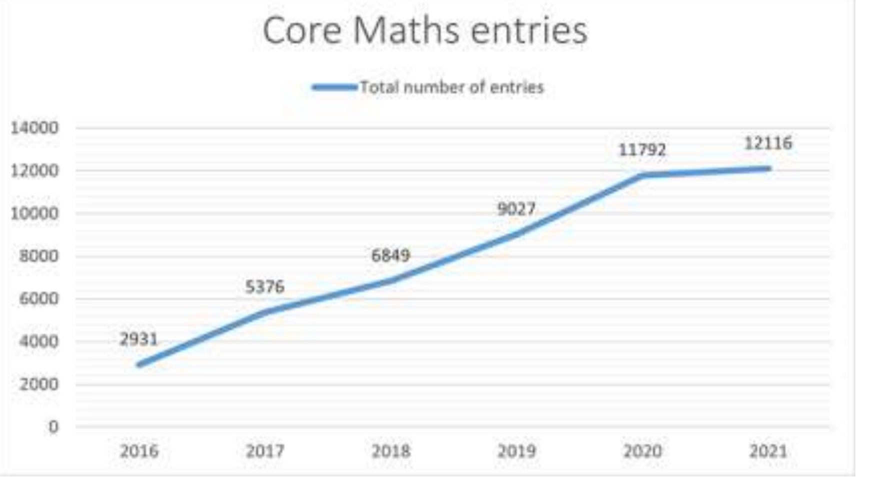
For mathematics A Levels across jurisdictions, note the apparent impact of 'decoupling' AS from A Level, and changes to funding structures in England, on AS participation, and on both genders, from 2018. The charts here are taken from AMSP. It is not possible to tell from easily-available data how many students certificate at AS without going on to A Level. However, some students who would have embarked on an AS in Mathematics or Further Mathematics and then decided to complete the A Level, and others who would have completed an AS only and benefited from that, are now not doing so:



UK	AS level Mathematics			AS level Further Mathematics		
% Change	Male	Female	All	Male	Female	All
2016-17	-1.70%	-0.96%	-1.41%	3.66%	7.03%	4.63%
2017-18	-48.95%	-50.30%	-49.49%	-34.54%	-33.20%	-34.15%
2018-19	-69.07%	-66.36%	-68.02%	-69.28%	-64.97%	-67.99%
2019-20	-30.06%	-27.86%	-29.16%	-8.34%	-11.55%	-9.39%
2020-21	-21.04%	-21.48%	-21.22%	-13.75%	-8.02%	-11.92%

Figure 3: Recent changes in AS Ma, Further Ma entries

In England, though in principle available elsewhere, Core Maths entries are still increasing, and now attracting near-equal entry by gender:



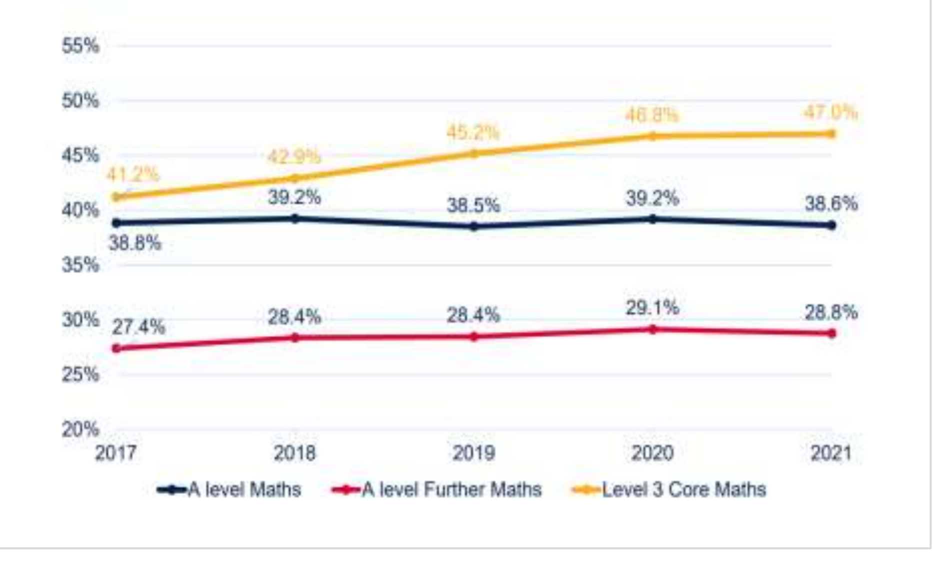


Figure 4:% of female entries for advanced school mathematics qualifications in England, Northern Ireland, Wales

In **Scotland**, advanced mathematics participation is dominated by Higher Mathematics, of whom a subset go on to take Advanced Higher Mathematics in S6. Other mathematical Advanced Highers have comparatively small entries. There was a concerning dip in girls' H entries in 2021, though boys participation in both H and AH Mathematics habitually exceeds girls' in recent years:

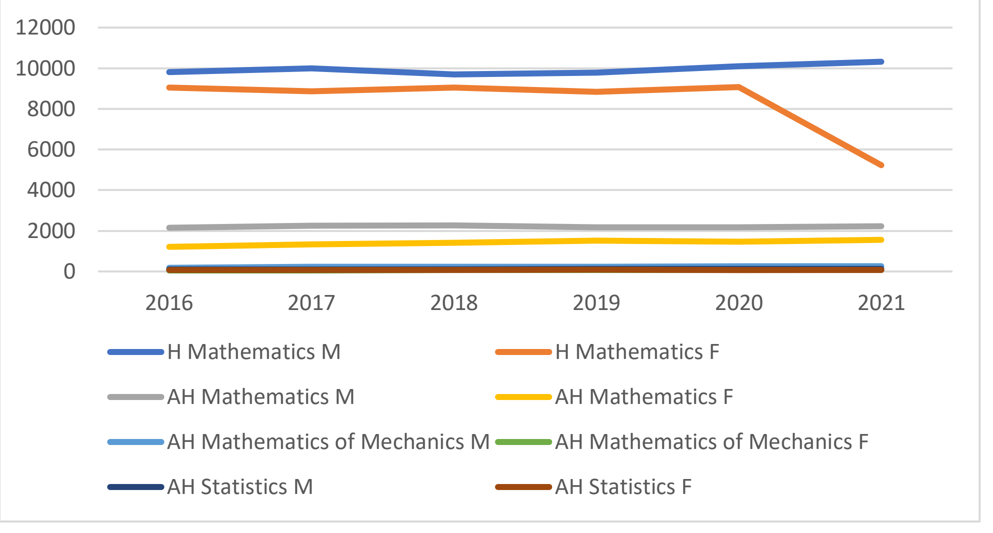


Figure 5: Scotland Higher and Advanced Higher mathematical studies participation

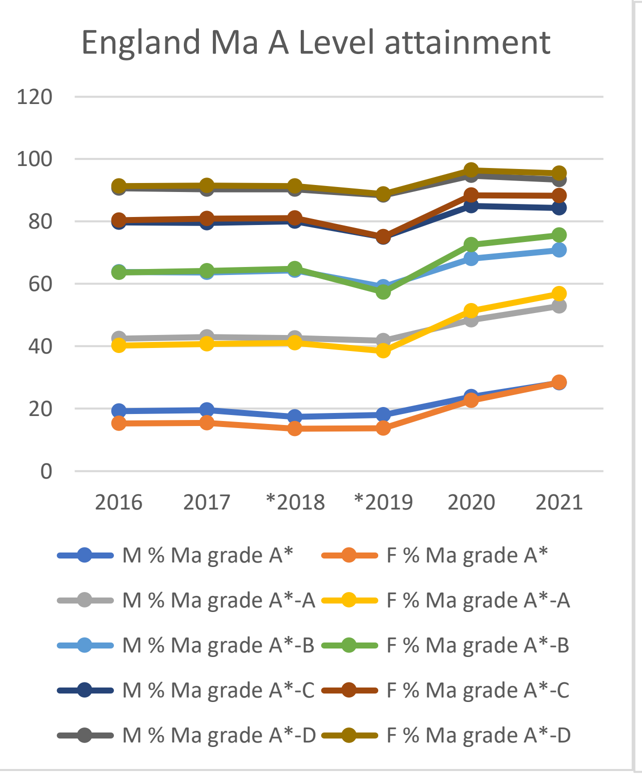
On the scale given, it is not clear that boys have out-participated girls in other mathematical Higher and Advanced Higher entries, but the numbers are small for both Mathematics of Mechanics and Statistics: under 100 for girls, up to 258 boys for Mechanics, and up to 125 boys for Statistics.

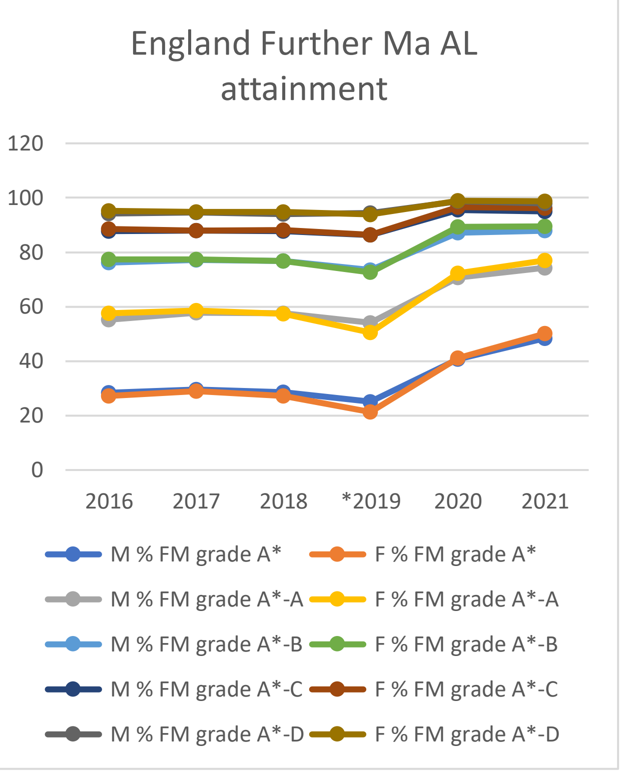
What we see, then, is that Core Maths (and to a lesser extent, Scottish Higher Mathematics), enjoys more equal participation by gender than do A Levels (especially Further Mathematics A Level) and Scottish Higher Mathematics. Core Maths participation is still relatively small compared with the potential pool of students but significant compared with A Level Mathematics numbers in Northern Ireland and Wales, or Advanced Higher entries in Scotland. But how does attainment by gender vary within these qualifications?

4.2 Attainment

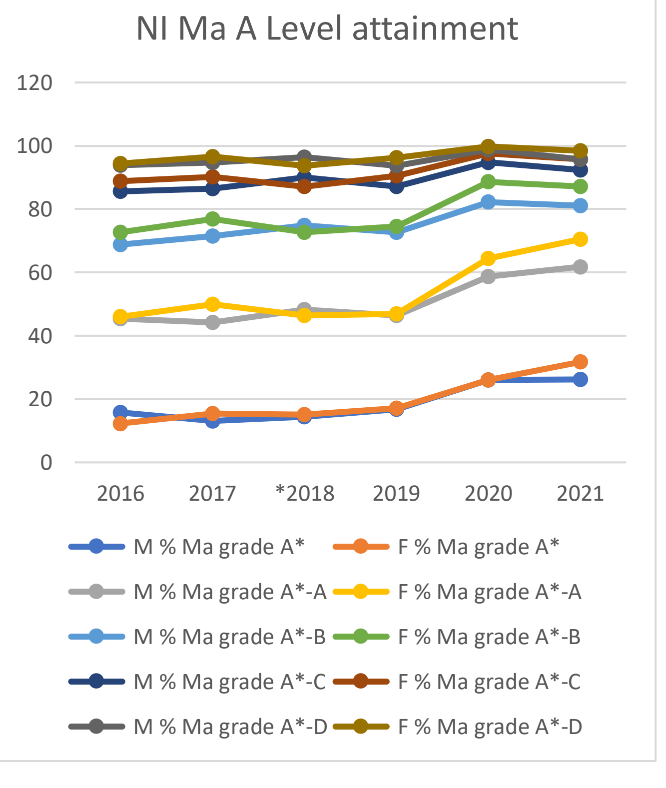
In the graphs below for England, Northern Ireland and Wales, attainment is given at four different levels for each of A Levels Mathematics and A Level Further Mathematics, since each is those levels is germane to the progression of students aspiring to different levels of next mathematical study. Cumulative % attainment data for the two A Levels is juxtaposed for each jurisdiction. Given that the scale of participation is much lower for Further Mathematics A Level, particularly in Northern Ireland and Wales - less than 500 for each gender in Wales, and for Northern Ireland less than 100 for girls - it is not surprising if there is some volatility in patterns of attainment. Note a common 'dip' in attainment over the introduction of new specifications, as teachers adjust, and also an overall rise in attainment over the last two years, with centre/teacher assessment.

