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Gender and Participation in Mathematics and Further Mathematics: Interim Report for the Further Mathematics Support Programme

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Summary of Findings

Case studies were conducted in four state-funded schools and one Further Education college identified as making an impact on girls' participation in mathematics at A-level. Teacher and student focus groups and observations were used to examine strategies and factors that have contributed to unusually high take-up of girls for A-Level mathematics.

The following common features were identified:

1) The case study schools had not been involved in specific initiatives to attract girls to study mathematics; instead there was a strong culture of encouraging many students to aspire to take mathematics at A-level. Girls did not see the need for such initiatives because the dominant attitude was "we're good at it, we enjoy doing it, why wouldn't we?"
2) The school and college departments are active in promoting mathematics as a subject that has wide applicability, and so opens doors to many valued degree courses and careers. The message repeated by girls in these schools emphasises this over the value of mathematics for accessing elite courses.
3) The schools all offer a Mathematics A-level option that includes statistics in year 12 and they promote this as beneficial because of its social-science applications.
4) Teachers instil a belief that students will succeed in Mathematics A-level. This is reported by the girls as critical in their choice, and it is accomplished by a combination of strategies.

    i) Schools A, C and D have chosen to introduce more mathematics topics and qualifications alongside GCSE in the year 11 scheme of work for students who are expected to gain a grade B or above. Girls value the opportunity to evaluate their interest in some topics they would meet in A-level, to test the emotional and social effects of working on material that they have heard is 'very difficult', and to discuss with their teachers how they are coping.

    ii) Teachers in all schools make themselves available to students both in and out of lessons. Girls report that teachers know them individually, know how they like to work and accommodate this. The girls valued opportunities to check understanding by discussion with friends, by quiet conversations with the teacher and to return out of lessons if necessary.

    iii) Individual girls feel they are repeatedly and positively encouraged by teachers to choose mathematics for A-level in private conversations and in public. There is no message in these schools that lower confidence affects one's mathematics ability. Instead teachers reiterate that the girls' past performances and work habits indicate that they will succeed.

5) There are at least two respected female mathematics teachers in each school who teach year 11 top sets and A-level classes, and are cited as influential by staff and students.

6) Schools are assisted by strong family appreciation of the value of mathematics and the role of hard work.
7) Further mathematics provision is stable in each school, and supported by senior staff.
8) Recruitment for further mathematics emphasises intrinsic motivation: teachers encourage students to consider whether they enjoy working independently on lots of mathematics questions, and build an understanding that this subset should take further mathematics: a ‘motivated core’ rather than a ‘clever core’.
9) There is a belief among teachers and parents that Further Mathematics A-level is not suitable for students considering medicine; this is highlighted in career advice for girls, for whom medicine is treated as a likely aspiration.

The Study

Case studies were conducted in four state-funded schools and one Further Education college identified as making an impact on girls' participation in mathematics. Teacher and student focus groups and observations were used to examine strategies and factors that have contributed to unusually high take-up of A-Level mathematics.

The case study sites were selected by a combination of these criteria:

- asking all FMSP area co-ordinators and IOE contacts for recommendations of schools or colleges that they considered to have unusually good girls' participation;
- examining published DfE school-level data on the proportions of girls entered for Mathematics and Further Mathematics A-level in 2012-13[1];
- ensuring some diversity in region and school type, including one school where classes are single-sex to 16 (as girls' participation is higher in single –sex schools) and one FE college (as 10% of A-level students are at an FE or Tertiary college)
- preferring schools with a non-selective intake (for greater generalisability)
- willingness to participate (2 initial requests declined)

In recent years, an average 40% of those completing Mathematics A-level are girls. The imbalance is greater for Further Mathematics (FM) A-level with just under 30% being girls (lower by a few percent in FM for the state-funded sector). For this study we chose not to prioritise this measure since the focus was on increasing girls' participation rather than comparison with boys'. Instead we used the measures given for England by the DfE: the proportion of girls completing mathematics and FM A-levels out of the cohort aged 16-18 who completed at least one A-level that year. On this measure, in 2012-13, all selected sites exceeded average performance:

2012-13	Number of students in A-level cohort	Number of Female Students in A level cohort	% of Girls completing Mathematics	% of Girls completing Further Mathematics
England	261,468	143,303	20.4	2.4
England (State-funded sector)	227,294	126,390	18.4	1.8

[1] DfE. (2014a). *A level and other level 3 results: academic year 2012 to 2013 (revised)*. Retrieved from https://www.gov.uk/government/statistics/a-level-and-other-level-3-results-england-2012-to-2013-revised

Three of our case study sites have asked to be named in this report, while two have pseudonyms.

The case studies are sited in the North-West, South-East, East Midlands and London, and have the following characteristics:

	Area	Gender	Type	Size of A-level cohort in 2012-13	Decile for % of Girls completing Maths (state sector only) in 2012/13	Decile for % of Girls completing FM (state sector only) in 2012/13
School A (Shenley Brook End School, Milton Keynes)	Town	Mixed	Academy	100-150	10 (10)	9 (10)
School B	Inner city	Girls to 16 then mixed	Voluntary Aided	Under 100	9 (10)	8 (8)
School C (Beauchamp College, Oadby)	City conurbation	Mixed	Academy	Over 300	8 (9)	7 (8)
School D	Outer city	Mixed	Academy	100-150	10 (10)	8 (9)
College E (The Manchester College)	City	Mixed	FE college	100-150	8 (9)	8 (9)

It is noticeable that few of these schools fall in the top decile for Further Mathematics entries, even when we exclude independent schools from the comparison. This results from our decision to avoid schools where internet searching suggested a history of selective intake. Many of the state-funded schools in the top decile are over-subscribed former grammar schools and we considered them less useful for determining how most schools can increase participation.

The research questions driving the study in each case are:

(1) How is girls' participation in mathematics related to their prior attainment in mathematics?
(2) Are there any intentional strategies addressing girls' participation in mathematics or STEM recruitment more generally? How are these conceived, operationalised and evaluated?
(3) Are there aspects of mathematics pedagogy that support girls' self-concept, enjoyment or interest in studying mathematics?

(4) Are there aspects of careers or teacher guidance that support girls' self-concept, enjoyment or interest in studying mathematics?
(5) What messages are current in school culture about who does mathematics?

Initial visits were made over a term in autumn 2014 to carry out the following data–collection methods at each site:

1. A 50 minute focus group of 3-5 mathematics teachers, including the head of KS5 mathematics, exploring their strategies for retaining girls in mathematics and their responses to contributory factors of pedagogy and guidance identified in the literature review.

2. Compiling quantitative data on mathematics class size, module choices and mathematics AS or A-level grade profile by gender for year 12 and 13 students for the years 2013-14 and 2014-5.

3. Observation of an A-level or GCSE mathematics lesson with a schedule based on factors identified as promoting participation.

4. A 50-minute focus group with five year 12 girls who chose to study A-level mathematics exploring their experience of mathematics classrooms, their perceptions of mathematics as a gendered subject and their reasons for choosing whether or not to continue.

5. In schools A-D, a 50 minute focus group of five year 11 girls predicted A* to B in mathematics GCSE with the same structure as above

Data was collected in the form of field notes and transcriptions.

Follow-up visits in autumn 2015-16 will confirm the stability and extent of the trends observed, provide data related to transition between year 12 and 13, and gather evidence of any new initiatives or further reflection on girls' participation.

Case Studies

Case Study School A: Mixed, Town Comprehensive

Shenley Brook End Academy

Shenley Brook End is a large, mixed comprehensive 11-18 converter Academy of about 1500 pupils. It recruits largely from its catchment - a district of a large town – and is a popular over-subscribed school. There is some movement of students for A-level, both in and out. In 2013 it lay in the fourth quintile for proportion of students with free school meals. The proportion of students from minority ethnic groups is higher than the national average but not a majority; most students are of White British origin. It has a history of involvement in mathematics, having previously been a Mathematics and Computing Specialist school and now involved in leading a maths hub.

In 2012-13, over 100 students completed at least one A-level; out of these, just under 40% of girls sat Mathematics A-level and just over 40% of the boys. Numerically the mathematics classes had slightly more girls than boys. This balance was the same for further mathematics numbers, with just over 5% of girls and 5% of boys taking the full A-level. The school was selected for this study on the basis of having nearly double the national average percentage of girls taking mathematics and further mathematics.

The data more recently collected shows that 2012-13 was in fact particularly strong for girls' participation. Since then, there have been more boys than girls in the mathematics classes, and numbers remain equal, though small, in the further mathematics classes. At the moment we would characterise the school as having consistently good and sometimes excellent participation of girls in mathematics and further mathematics compared to other large, mixed comprehensive schools.

Organisation

The school offers five different mathematics-related AS-level options in year 12: Mathematics with decision mathematics (D1), Mathematics with mechanics (M1), Mathematics with statistics (S1), Further Mathematics (C1-3 + FP1, M1,S1 & D1) and Statistics (S1, S2 & S3). Many more boys than girls choose the mechanics and decision options and this is understood by the teachers as resulting from the association with physics and computer studies A-levels, reported as predominantly male choices. More boys also choose the Statistics AS-level, predominantly those with GCSE-grades at C or below. This can be explained by the school encouraging students with lower GCSE grades into Statistics AS-level and the national trend that more boys than girls with such grades choose to continue with mathematics. This leaves the relatively high participation of girls overall manifesting itself in Mathematics with statistics and in Further Mathematics, where girls form 50% of the classes.

Students start Key Stage 4 programmes in year 9. In mathematics, students are taught in five sets per half year group, preferably with the same teacher throughout. As well as

GCSE mathematics, most students in both top sets are prepared for AQA Level 2 Further mathematics and the students in sets 2-3 are taught GCSE Statistics. There is a degree of individual choice allowed by the department and some top set students work independently on Statistics instead. This preparation is significant for two reasons: students explain that they know what is involved in Mathematics A-level: "I think that the one that probably appeals to me most is probably maths with statistics, because it's the same as maths now"[2], and teachers see it as having particular benefit to girls because they need encouragement: "a bit of a taster of what is to come, and if anything it gives those unconfident girls a bit of 'I can do this'. It's a stepping stone. 'I can actually do this'." Teachers are committed to giving the majority of pupils from year 9 onwards experiences of challenging mathematics and they explicitly connect this to aiming to inspire further study.

Initiatives/promotion:

The department reports no initiatives targeted specifically at girls; instead there is a background culture of promoting engagement in mathematics. There is a scheduled mathematics visit or trip for each year group. The year 10 trip to Alton Towers for top sets is designed as an introduction to Mathematics A-level. Both staff and students reported this trip as appealing to girls and informative about A-level options. Beforehand, students attend a 1.5-hour after-school session where they are introduced to problems from mechanics, statistics and decision mathematics that they will solve during the visit. Afterwards, some lessons are given over to groups planning their own theme park, with the prize often won by girls.

The school gives clear careers messages that mathematics is a subject that opens doors and has practical relevance, facilitated by a mathematics teacher having a pastoral role for years 12 and 13. By year 11 students had researched university courses and found that mathematics was necessary for a range of careers including the forces and sports science. Students received strong, ongoing support from particular teachers: "I found that they were encouraging. They said it would be a good idea. They kept on saying it would open up opportunities. It's an all-round subject. Goes with everything." They worried that mathematics was known to be hard but were reassured that all students in the top sets could succeed. Most girls had also considered further mathematics, where the teachers' encouragement is experienced as more conditional, taking the form of asking whether the student feels personally motivated to tackle lots of questions.

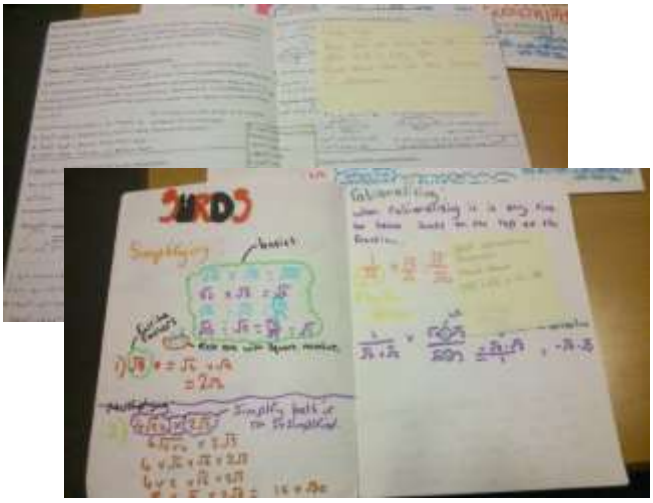
Teaching culture

Mathematics teaching in the school is considered strong. There is an emphasis on providing challenge and not giving students "something they find straightforward". Teachers recognise that students are uncomfortable with this, and that they need to build confidence, particularly for girls: "I've got the top year 11 this year and I am spending a lot of time, a lot of lunch times, just talking to the girls. And they have got the 'Can I do A-level?" attitude.