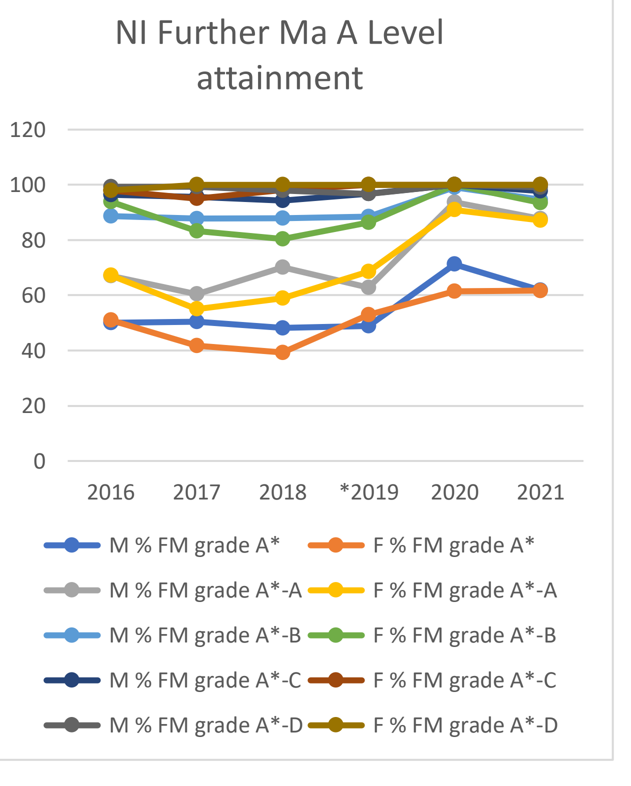
In England, A Level Mathematics shows some evidence of boys outperforming girls at the highest levels, with girls slightly outperforming boys at lower grades – until 2020/2021, when girls clearly benefitted differentially from the assessment systems used. In Further Mathematics, performance