[2] The quotations in the report are taken either from the focus groups with year 11, 12 and 13 girls, or from teachers. The teacher's gender is not given as in some cases this could identify the teacher in the department.

‘Am I capable of it?’ And I am doing a lot of ‘You are capable of it. You are a perfect A-level student.’ It's a lot of that. It's almost like I need to tell them they’ve got the confidence.”

Girls in the school feel that teachers give the same messages to boys and girls about mathematics attainment. They know of at least two female mathematics teachers who take higher level GCSE and A-level classes. Girls feel that boys’ behaviour in mathematics lessons tends to be more public than their own in aspects such as asking for help, comparing achievements and claiming knowledge, but explain these differences as social preferences that may be counterproductive for learning. Both teachers and students value teachers who use their knowledge of how their students learn; such as purposefully directing questions to quieter students and making time in the lesson for individuals to ask for help more privately. The long-term relationship with the same teacher contributes to a sense of mutual trust: “she treats everyone in the class equally, so you don’t feel undermined by other students and you feel that...you can do exactly as much as all the other students can do.” Many students report that the teacher “lets you go your own way and helps you because she knows what you like to do.”



One teaching and learning initiative that staff consider influential in supporting girls’ self-concept in mathematics is the use of reflection books through years 7 -11, in which students are asked to produce one-page summaries of their learning. Staff noticed that many girls created thoughtful personalised records. The girls also commented on these as resources that supported their resilience in overcoming challenges: “Instead of redoing it, I can just use that reflection from say Year 9, when I understood it then, if I forgot what it's about. As you move on it's like you're producing your own revision guide. Because it's all about how you’ve understood it and you’ve interpreted it.”

Summarising factors in the school’s success

Three related factors ensure the school’s success in recruiting girls to A-level mathematics:

- Teaching at the school prepares many Key Stage 4 students for A-level mathematics and provides connections with A-level content that demystify reports of its difficulty.
- Students feel that a range of different ways of learning mathematics are valued and supported by teachers, and will lead to success.
- Careers advice in the school starts early and promotes mathematics as keeping options open, with a particular emphasis on the broad career relevance of mathematics with statistics.

Boys and girls take further mathematics in equal numbers in the school. However teachers feel that girls’ participation is restricted by the requirements of universities and the view that further mathematics narrows careers options, specifically for medicine.

Case Study School B: Single-Sex to 16

School B is a federated (nominally catholic) comprehensive in an inner-city area. Unusually, it comprises separate boys' and girls' schools 11-16, together with a mixed sixth form – over 1500 students overall, with similar numbers of boys and girls. The proportion of students eligible for pupil premium is over twice the national average; about half have English as a second language. It recruits from an area that includes other (non-denominational) comprehensive mixed and single sex schools. The girls' school is seen to be more successful than the boys'; the sixth form is also seen as successful although many more academic students go elsewhere at 16, there being multiple choices easily accessible. About 25% of students are of White British origin with an above average proportion of students from minority ethnic groups, the biggest of which is Black British African.

In 2012-13, fewer than 100 students completed at least one A-level; out of these, under 40% of the girls sat Mathematics A-level and over 40% of boys. 3% of the girls took Further Mathematics A-Level, and 10% of the boys. The school was selected for this study on the basis of these above-average proportions of girls taking mathematics and further mathematics in a large, comprehensive school.

The data more recently collected shows that girls' participation in the mathematics classes has been variable but similar to 2012-13, and teachers report that in most years, but not all, boys' participation only slightly exceeds girls'. In some years further mathematics participation is comparable, in others there are only boys. Girls' participation in 2015-16 promises to be particularly strong, with an outstanding cohort of girls in the top set staying into the sixth form and choosing to study mathematics and/or further mathematics. At the moment we would characterise the school as having consistently good and sometimes excellent participation of girls in mathematics and further mathematics compared with other large, mixed comprehensive schools.

Organisation

The school usually offers two classes for mathematics AS (different option blocks), both studying C1, C2 and S1. Further Mathematics AS is studied in parallel, with FP1, D1 and S2. Drainage between years 12 and 13 is usually significant, largely because of failure in other subjects. In year 13 they continue with two smaller teaching groups, studying C3, C4 and M1 for A-Level Mathematics and FP2, M2 and either D2 or FP3 for Further Mathematics, the latter a guided choice by students depending on their mathematical fluency. Further mathematics is normally regarded as a choice for the enthusiastic and interested, rather than the exceptionally able. All post-16 mathematics classes, and many KS3/4 classes, have more than one teacher. Combinations with mathematics are very varied, in part explained by a well-recognised trend that able scientists, particularly girls, go elsewhere at 16 to continue mathematics and science because of challenges in keeping effective science teachers.

Girls in the sixth form are generally recognised as being more robustly confident than boys in relation to their academic work – apart from new arrivals to the country, although most of those quickly settle. Teachers (and the Head of Sixth Form) attribute this to single sex classes to 16, where girls are overall more successful than the corresponding boys' classes. Year 11 and 13 girls interviewed certainly appeared to have no doubt they were "relatively good at maths" and to be confident to enter a range of career domains including those traditionally male-dominated.

Until recently many students would take mathematics GCSE early and sometimes repeatedly and then concentrate on studying for other GCSEs, sometimes taking Statistics GCSE if their mathematics understanding was perceived to be strong. All teachers interviewed expressed pleasure that this is no longer possible except at the end of year 10, which management generally considers a risk to accountability indicators. They are still debating taking 'two bites at the cherry' by entering year 10s to the upcoming GCSE, since it is recognised to be harder. Mathematics teachers considered early entry, whatever the reason, a risk to long term robustness and depth of mathematical understanding.

Continuity of staffing is not the first priority for the Head of Department, although he recognises its merits. He, and the Head of Sixth Form, consider the mathematics department to be strongly staffed, with some exceptional teachers who support students in "almost out-performing themselves" at GCSE. He notes that this can cause problems (and tensions) for mathematics A-level study: the school has a policy of open-access-with-a-B, and some students with the required grades lack secure understanding. The Head of Department currently prioritises suitable staffing and structure for boys' classes, since it is they who are considered to be underperforming at GCSE.

Initiatives/promotion:

The department reports no initiatives targeted specifically at girls; there is however a strong mathematical ethos in the department and a number of small-scale initiatives to promote engagement and celebrate success. In recent years trips outside school have been pruned severely, as a school policy to allow more teaching time, but the department runs trips to local universities in the sixth form, and there is a year 10 'Engineering club' well-supported by girls in particular, and supported by undergraduates from a prestigious university. Year 11 top set mathematicians of both genders also benefit from support by a retired don living locally.

There are clear careers messages in the school that mathematics is a subject that opens doors and has practical relevance. Year 11 students described it as a "facilitating subject" following career guidance sessions with the Head of Sixth Form. All students interviewed chose A-Level courses primarily by enjoyment, though where a career path was espoused they had some guidance from staff and older students about sensible combinations of subject. All felt their mathematics teacher had positively encouraged them to continue with mathematics, and some expressed it more strongly: "In our set, there's no choice – anyone who's going to look (teacher) in the eye, is doing AL maths, and they're staying here to do it unless they've got a very, very good reason' (year 11 student). This apparently served to

boost students' confidence they could succeed, even though they knew from results, displays and talking with teachers that A-Level mathematics was relatively hard. The Head of Sixth Form feels post-16 participation in mathematics is least valued by white British parents, with a high value being given by other ethnic groups.

Teaching culture

Mathematics teaching in the school is considered strong. Students are aware of several female mathematics teachers who take higher level GCSE and A-level classes, and the mathematics corridor has a disciplined, mathematical flavour in which displays (for example, of ways to approach problems) are clearly read and applied. Hard work is valued by teachers and girls ("sometimes the boys don't know what work is"). All teachers give freely of their time to support students of both sexes, but one teacher (of year 11 top set girls) is outstanding in this regard. Teachers felt the current GCSE stretches students towards the end, but that most students did not need to think overly hard to get a respectable mark. They felt obliged to "teach to the test" in that regard, even while recognising this was not always in students' long-term interests. Most teachers are happy to try innovations, for example establishing routines that build expectations of greater challenge but as above, this was usually targeted at boys.

Girls were happy to learn in single sex classes to 16, and found no significant difficulties in mixing thereafter, although they described many of the boys as "rather immature". They did not identify differential teacher treatment of boys and girls except to deal with this. There was no recognition of mathematics as gendered within the school, although some career stereotypes were recognised and dismissed. A recent external observation of gendered behaviour in the sixth form found girls if anything more confident than boys to participate in lessons across the curriculum, including mathematics. Girls felt teachers through the school knew them well as individuals both socially and mathematically, and taught them accordingly: they particularly valued teachers who challenged them and worked them hard, and who had high expectations of themselves and of students.

Summarising factors in the school's success

There are two factors that account for girls' high participation in mathematics:

- Mathematics teaching, and single sex grouping, in the school inspire confidence and although the school is focused on exam performance in KS3/4, some mathematics teachers are aware of disadvantages for students' mathematical understanding when students are not challenged, and are able to mitigate some of this.
- There are particular (female) teachers in the school who act as personal champions for the group of top set girls and their future participation in mathematics, both within the student group and in the department.

Further mathematics also gains from the popularity of the mathematics department and is seen as a secure second AS-level subject, especially by students recently arrived from abroad.

Case Study School C: Upper School

Beauchamp College

Beauchamp College is a large, comprehensive 14-18 converter Academy of about 2000 pupils. It recruits locally within a city conurbation and is seen as one of the more successful schools in the area. In 2013 it lay in the lowest quintile for proportion of students with free school meals. The majority of students are from established minority ethnic groups. Mathematics is a strong department in the school, which is involved in leading a maths hub. In 2012-13, several hundred students completed at least one A-level; out of these, over 25% of girls sat Mathematics A-level and around 40% of the boys. Numerically the mathematics classes had nearly twice as many boys than girls. This ratio was similar for further mathematics numbers, with 2% of girls and 4% of boys taking the full A-level. Despite the prevalence of boys, the school was selected for this study on the basis of recruiting above-average proportions of girls to take mathematics and average proportions for further mathematics in a very large comprehensive school.

The data more recently collected shows that girls' participation in mathematics has risen, and almost equal numbers of boys and girls currently take AS- and A-level. This has not extended to further mathematics year 12 recruitment which remains below 30%. We would characterise the school as having consistently strong participation of girls in mathematics, and average participation in further mathematics compared to other mixed state schools.

Organisation

The school offers two mathematics options: Mathematics with mechanics and statistics (S1 in year 12, M1 in year 13) and Mathematics with Further Mathematics (C1- 4, FP1, S1 in year 12 then M1, M2, S2, FP2 -4 in year 13). Mathematics appears in every timetable block and most classes have a similar gender balance, with a few being predominantly male or female because of other subject combinations. Teachers value the lack of choice in applications as they notice an initial student impression that the mechanics module will be less interesting for girls, not borne out in teaching. The statistics module is taught in year 12 because of its all-round popularity through connections with subjects such as Psychology and Sociology. There is also the opportunity to start AS-level Further Mathematics in year 13, and here the proportion of girls (36%) is slightly higher than for two-year FM. The main rationale for this class is to support those who decide during year 12 to study economics at university (although any students with A grades in maths may enter) and it is promoted actively by the department, in part to secure its existence.

In KS4 mathematics, the three parallel top sets (out of five) are prepared for AQA Level 2 Further Mathematics concurrently with GCSE. There is a strong expectation that all students in these sets will continue to A-level, and the Level 2 Further Mathematics is explicitly framed as the start of that process, with students who choose not to study it being asked to move down a set. The girls reported this as a social pressure that succeeded in converting doubters: "like further maths, because it's part A-level, so they saw the course

and they knew that they wanted to do it." The Level 2 course is required for A-level FM entry but not for mathematics which also recruits substantially from sets 2 and 3.

The GCSE profiles of girls and boys studying A-level Mathematics are similar for A* and As, supplemented by more boys with B grades (the minimum requirement). Staff report that able girls more "often feel the need to be really, really good at it [mathematics]". Level 2 Further Mathematics is seen as important in familiarising students with challenge and establishing confidence: "you're supposed to find it hard. It's supposed to be difficult. If it's easy it means you should have moved on." The girls report themselves as cautious in assessing future workloads, rather than lacking confidence, and value the extended opportunity to discuss the nature of A-level topics and test their responses.