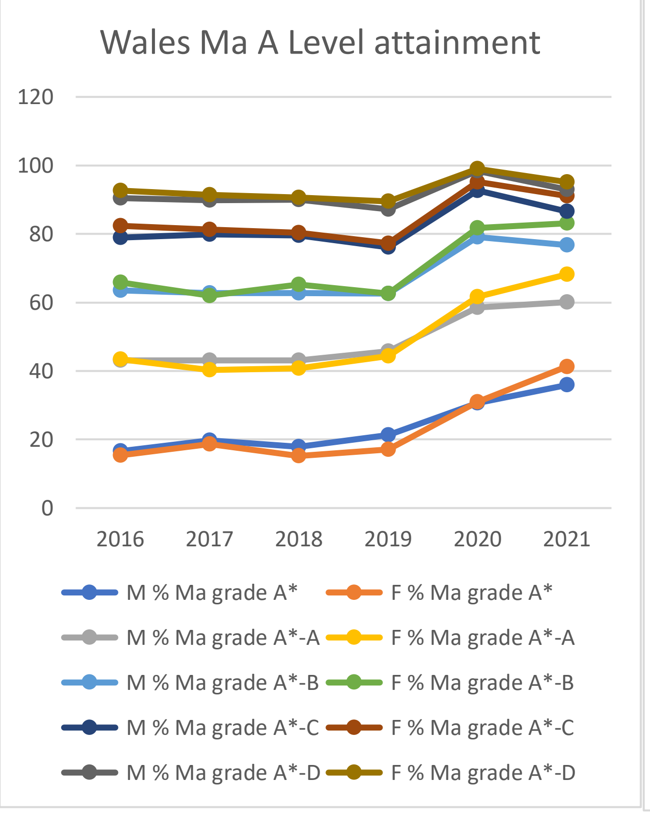


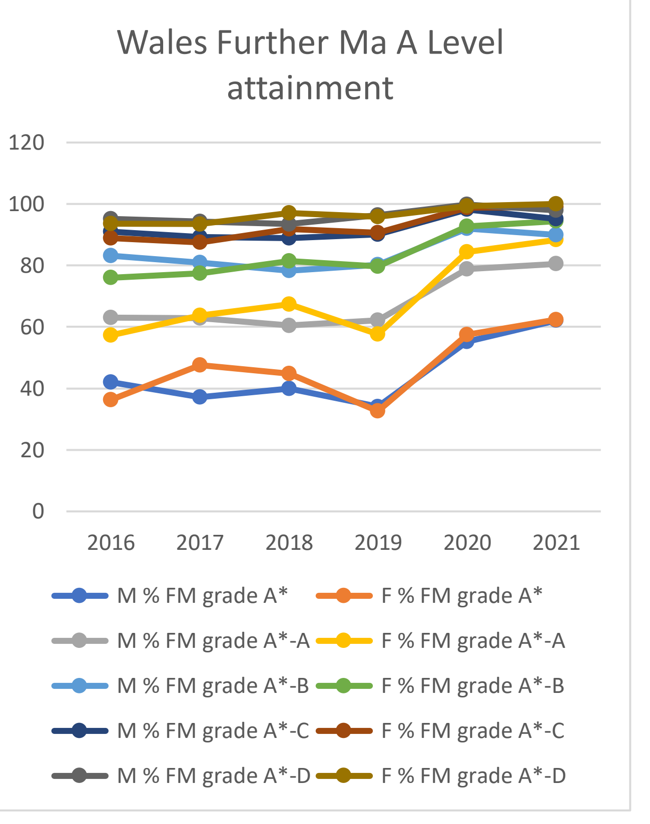


in recent years has been very comparable across genders, although assessment of new specifications in 2019 seems to have particularly impacted girls, and again, they seem to have particularly benefited from the assessment modes used in the last two years. The general increase in grades awarded in the last two years, and the particular differential change in girls' grades, is true across ***the three jurisdictions***, except for Further Mathematics in Northern Ireland - perhaps a particular feature of the small cohort. In general, though, performance in these two A Levels in each of Northern Ireland and Wales appears pretty comparable across gender.



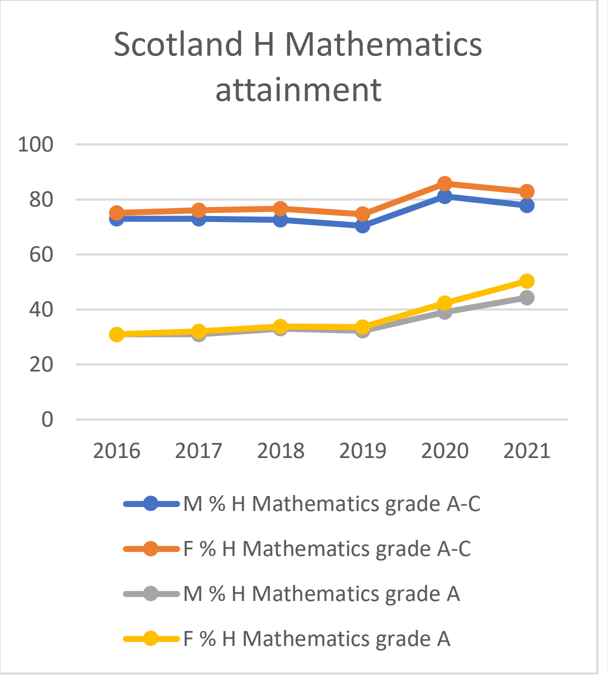


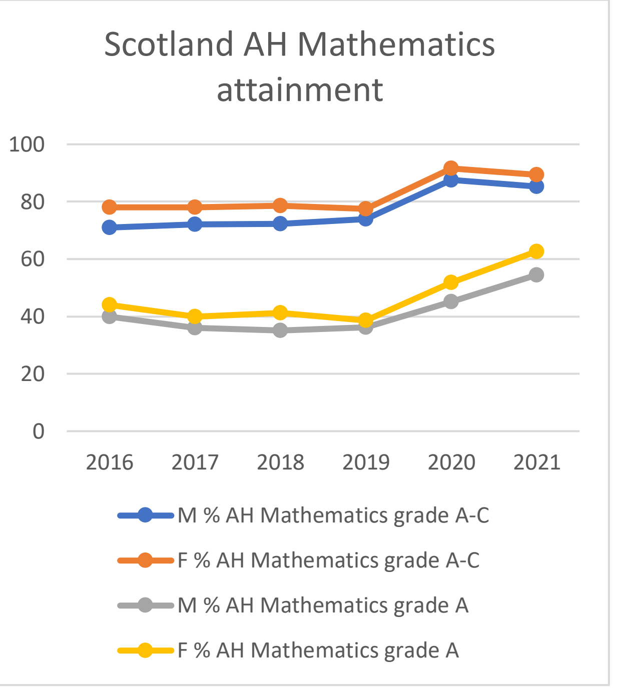


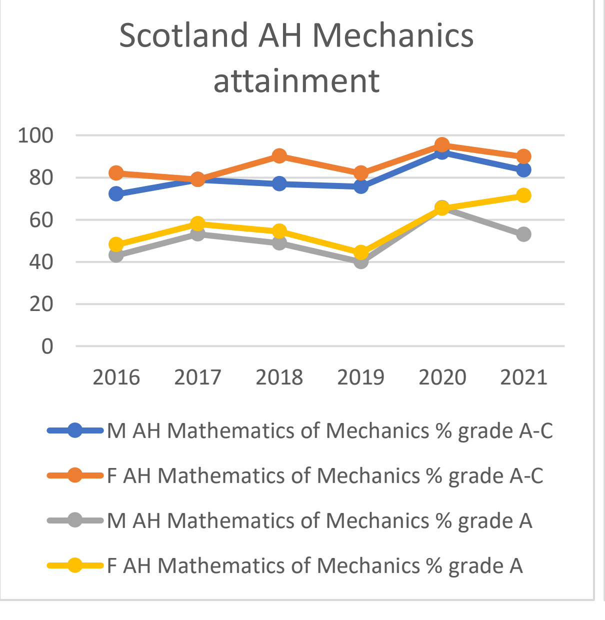


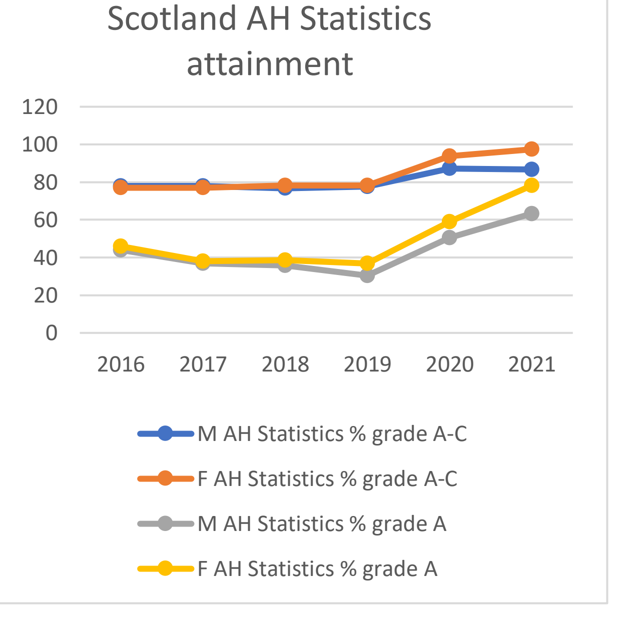
The new A Level specifications have had even less time than new GCSE specifications to settle down, with first full cohort assessments taking place in 2019. There is as yet no clear evidence of any impact on either participation or attainment from the introduction of new specifications or their previously experienced new GCSEs in this data, despite some evidence of the new A Levels being experienced as relatively demanding, and participation by an increasingly 'clever core' (e.g. Golding, 2021).