Year 11 girls are similarly cautious about the difficulty of further mathematics and its 'exchange value': what it is worth in the currency of qualifications for university courses. Hesitations are compounded by the requirement to choose it as a fifth A-level which "also puts pressure on you, because you're doing a lot more. And the step from GCSE to A-level is a lot. And the amount of work you have to do and fit around your life outside school, it's quite difficult I think. I think that scares you because you can only do it like that." Year 12 girls believe that it has less currency for universities "especially courses that girls want to take […]: a lot of them would only consider one of the two grades anyway."

Initiatives/promotion:

The department reports no initiatives targeted specifically at girls (although girls do mention some in science). Girls report a message of high aspirations that is echoed by parents, peers and the school. It is assumed that they will apply for good universities and do well: "which means taking maths, because you need maths if you want to go to those places". Mathematics is valued as a currency that keeps their options open and is a gateway to specific careers, including medicine, optometry, food nutrition, youth work, forensic science, and physics. Both staff and students call on examples of girls in the school who have achieved very highly in mathematics.

The girls' rationale reflects a conscious departmental message about the future utility of mathematics that is promoted through extensive corridor displays and speakers on open days: "these people have studied maths and this is what they do; and this is what you can do. Trying to show them how many more jobs perhaps require a certain level of mathematics that they wouldn't necessarily assume was the case." The messages refer to both GCSE and A-level topics, raising the overall profile of mathematics for all. The diversity of careers and mathematical topics shown matches the recommendations from the literature for effective promotion.

The girls have been offered girl-only, out-of-school Physics and Engineering initiatives fairly regularly through their secondary education and there is some disagreement about whether mathematics is one of these STEM subjects who need actively to address a shortage of girls. One girl cited both an inspiring teacher and a desire to challenge constraints as her reasons to study science. In line with the research evidence that questions the effectiveness of stereotype-opposition messages, the group response is that this requires unusual emotional resilience: “But then you see you're probably quite a strong minded person to think that way, that you want to rebel against it – which is good for you; but unfortunately most girls I'd say would probably just...Yeah, they want to escape it rather than fight it...the stereotype.”

Overall the popularity of mathematics for A-level among girls is down to the message of all-round success given in the school: “Because girls take maths needless of their gender; there's no need for positive discrimination in this college because it's such a good department that girls and boys both take maths.” They are inspired by the number of women teachers that they see in the mathematics office, although they are clear that it is the quality of a teacher and the teacher-student relationship that matters more than gender.

Teaching culture

Students enjoy mathematics lessons because they are successful with the work and like the purposeful classroom environment enlivened by discussion. The teacher is the most important factor cited for enjoying mathematics: although they expect to think for themselves in doing questions, they appreciate when the teacher motivates them or is “playful” by including real life connections and anecdotes about history. The school gives the message that you can be enthusiastic and curious about mathematics. There are regular recreational mathematics events such as the UKMT and FMSP challenges, a maths carousel competition and a weekly maths society. Although they may not attend the extra-curricular events, they are made aware of them. For example, one teacher brings maths society problems into normal lessons: “he’ll tell us a problem at the beginning sometimes and then everybody just talks about it in the lesson...like how do you do this? And then like whilst doing their work kind of thing.”

In lessons, girls feel that they are equally able in mathematics as boys and don’t lack confidence. Nevertheless they say they make judgements based on personal encouragement from teachers that they are making the right choice, and previous experience of being able to access help if they need it. The mathematics department’s open door policy and attitude of “really caring” is a factor in their choice. This importance for these girls of making the right informed choice is underlined when they suggest that they lack positive reasons to do further mathematics. They feel that only a few students are explicitly approached by teachers to choose it, and several were disappointed there were no taster sessions available on year 11 open day: “All I was told is it's so much harder. And I wasn’t really told about a lot of the benefits of it really.” This contrasts with the emphatically inclusive message about Mathematics A-level.

Factors in the school's success

In summary, there are two related factors in the school's success in recruiting girls to A-level mathematics:

- Teaching at the school launches able Key Stage 4 students into A-level mathematics and makes participation feel expected, personally achievable and pleasurable.
- Careers advice promotes mathematics as relevant and essential for keeping options open and achieving career goals, confirming girls' judgements in their subject choices.

More boys than girls take further mathematics in the school, and this is associated with a perception that students feel they need to provide their own impetus to choose it.

Case Study School D: Rapid Improvement in Mathematics

School D is a large, comprehensive 11-18 converter Academy of over 1000 pupils in an outer city area. There is also a Primary department of a similar size. It recruits largely from its catchment – a suburb that is often a first move from more stressed inner city areas – and is seen rapidly improving. It has an above-average proportion of students with free school meals. The vast majority of students are from minority ethnic groups, with about 10% in the early stages of language acquisition. It has experienced substantial improvement in recent years, gaining 'outstanding' in its last full inspection and going from strength to strength in terms of measurable outcomes since then.

In 2012-13, over 100 students completed at least one A-level; out of these, just over 60% of the girls sat Mathematics A-level and just over 70% of boys, but similar numbers of each. In further mathematics, over 3% of girls and the same of boys took the full A-level. The school was selected for this study on the basis of these above-average proportions of girls taking mathematics and further mathematics in a large, comprehensive school.

The data more recently collected shows that since 2012-13 participation in mathematics post-16 has continued to thrive, currently with 82 students in year 12 mathematics (two-thirds of the cohort) and 52 of 72 Mathematics AS-level students continuing to year 13 (5 setted classes in year 13, and 7 in year 12, plus two further mathematics classes in each). Overall, numbers taking mathematics in recent years have been similar for boys and girls, although some years have seen significantly more boys taking further mathematics, which is regarded as an extra for the very interested. At the moment we would characterise the school as having excellent participation of girls in mathematics and further mathematics compared with other large, mixed comprehensive schools.

Organisation

All mathematics groups take C1, C2 and S1 for AS and C3, C4 and S2 for A-Level, but many start work on C3 in year 12. The choice of Statistics only is intended for accessibility. Further mathematics students take FP1, FP2, and usually D1, D2, M1 and M2, though modules vary slightly by year.

A very distinctive feature of the department is that students take GCSE mathematics from year 8 on, whenever the school feels they are ready to achieve at near target grade. Many will retake GCSE to get a higher grade, but most end year 11 with at least one additional qualification, whether Statistics GCSE, Level 2 Further Mathematics, level 3 Additional Mathematics (top set only), or C1. For example, the year 12 students from set 5 of 7 A-Level sets had all passed Level 2 Further Mathematics. Teachers and students feel this gives them a well-founded belief they can succeed in mathematics, and a head start to AS/A-Level. There are nine sets per year group, and by the start of year 11 all except the lowest two groups will typically have at least a C grade at GCSE. Students in set 7 are confident to voice their wish to do AS Mathematics, and to attempt to get the requisite A

grade. The department does admit, and support, B grade GCSE students by personal decision. Year 11 students are generally confident they know what is involved in AS/A-Level Mathematics since they have met some of the material; they have also already experienced success compared with other subjects. Continuity of teacher is not a high priority, and would be difficult to achieve, given very high turnover of teachers. However, mathematics classes throughout the school, including at A-Level, generally have just one teacher for the year.

Initiatives/promotion:

The department reports no initiatives targeted specifically at girls, and seemed unaware they are particularly successful at attracting girls into post-16 participation, although they are clearly recognised as a highly successful department overall. They take sixth formers on university-organised mathematics days, and the main school offers opportunities to participate in a variety of in-school enrichment events and competitions, although participation in competition is, as is the case nationally, more popular with boys.

There are clear careers messages in the school that mathematics is a facilitating subject: year 12 students could quote a number of jobs that needed mathematics from KS4 careers information. They had also already engaged with university requirements for their planned careers, with most knowing what those were and having chosen their A-Level subjects accordingly. Both students and teachers recognised the department as proactive about encouraging more successful students, in particular, to continue with mathematics, and teachers say girls are more likely than boys to consult them about such choices, but also more likely to need reassurance that they can succeed post-16. KS4 post-GCSE success is frequently used as a means of providing that reassurance. Encouragement for taking further mathematics is much more selective: it is perceived to need an unusual degree of interest and commitment (though not exceptional prior attainment) given the dominant place mathematics then takes in a student's timetable.

Girls and teachers identified the school's multicultural background as both highly aspirational for their children's mathematics attainment at GCSE and beyond, and highly supportive of continued participation in mathematics post-16. Hard work as a key to success is also reported to be highly valued in the vast majority of homes.

Teaching culture

Mathematics teaching in the school is considered strong, and there is a large number of "successful" female teachers of mathematics, bringing what teachers describe as "feminine habits" (of detailed organisation, colour coded boardwork) that they feel gives role models girls can identify with. Girls are more proactive than boys in seeking to work with, or move to the classes of, teachers they know they can learn well with, and this is often allowed. All students are encouraged to make use of the mathematics staffroom for support and input at nearly any time, and sixth form girls reported they had worked together outside lessons since KS3, also supporting less successful peers, and continued to do so. Teachers aim to build up challenge gradually, in highly structured ways, but the aspirations in terms of further courses pre-16 clearly provide a good range of that. The department provides very

detailed and extensive written mathematics materials for post-16 students, and girls say they feel very secure with that.

Teachers and year 12 girls recognise that boys often behave in distinctive and relatively immature ways, but do not perceive mathematics in the school to be in any way gendered – rather, that teachers try to respond to individual needs. Girls feel well-known to their teachers both mathematically and socially, despite a general lack of continuity in teacher. They recognise work-related gender stereotypes but feel they are not deeply espoused by the communities from which they come.

Summarising factors in the school's success

There are several related factors in the school's success:

- Students are emotionally and cognitively prepared for A-level by a Key Stage 4 curriculum that builds up challenge gradually, in highly structured ways.
- The school confirms family messages that many students will need mathematics in their careers; and adds a message that the majority of students can succeed in mathematics, and encourages them to aim for A-level from KS3 onwards.
- Girls feel that they are known by their teachers and that their personal work habits are attended to.

Further mathematics is not presented as much more difficult than mathematics. However recruitment focuses on a narrower range of those who display marked interest.

Further Education College E

The Manchester College

The Manchester College is a large inner-city College. It recruits from a very wide catchment including outlying rural areas and is seen to be upcoming. The large majority of its students come from areas of high economic and social disadvantage, and are from minority ethnic groups; a significant minority are recently arrived, with very limited English.

In 2012-13, over 100 students completed at least one A-level; out of these, just under 30% of the girls and just over 55% of boys sat Mathematics A-level, though numerically there were similar numbers participating. 3% of girls completed Further Mathematics, and 10% of boys. The college was selected for this study on the basis of these above-average proportions of girls taking mathematics and further mathematics for Further Education colleges, where participation tends to be relatively low[3].

The data more recently collected shows that since 2012-13 girls' participation has generally been numerically less than boys', though still at a good level for FE while the present year 12 shows roughly gender-balanced, and increased, participation of over 100 students (in a bigger cohort of around 150). In further mathematics, participation is generally greater by boys, although usually more girls than boys pick up AS Further Mathematics in year 13, when they've become "hooked" on it. This teacher adds "we don't push further mathematics – it's a specialist pathway." For a Further Education college we would currently characterise it as having consistently good participation of girls in mathematics with some participation in further mathematics.

Organisation

The college in recent years had 2 or 3 Mathematics groups in year 12, plus one Further Mathematics group, and these generally roll over into year 13 although they shrink. There is some continuity of teacher, but just one teacher has responsibility for each group. This year there are six Mathematics groups in year 12, organised as three sets in two option blocks, plus two Further Mathematics groups in different blocks. The gender balance varies considerably between groups. Grade B at GCSE is required for entry to AS Mathematics, although significant numbers of students come from other education systems; typically, of those who have GCSEs, about half have grade B and half grade A/A*. Students typically take S1 in AS and either S2 or M1 in year 13, but it does vary by student. In further mathematics the applied modules taken vary, depending on interest and background.

In any mathematics classroom students will typically be working on several different foci, perhaps in pairs, and supported by a textbook, with the teacher pulling together a group of students when a common challenge emerges. Response to individuals is highly valued, with students recently come from different countries encouraged to carve an individual

[3] In 2013-13, 14% of the female cohort in FE or tertiary colleges took mathematics and 1% took further mathematics

programme. Similarly, timetabled further mathematics classes are attended by single mathematicians and year 13 classes attended by year 12 students because of the support available; teachers will often offer additional support during a 'free period' either in an empty classroom or in another teacher's class.