In Scotland, similar patterns can be seen in relation to grades awarded over 2020 and 2021 via the Alternative Certification Model: outcomes have risen, even though many students' education has been significantly disrupted, and girls have benefited in particular from the assessment model used. Other analysis shown suggest that even before the pandemic, girls have often outperformed boys in Mathematics Higher and Advanced Higher assessments, though not always significantly so. That is also true of the Mathematics of Mechanics and of the Statistics Advanced Highers.









Across the UK, unusual patterns of grades awarded over the last two years raise questions of fairness to current and other cohorts, and of exchange value in an education market where goal-posts have clearly shifted, especially as students awarded in 2020 or 2021 often had significantly reduced opportunity to learn the published specification: However, the issue of future assessments is also not straightforward: there is some evidence that the assessment approaches adopted for 2020 and 2021 have some advantages in terms of promoting steady, conscientious, collaborative and clearly communicated mathematical work, and require less risk-taking behaviour than assessment by high-stakes examination. They might therefore offer more valid assessment of some mathematical behaviours though it is also important that students also have to synthesise their learning so as to build on it in their future pathways (Golding, 2021).

The above data only reflect what is measured with the particular assessment tools used, and are difficult to relate to fixed standards or international norms, except indirectly, e.g. via Higher Education and economic participation and performance (although some National Reference Tests are now carried out in relation to GCSE Mathematics material, in England). A wider grasp of upper secondary mathematics performance, attitudes and experience can be gleaned via two key large-scale international assessments, PISA and TIMSS. National reports on performance in each of these are available from government and assessment websites.

Significant differential participation in favour of boys is evident in all advanced school mathematics qualifications in the UK with the exception of Core Maths, with e.g. A Level entries remaining fairly steady. It is not clear how plummeting AS entries in England have impacted the number of *students* studying some advanced school mathematics.

As with GCSE and N5 mathematics qualifications, the approaches used to assessment during the pandemic resulted in significantly improved grades across advanced school mathematics qualifications, and especially so for girls. However, even before then, there is no systematic evidence of boys routinely outperforming girls at this level, except at the highest grades for Mathematics A Level in England. Neither is there clear evidence that any of the recent changes to mathematics curriculum and assessment have impacted (positively or negatively) on (girls' or boys') participation or attainment in advanced school mathematics.

5. International large-scale assessments of performance, experiences and affect, and the UK students' profile within those

5.1 What is PISA?

PISA is an OECD initiative, assessing 15-year-olds' literacy, mathematics literacy, and science literacy, and associated affect and experiences, on a 3-year cycle, with the last completed cycle in PISA 2018. Each cycle has a different focus, with PISA 2012 and PISA 2021/2 focusing on mathematical literacy. Assessments are designed to examine how 15-year-olds can apply what they have learned in school to real life situations, using their skills of reasoning, interpretation and problem solving rather than simply remembering facts. 'Mathematical literacy' here describes the capacities of individuals to reason mathematically and use mathematical concepts, procedures, facts and tools to describe, explain and predict phenomena across personal, occupational, societal and scientific contexts, drawing on '21st century skills'[1]. PISA 2021 will draw on enhanced digital affordances for exploration and modelling, including basic spreadsheet manipulation and linked interactive representations. All four UK countries have participated in recent cycles of PISA. Both England and Wales show an improving trend across successive PISA cycles, while Scotland's performance has stagnated (with some improvement by boys and decline by girls); Northern Ireland's has remained broadly stable. UK boys as a group typically show a slightly wider spread of attainment, though not always significantly so; in mathematics in 2018, boys significantly outperformed girls in England and Scotland but there were no significant differences in Wales or Northern Ireland. However, in the recent PISA 2021 Field Trial for England, Northern Ireland and Wales, there was no significant difference in performance between boys and girls, although there was in terms of questionnaire responses (Field Trial data for Scotland not yet available).

5.2 Recent mathematics literacy performance in PISA

In Table 1 below, 'low performers' do not reach the baseline level of proficiency in mathematical literacy. They can solve problems involving clear directions and requiring a single source of information, but cannot engage in more complex reasoning to solve the kinds of problems that are routinely faced by adults in their daily lives. There has not been a significant change in the % of low, or high performers in the UK since 2006, though spread in performance closed slightly in 2018.

*Table 1: PISA performance by gender in 2015 and 2018 *=significant difference from previous cycle*

Mathematics performance	PISA 2015 mean	PISA 2018 mean	% 'low performers'		% 'high performers'	
			2015	2018	2015	2018
England M	499*	511*	23	19	11	14
England F	487	498				
Northern Ireland M	497	489	18	18	7	8
Northern Ireland F	490	495				
Scotland M	494	497*	20	23	9	10
Scotland F	487	481*				
Wales M	483*	488	23	21	5	7
Wales F	473	486*				
OECD mean M	496*	492*	23	24	11	12
OECD mean F	488	487				

5.3 PISA 2021/2

PISA 2021/22 Is not yet complete. It will have a focus on mathematical literacy, and associated survey items will reflect that. The corresponding 2020 'Field Trial' is, though, complete and outcomes for England, Northern Ireland and Wales have been analysed (Scotland's were not accessible). They were not disaggregated by jurisdiction because of sample size. Gender is reported as male/female/other, though no field trial respondents chose 'other'. There were no statistically significant differences in attainment between by gender, but survey responses show some persistent differences in attitudes and perceptions by gender, and those are important because they impact future participation.

[1] Analysed as critical thinking, creativity, inquiry, information use, systems thinking, communication, reflection, and self-direction, initiative and perseverance.

Golding et al. (2022) report them by the "Five factors that are widely found to affect students' intentions to study mathematics at A-level that could be influenced by school practices" (Smith, 2014):

Table 2: PISA Field Trial for England, Northern Ireland and Wales 2020 survey findings (Golding et al., 2022)

Factor	Why is this important?	PISA 2021/2 Field Trial Finding
Prior attainment/self-assessment of that	These limit perceived options for future study (Matthews & Pepper, 2007; Noyes, 2009).	56% of boys report that "Mathematics is easy for me" compared to 37% of girls ($p < 0.05$)
Enjoyment	Students are more likely to continue studying mathematics if they have positive emotional responses to it (Mujtaba & Reiss, 2013).	Girls enjoy maths less: mathematics is often their least favourite subject, including for those who reporting it "easy". "Being anxious and upset" is more common amongst girls ($p < 0.001$). Anxiety is more frequently related to "doing well" rather than to doing mathematics (both genders).
Interest in mathematics	Interest is a prerequisite for girls choosing to study it when optional (Brown et al., 2008).	Girls are less interested in their maths lessons than boys. They are less interested in careers using mathematics ($p < 0.005$). Interest increases to a majority when the question is posed via career utility.
Perceived utility of mathematics	Girls perceive less utility than boys (Halpern, 2007; Hodgen et al., 2013); it is a common reason given for avoiding mathematics (Brown et al., 2008).	A majority of both genders report lessons fail to make the relationship between mathematics and the real world obvious. Girls are statistically more likely to report that this relationship is not made in their lessons ($p < 0.05$).
Perceived competence	Perceived (incl. relative) competence can limit future choice (Noyes, 2009)	Girls are less confident and feel less encouraged by teachers than boys ($p < 0.05$). Girls are less likely to believe mathematics performance can be improved through effort ($p < 0.005$). (Though note: 1) Responses have historically shown to have gender bias as boys overestimate their performance (Jerrim et al., 2019) 2) When questions were mathematically specific, girls were equally confident.

Such gender-differential findings were common across OECD in PISA 2012, the last cycle to focus on mathematical literacy. *For example,* some 25% of boys but 35% of girls reported that they feel helpless when doing mathematics problems, and girls were more likely to have low levels of self-efficacy than boys. No gender differences in confidence were observed when students were asked about doing more abstract, classroom content-matched tasks, but gender differences were striking when students were asked to report their ability to solve applied mathematical tasks, particularly when associated with stereotypical gender roles (such as calculating the petrol-consumption rate of a car). Looking ahead to possibly more embedded use of digital tools for mathematical purposes, it is also clear from Field Trial data that girls tend to prefer to use digital tools rather differently, and feel confident and enjoy different aspects of that use, than boys.

Across most participating countries and economies, differences in levels of mathematics anxiety related to gender were wide, with girls typically reporting stronger feelings of mathematics anxiety than boys, and boys more likely than girls to participate in mathematics-related extracurricular activities. Gender differences were particularly pronounced with respect to playing chess and programming computers. In all but six participating jurisdictions boys tend to have greater intention to pursue mathematics in their studies and careers than other subjects: Turkey was the only country where girls had more positive intentions than boys of continuing mathematics study.

On average across OECD countries, boys were more likely than girls to report that the following: that most of their friends do well in mathematics; that their friends work hard at mathematics; that most of their friends enjoy taking mathematics tests; that their parents believe that it is important for their child to study mathematics; that their parents believe that mathematics is important for their career; their parents like mathematics (and gender differences are more pronounced than socio-economic disparities). PISA 2012 responses (the last to include mathematics as a focus) in UK countries varied somewhat, but were broadly consistent with OECD trends. Taken together, these survey responses present a persisting picture of affect, social environment and perceptions significantly less conducive to girls' continuing participation in mathematics, than to boys'.

5.4 What is TIMSS?

TIMSS assesses mathematics and science performance, attitudes and experiences of 'grade 4 and 8' students (ages 9/10 and 13/14) on a four-yearly cycle, with items more closely related to the curriculum, although sometimes with a different profile of weightings. England has participated in every cycle of TIMSS since its inception, at both grade 4 and grade 8 (English years 5 and 9). Northern Ireland has participated in recent cycles of TIMSS at grade 4 (primary year 6) but not at grade 8, and Scotland participated in 1995, 2003 and 2008. Wales have not participated in recent cycles of TIMSS. In England in TIMSS 2019 mathematics, Y9 students performed significantly above the international mean, in the second highest group of countries, though with no significant improvement over previous cycles, although Y5 performance showed significantly improvement over that in TIMSS 2015. This report focuses on findings in relation to English year 9 mathematics. The TIMSS curriculum matches the intended curriculum in England quite well, though items tend to be less structured, and to draw on more cross-mathematical thinking, than is apparent in many English classrooms (e.g. Ofsted, 2012). Both PISA and TIMSS use 'Trend items' that are carried through successive cycles, so as to benchmark performance over time. Scores from successive cycles can therefore be compared to give a valid comparison of performance over time.

5.5 Mathematics performance in TIMSS

In each of 2019, 2015, 2011 in England, boys and girls performed similarly in TIMSS year 9 mathematics, and a similar percentage of year 9 boys and girls reached each of the TIMSS 'benchmarks'. The picture was more mixed in comparator countries, though many showed boys outperforming girls. In England, survey responses showed significantly more y9 boys strongly valued the subject than girls (43% vs 34%), while significantly more girls did not value the subject (12% vs 9%). Significantly more y9 boys were very confident in comparison to girls (18% vs 10%), while, similarly, significantly more girls were not confident (44% vs 30%).

PSI ('problem solving and inquiry') **tasks** were introduced in TIMSS 2019 to gain insights into how using digitally-based interactive assessment items could be incorporated into TIMSS. Overall, facility of PSI items was comparatively low. In England at y9 performance by gender was fairly comparable, although detailed analysis of process suggests girls were significantly less likely to take risks in their responses (Mullis et al., 2021).