Initiatives/promotion*:*

The department reports no initiatives targeted specifically at girls; instead there is a background culture of promoting engagement in mathematics, and science and technology employment opportunities in the area are expanding rapidly, which might in part account for increased participation. However, the college does monitor participation by gender and actively evaluates promotional literature for gender bias. One teacher is Science, Technology and Engineering coordinator, and organises a considerable number of enrichment events, both in college and beyond, for example a "reverse engineering" day for all Mathematics, Computing and Physics students. The department also organises training and activities for accredited year 12 student "STEM ambassadors", who work with Primary students to promote STEM activities, in the process developing significantly in their appreciation of those areas, and STEM-related identities, themselves. Such opportunities are open to all year 12 STEM students, and about half these 'ambassadors' are usually girls. The local universities are proactive in providing STEM-related outreach activities, including for those perceived as the "most able", and this teacher is very active in both promoting those to students and soliciting feedback and reporting afterwards. Follow-up publicity in the college and beyond helps to give STEM subjects a high profile in both the immediate and wider areas.

There are clear careers messages in the college that mathematics is a subject that opens doors and has practical relevance, and the large school liaison team supports young people in greater awareness of STEM opportunities, and also in making pathway, rather than just subject-driven, choices. These include messages that further mathematics is important for mathematics-intensive courses at the more competitive universities. Most young women interviewed had chosen mathematics for very positive satisfaction reasons, but also because they knew it to support very clear career goals. They had had very mixed experiences pre-16 with mathematics although many had encountered a very effective and enthusiastic teacher at some stage; they clearly felt confident to succeed in mathematics, even if via very hard work. Most had already researched university courses and talked fluently about their options, clearly influenced and informed by older siblings/cousins or peers.

Teaching culture

Mathematics teaching in the college is considered strong, and historically has always included teaching by a young, lively and effective female teacher. Students talked about the importance to them of positive relationships with teachers, and of feeling well-supported, and expressed great confidence in the effectiveness of the range of permanent teachers of mathematics at the college. Students largely do not work together outside lessons since they do not stay in college, but do habitually depend on one another during lessons, and felt they were encouraged to use peers as a first resort and teachers as a second. As described above, the ethos is one of a high degree of individualisation, and students feel well-known and individually valued. They recognise mathematics as a relatively demanding A-Level subject but also articulated the satisfaction of making progress from being stuck.

Girls talked about the importance of a culture of hard work and of valuing of mathematics; some were quite scathing about what they identified as a "mainly white British culture" of "anything goes", and "it's smart to be a blockhead/dumb down", seeing those as attitudes which did a disservice to young people in the medium term. In contrast, they largely described their own families as supportive of their subject choices, but with associated high expectations, especially of effort. Neither they nor teachers recognised a gendering of mathematics at the college, but again associated it mainly with a white British stereotype and felt confident and supported to pursue their personal preferences. College teachers felt there was a greater problem with gendered A-Level participation in some Arts subjects, for example English. The mathematics corridor celebrates achievement overtly, with a reasonable balance of gender displayed.

Girls felt relationships with teachers, security, structure and contextualisation/stories were all valued more by girls than boys, and spoke highly of college teachers in these regards; teachers said they went to some effort to expose the department ethos when school students visited for open days, since "it's important they feel they can fit"; students reported they felt "well encouraged" to take mathematics by college teachers, though also aware of the demands it was likely to make. Some had had negligible input about subject choice or future pathways from their schools, so had been completely dependent on college or family/friend interactions to make those decisions.

Summarising factors in the college's success

Clearly an FE college has different strategies from a school in that they cannot 'grow their own' mathematics students in the way that the four previous case study schools have aimed to do. This college has:

- Developed an identity for itself that is centred around engineering and technology employment opportunities, and is recognised within the college and in the local press;

- Invested in personal careers advice for new students, and for prospective students at open evenings, emphasising pathways in which mathematics is an essential companion or central subject;

- Created an atmosphere in which students find it easy and rewarding to take on extra work and seek help, including support for individualised further mathematics programmes of study.

Findings and Initial Recommendations

Our five case studies portray strong mathematics departments in strong, well-regarded institutions, and this is an understandable outcome of our selection criteria: we know from previous research that girls are more likely to say they will choose mathematics in schools with larger Mathematics A-level cohorts[4] and when they have positive perceptions of their mathematics lessons and teachers[5], both of which contribute to teachers and students reporting that a department is strong.

The following section identifies common features of the four schools that we consider relevant to girls' above-average participation in mathematics at A-level. There is considerable variation between the schools in size, attainment, areas of concern and atmosphere. The details of what they do are different but there are also common factors and strategies. We add when these features are also present in the practices of College E.

1) The case study schools had not been involved in specific initiatives to attract girls to study mathematics; instead there was a strong culture of encouraging students to aspire to take mathematics at A-level. Girls did not see the need for such initiatives because the dominant attitude was "we're good at it, we enjoy doing it, why wouldn't we?" In these schools there is a strong expectation, even pressure, from teachers on students that they will get a B and above at GCSE and then choose A-level mathematics. This expected mathematics pathway is communicated before year 10, and as early as year 8.
2) The school and college departments are active in promoting mathematics as a subject that has wide applicability, and so opens doors to many valued degree courses and careers. Girls in this study aspired to careers/degrees in: the forces, sports science, law, teaching, maths, maths & music, bio-chemistry, medicine , neurobiology, dietician, orthoptics, youth work, engineering, physics, computing, forensic science, aeronautical engineer, computer engineer, pharmacy and other medical sciences, and several had not yet decided. This argument is visible in corridor and classroom displays of the relevance of mathematics to careers and to 'changing the world'. Girls report it significant to their enjoyment when teachers take the time to explain how abstract mathematics topics can be applied in practical situations. It is significant to their decision making when teachers talk to them personally about their futures and the flexibility of mathematics in whatever they decide. The message repeated by girls in these schools

[4] Tripney, J., Newman, M., Bangpan, M., Niza, C., Mackintosh, M., & Sinclair, J. (2010). *Factors influencing young people (aged 14-19) in education about STEM subject choices : a systematic review of the UK literature*. Wellcome Trust.

[5] Mujtaba, T., & Reiss, M. (in preparation). Girls in the UK have similar reasons to boys for intending to study mathematics post-16.

emphasises broad exchange utility for good courses over the value of mathematics for accessing elite courses.

3) The schools and college all offer a Mathematics A-level option that includes statistics in year 12, and these teachers do not suggest that this is a less interesting or demanding option, which may suggest that they teach it well. All schools promoted statistics as beneficial because of its social-science applications, and noted that it was then more attractive to girls; one school critiqued the gender splits a free choice would produce and specified mechanics for all.

4) Teachers instil a belief that students will succeed in Mathematics A-level. This is reported by the girls as critical in their choice, and it is accomplished by a combination of strategies.

   a) Schools A, C and D have chosen to introduce more mathematics topics and qualifications alongside GCSE in the year 11 scheme of work for students who are expected to gain a B or above (and in some cases already have). In itself, this establishes habits of high expectations and hard work. The actual effect of gaining another qualification is not mentioned by staff or students. Instead the girls value the opportunity to evaluate their interest in some topics they would meet in A-level, to test the emotional and social effects of working on what is reported to be a very difficult material, and to discuss with their teachers how they are coping. In school B, the girls report similar feelings from working on the most advanced GCSE material. In school A, the trip that introduced A-level material was popular for the same reason.

   b) Teachers in all schools make themselves available to individual students both in and out of lessons. Requests for help are taken seriously. Girls report that teachers know them individually, know how they like to work and accommodate this. Teachers in the three mixed schools described only one purposefully girl-friendly teaching strategy: to direct questions to quieter students. This was observed in during whole-class teaching phases of lessons where some students, usually boys, made the majority of spontaneous comments about learning, and teachers encouraged others to contribute questions, answers or comments. The girls reported a slightly different perspective on teaching strategies: they valued teaching that gave opportunities to check understanding by discussion with friends, by quiet conversations with the teacher and to return out of lessons if necessary. In several of the schools, and in the college, it is usual for students to choose which A-level modules or year 11 qualifications they would study, and although some girls disliked the lack of whole-class teaching and organised group work that resulted, they still valued the responsiveness to individual preferences.

   c) Girls in these schools feel they are repeatedly and positively encouraged by teachers to choose mathematics for A-level in private conversations and in public. This happens without any mention of stereotypes of gendered participation in mathematics. Teachers suggest that girls lack confidence compared to boys, while girls frame this more positively as being mature and cautious in their decisions. There is no message in these schools that lower confidence affects one's

mathematics ability. Instead teachers reiterate that the girls' past performances and work habits indicate that they will succeed.

5) There are at least two respected female mathematics teachers in each school who teach year 11 top sets and A-level classes, and are cited as influential by staff and students.

6) Schools are assisted by strong family appreciation of the value of mathematics and the role of hard work. Family encouragement was brought up spontaneously by the girls who suggested that high family expectations in general were connected with continuing with mathematics. In schools B, C and D, and college E this was also linked to the high valuation of mathematics within families in minority ethnic communities. In those situations, schools had a role in providing accurate and realistic careers advice.

7) Further mathematics provision is stable in each school, supported by senior staff, with a protected place in the timetable even in years when numbers are small.

8) Recruitment for further mathematics emphasises intrinsic motivation: teachers encourage students to consider whether they enjoy working independently on lots of mathematics questions, and build an understanding that this subset should take further mathematics: a 'motivated core' rather than a 'clever core'. Even in these schools, there is less direct encouragement to take further mathematics. Some girls felt that this affected girls' participation: those who publicly put themselves forward during year 11 (mainly boys) were welcomed and increasingly referred to as motivated future further mathematicians, while those who were quieter (mainly girls) were not.

9) There is a belief among teachers and parents that Further Mathematics A-level is not suitable for students considering medicine; this is highlighted in career advice for girls, for whom medicine is treated as a likely aspiration. Some schools have responded to university requirements for grades to be achieved in year 13 and managed teaching so that the Mathematics and Further Mathematics A-levels are completed together.

Recommendations

It was heartening that the schools and colleges approached for this study showed an interest in increasing the participation of girls in mathematics. Although identified as already successful, they took the view that encouraging girls' participation was desirable for students and would benefit the mathematics department: in particular they described girls' resilience in solving problems as an ideal A-level quality. All shared the view that there were good-enough girl mathematicians who were not choosing mathematics. These were observations made during the research by individuals; at the outset the schools reported that gendered participation was not a current or priority issue. Their awareness of the national picture of girls' under-representation in STEM was mentioned - if at all – as local to physics and engineering. Their interest suggests that this may be a good time to raise the profile of strategies to recruit girls.

The study reinforces the importance of the FMSP's role in the professional development of KS4 teachers and departments. The practices identified in this research as influential for

girls' participation were considered general good practice in the case study schools. They are felt to be beneficial for all students, but differentially so for girls.

Three goals for professional development are relevant to girls' participation, and would benefit all students:

- Teachers should be familiar with A-level syllabuses and content so that they can perform their leading role in overtly orienting students towards it during years 10 and 11. Girls in these studies were heavily influenced by class teachers who could tell them what to expect of A-levels, and who highlighted during lessons how their existing mathematical ways of working would benefit them.
- Teachers should have a repertoire of mathematics activities and strategies that allow students to experience challenges and seek help without a whole-class audience, including those for individual-, pair- or group-work. Although whole class teaching and assessment are important and effective classroom strategies for promoting learning, the clear message from girls in this study is that they are not enough. Instead they value less public exchanges and support in developing their own ways of understanding and working on mathematics.
- It is important that teachers and others engaging with girls (including both parents and teachers of other subjects) give overt messages that they expect girls (and boys) to succeed in mathematics, and that this will sometimes require persistence and hard work, as well as short-term failures. Such messages are still sometimes counter-cultural. Girls in the study valued and responded to such support, but it needs to be given on an individual as well as a wider basis, particularly in relation to success in pursuing Further Mathematics.

The study also shows the importance of career advice that emphasises the relevance and broad utility of mathematics. Of course many schools convey this message; but the study schools did so in or before year 10 and with a wide range of specific examples. Several of our case study schools were already using published posters in classroom displays to promote the relevance of mathematics, but they had less developed strategies about planning for recruitment events. We recommend that FMSP should develop a limited collection of activities for use in open evenings, taster days, mathematics lessons and other opportunities to promote mathematics and further mathematics. These activities should introduce A-level topics through problems accessible to year 10 students and parents. There should be separate promotional activities for Further Mathematics that should stress its distinctiveness and variety so that it is not viewed as more of the same.

Institute of Education

Gender and participation in mathematics and further mathematics A-levels: Interim Report for the Further Mathematics Support Programme

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