All four UK nations have participated in recent PISA assessments of mathematical literacy. England and Wales show an improving trend across successive PISA cycles, while Scotland has declined and Northern Ireland has remained broadly stable. Boys have often somewhat outperformed girls, but not always. Accompanying surveys of mathematics-related beliefs and experiences show marked differences by gender, in ways known to be detrimental to girls' future participation, and these differential reports are remarkably persistent across time and UK country.

Only England has participated in recent, mathematics curriculum-close, year 9 TIMSS assessments. There has been no significant difference in performance by gender in recent cycles, including, overall, in the recent 'PSI' (problem solving and inquiry) items though again, students' reported affect and experiences are differentially detrimental to girls' continuing participation.

6. Participation and attainment contextualised more widely

This section gives a brief and high-level overview of the wider picture, and of some of the factors thought to underlie gender-differential participation, particularly at the upper secondary level and beyond. Globally, gaps in participation are generally wider in wealthier countries, where young people are also, on average, less positive about science, technology and mathematics (World Bank, 2020). Smith (2014) gives a more detailed overview of relevant evidence by 2014. Education Scotland (2015) and DfE (2020) show that within and beyond the UK there is wide-ranging, but far from uniform, evidence of gender differences in STEM participation, and sometimes, attainment, but not potential. Such sources show performance and attitude gaps in mathematics in the UK appear early: they can be seen pre-school. For girls, 'relevance' to their lives appears to be a key driver for choices made. Further, girls often lack self-efficacy, or confidence in their own abilities, in STEM subjects even when their performance is comparable with boys', and they suffer disproportionately from mathematics anxiety, from primary school onwards. Further, they are less tolerant of rote learning, giving greater value to meaning- and connection-making. Girls can perceive science and technology as subjects that are incompatible with their ideas of femininity and lacking in the human-centred aspects important to their value systems (Archer et al., 2014). Again, these traits occur widely, including across the UK, and are reflected also in international surveys. Teaching which privileges meaning- and connection-making is of long-term benefit to the range of students, so there are a variety of reasons for its promotion.

In England, Matthews & Pepper (2007) point to differences in the profile of reasons given for studying A Level Mathematics, with boys focusing more on the usefulness of mathematics and girls on their enjoyment and capacity to cope. Such differences persist through to e.g. the PISA survey findings reported above, and throughout the UK (e.g. Cann, 2009). They identify evidence that suggests girls are more likely to achieve, and to continue participation from single sex classes, or when taught by same gender role models, whereas for boys these measures are likely to be counter-productive, on balance. They show that multiple choice and high-stakes examination assessments typically favour boys, whereas continuous and low-stakes assessments favour girls, and so also support their participation. However, there is some evidence that recent in-pandemic modes of assessment have also served to exacerbate 'imposter syndrome' in mathematics post-GCSE and at university entrance, and that disproportionately affects girls (Golding, 2021).

Noyes (2009) shows that girls' participation in England can be undermined by their relatively high average GCSE performance, since choices are influenced by relative, as well as perceived absolute, prior attainment. Schools with relatively highly attaining mathematics departments, then, might expect to see higher participation post-16 – as reflected in Smith & Golding (2016). Many school-, peer-, family- and societal factors that support girls' participation also support boys', for example positive pupil-teacher interactions, although for girls this might take a slightly different form of interaction: Smith & Golding (2016) found girls particularly value informal, less public opportunities to interact with teachers, and teachers who explicitly recognise achievement, provide challenge and support persistence through that, and affirm mathematical identities. Parents, peers and other important adults also have roles in giving girls, in particular, confidence to continue to participate. Girls are more likely to value classrooms that emphasise discussion and understanding rather than having an emphasis on speed and competition, and often have different perceptions of their classroom ethos and teaching than boys do – again, echoed in TIMSS and PISA responses. Schools and colleges successful in achieving high levels of girls' participation used low key role models operating at a range of mathematical levels, and talked with girls as if assuming they would persist in, and be successful with, continued mathematical engagement.

There is also wide evidence of significantly gendered participation at the tertiary level, with UNESCO (2017), World Bank (2020) and Roy et al. (2020) analysing that as country income rises, the gender gap between the likelihood of studying in a STEM field widens, and this translates into occupational sex segregation in the workforce. This is beyond the report's direct scope, but underlines why understanding drivers at a lower level is so important. Even when women study in STEM fields, they are less likely to pursue careers in STEM. Eastern European countries are an exception. Relative to the share of women who have attained tertiary education, women's participation in research shows a precipitous drop. The share of women working in the mathematically-intense fields of data and artificial intelligence, engineering, and computing is especially low. Bias and stereotyping also emerge in the home: for example, parents show a greater preference for sons to work in STEM. Women's experiences in both educational and employment settings are consistently less positive than men's, and there seems to exist a pattern of fewer women authors in theoretical disciplines and subdisciplines, while a larger presence is found in applied and collaborative fields. In Mathematics, the proportion of women among authors of scientific papers has growing from <10% for the 1970s cohorts to >27%, though the proportion in 'top journals' remains beneath 10%.

International studies show gendered gaps in upper secondary mathematics participation are not inevitable, but they are widespread, and often related to comparatively poor mathematics-related affect or unhelpful stereotypes. Girls value, and are influenced by, mathematics-supportive teacher classroom approaches and supportive interactions with influential others. Participation at this level is supported by ambitious, connection-making teaching which embraces appropriate challenge and supports students through that. There are also significant gendered issues at the tertiary level and in the workforce, including academia

7. What approaches are thought to increase girls' participation?

Most of the evidence concerned with understanding and addressing gender differences in mathematics participation and attainment, and is focused on relatively high-attaining students, who typically succeed in an A Level or equivalent, and on addressing tertiary participation. However, Harkness & Stallworth (2013) analysed the participation of high school girls struggling with mathematics, and reported a lack of connection to the knowledge, and lack of confidence in their own independence when doing mathematics. The authors suggested that schools could be more active in helping girls 're-perceive' mathematics. Much of the school-level evidence supports approaches that are thought to support participation of girls *and* boys. Few systematic interventions have targeted parents, although parents influence children's achievements and aspirations (e.g. Archer et al., 2014). Even a one-day event that engages parents of girls can contribute to reshaping parental attitudes toward e.g. their participation in engineering (Roy et al., 2020).

In terms of teaching and classrooms, the literature (e.g. Cassidy et al. (2018); Mujtaba & Reiss (2013)), suggests that ambitious, connectionist teaching is likely to particularly benefit girls' self-efficacy, and so their continued participation. Routinely using examples of the applications of mathematics - in STEM but also in social science, personal life and wider society, and especially in relation to people-facing roles or issues - tells girls (and boys) that becoming a user of mathematics is relevant for them. Routine use of role models and reference to applications of mathematics, at all levels, provide examples of the kind of success that one may achieve and often supply a template of the behaviours necessary for success, especially if stereotypes are also challenged in a low-key way (Mendick et al., 2008). Roy et al. (2020) promote teaching all students about gender equity, and evaluating learning materials for gender bias, as well as encouraging relevant single-sex activities to raise girls' self-confidence and possibilities for expressing themselves; AMSP suggest further small-scale interventions in classrooms, with parents, in participation messaging, for which there is evidence of impact. But early differentiation of attitudes and beliefs by gender suggests such approaches need to begin in primary school, if not earlier.

The PISA findings outlined above suggest, similarly, that productive approaches might include: Focusing on student engagement and meaning-making with particular mathematics, rather than their overall 'performance'; explicitly reinforcing everyday successes of all sizes; addressing the vicious cycle of anxiety and poor results through more constructive and formatively-focused approaches to assessment; further building links between real-world utility and mathematics (perhaps with a focus on use in employment, but also of application of mathematics to 'real world' issues such as climate change, over-population, infant mortality, spread of disease…); explicitly intervene to support more valid self-assessment by both genders. Other evidence suggests such approaches are likely to benefit all students, but girls disproportionately.

Although strictly beyond the scope of this report, note that at the tertiary level, mentorship from faculty predicts the development of a science identity as well as deeper interest in science and promotes persistence in science fields among female undergraduates (Roy et al., 2020), but there is also evidence of the efficacy that many of the above interventions, including the approach to teaching, continue to have relevance in Higher Education.

Teaching mathematics for meaning-making and for connections, including to realistic uses of mathematics in across a wide range of contexts, supports the participation of all students, but especially girls. That teaching should also challenge, encourage, support and specifically affirm the mathematical identity and capabilities of all students. It should offer opportunity for working in a range of both collaborative and independent, discursive ways. Developing curricula and pedagogies should also build on gender-specific preferences and interests in harnessing digital tools for mathematical purposes. Other small-scale interventions should target the range of influences on young people's pathways decisions: their peers, their parents and other influential figures, extra-curricular activities, the resources they use and images and roles they encounter, to promote gender-inclusive messaging. Teachers might also consider single-sex activities on occasion.

8. Conclusions

This analysis shows that mathematics education provision in each of the four UK jurisdictions is in a state of flux. Recent changes have not yet settled down, and the 2020-2022 pandemic has led to particular disruption to learning and assessment, while also offering evidence of alternative approaches to assessment and their impact on grading by gender. Large numbers of poorly progressing students of both genders continue to have mathematically unhelpful experiences post-16 that need addressing.

Across the UK, there is not a gendered issue in participation in near-compulsory mathematics courses to age about 16, nor attainment within those. However, there is significant differential participation in favour of boys evident in all large advanced school mathematics qualifications in the UK except Core Maths. It is important to better understand that trend-disrupting gender-comparable participation observed in Core Maths, so as to apply relevant learning to future qualification development. The gap is also somewhat less pronounced in Scotland's Higher Mathematics: a broad curriculum in S5 seems to support good scale participation, fairly, but not equally, inclusive of girls. Across the UK, there is no systematic evidence of boys routinely outperforming girls at this level, nor clear evidence that any of the recent changes to mathematics curriculum and assessment in the UK have impacted (positively or negatively) on (girls' or boys') participation or attainment in advanced school mathematics – in part because new qualifications have often not yet had time to bed down, and both learning and assessment have been disrupted significantly during the pandemic. The approaches used to summative assessment during the last two years, though, have resulted in significantly improved outcomes across age 16 and advanced school mathematics qualifications, and especially so for girls, and there might be lessons to be learned from that.

Performance in the UK can be benchmarked in large scale international assessments. Importantly, surveys of mathematics-related beliefs and experiences within both PISA and TIMSS show students' reported affect and experiences, across attainment levels, are differentially detrimental to girls' continuing participation. Those differential reports are remarkably persistent across time and, for PISA, UK country. They are repeated in many, but by no means all, other jurisdictions. There are also significant gendered issues at the tertiary level and in the workforce, including academia.

The analysed data is of course focused on differences in participation, attainment and affect by gender: the situation regarding intersectionality with other characteristics is complex. However, there is overwhelming evidence that participation in the UK remains disappointingly gender-biased, with significant, and likely increasing, implications for individual and for societal thriving. The literature suggests broad pedagogical, and some smaller-scale, but important, principles that are promising but need to be communicated and enacted:

- ***Pedagogy*** should support mathematics for meaning-making and for connections, including realistic uses of mathematics in across a wide range of contexts (cf Core Maths). It should challenge, encourage, support and specifically affirm the mathematical identity and capabilities of all students, and should offer opportunity for working in a range of both collaborative and independent, discursive ways. Teachers might also consider single-sex activities on occasion.

- ***Other interventions*** should target the range of influences on young people's pathways decisions: their peers, their parents and other influential figures, extra-curricular activities, the resources they use and images and roles they encounter, to promote gender-inclusive messaging.

Such approaches are thought likely to support the mathematical development and participation of all students, but of girls in particular. New and emerging curricula and pedagogies should also build on gender-specific preferences and interests in harnessing digital tools for mathematical purposes.

A broader curriculum post-16, and incorporation of mixed, less traditional forms of assessment, also show potential.

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