# *Choosing Further Mathematics*

DR HOWARD TANNER
*University of Wales Trinity Saint David*

DR SOFYA LYAKHOVA and DR ANDREW NEATE
*Swansea University*

## ABSTRACT

'Education in the UK is failing to provide the increases in the numbers of school-leavers with science and mathematics qualifications required by industry, business and the research community to assure the UK's future economic competitiveness' (The Royal Society, 2008: 17). Furthermore, the proportion of students in Wales following mathematics courses post 16 is lower than in England (GSR, 2014). In particular, although the situation has improved, fewer students in Wales choose to study further mathematics (FM). This paper explores the reasons for student choices in mathematics and FM in order to make recommendations about how to increase participation. Phase one of the study used a questionnaire to access the opinions of students studying mathematically based courses in sixth forms and colleges to explore the reasons behind their choices and the factors influencing their progression or otherwise in mathematics. In phase two, small focus groups of students in selected schools and colleges were interviewed to enrich the questionnaire data and provide further insight into their decisions. The study identified a lack of information from peers, siblings, parents and teachers about FM as a factor restricting choice. Current models of delivery contribute to the false perception that FM is harder than mathematics and only suitable for the most talented mathematicians. We suggest: developing teachers' knowledge and skills so that whenever possible students can be offered FM as a fully timetabled subject; promoting FM to parents; and establishing student champions to encourage participation.

**Key words:** mathematics education, further mathematics, student choice

*https://doi.org/10.16922/wje.18.2.4*

*Introduction*

The study of mathematics is of benefit to both society and the individual (Mendick, 2008; Noyes, 2009). It is often described as a powerful subject and there is evidence that it acts as a critical filter into financial success and lucrative careers (Mendick, 2008; Dolton and Vignoles, 2002). However, the UK has been deemed to be failing to produce enough students with a suitable level of mathematical literacy to face the economic challenges of the future, and, when compared to other developed nations, the UK has the lowest rate of mathematics participation amongst post-16 students (The Royal Society, 2008; Hillman, 2014). Even between the nations of the UK there are differences in the uptake of post-16 mathematical courses, with participation rates in Wales below those in England (GSR, 2014). In this study we investigate the motivations and barriers for students in England and Wales in choosing to study the FM A level qualification as part of their post-16 education.

A levels are standard qualifications in England, Wales and Northern Ireland, and are typically studied between the ages of sixteen and eighteen. Mathematics, as a subject, has a special position within the A level system in that there are two separate A level qualifications available: mathematics and FM. The FM A level can be seen as broadening the mathematics curriculum by introducing new topics to students, rather than presenting mathematics at a higher level.

Currently, A level FM is among the ten fastest growing subjects in England and Wales, but this was not always the case. Following reforms to post-16 education, in 2000, participation in FM declined rapidly and the subject was no longer offered in many schools and colleges. In 2003, Mathematics in Education and Industry (MEI), an educational charity, established a five-year pilot project in England called 'Enabling Access to Further Mathematics' to reverse this decline, with the aim that every student who could benefit from FM should have access to study it. The project was subsequently followed by the Further Mathematics Network, and in 2009, by the establishment of the Further Mathematics Support Programme (FMSP). An independent Further Maths Support Programme Wales (FMSPW) was subsequently launched as a pilot programme in 2010. The main focus of FMSP and FMSPW is to provide tuition for FM A level to all students who cannot access the subject through their local post-16 schools and colleges. This is done by a mixture of face-to-face and online learning with occasional revision days hosted in a local university or college.

**Figure 1: Percentages of A level mathematics students taking A level FM in England, Northern Ireland and Wales since 2003 (JCQ, 2016)**


The impact of both FMSP and FMSPW on participation in FM has been considerable (Searle, 2009; Miller, 2014). For instance, the proportion of A level mathematics students taking FM has rapidly increased since the inception of both FMSP and FMSPW as illustrated in Figure 1 (see also Searle, 2011; Searle, 2012; Searle, 2014 and Miller, 2014). For comparison Figure 1 also includes Northern Ireland where no similar support has been established.

However, post-16 qualifications are currently being reformed again in terms of their content and structure in both Wales and England. In this environment, it is important for the future of the FM A level, 'to have a sound understanding of what drives participation and how curriculum and qualifications reform might impact upon uptake' (Noyes and Adkins, 2016).

Here we will shed light on what drives or blocks participation in FM amongst students in England and Wales, and make recommendations to improve participation. This study arose from the authors' work with both FMSP and FMSPW.

### *Mathematics and FM A level*

Mathematics is a compulsory part of the national curricula in England and Wales up to the age of sixteen, at which point students complete examinations in a range of subjects for the awarding of General Certificate of Secondary Education (GCSE) qualifications. Students gaining at least five good GCSE grades (A*–C) are usually then able to proceed to study towards General Certificate of Education Advanced Level (A level) qualifications. These are the standard entry qualifications for universities in England and Wales.

Since substantial reforms to the structure of post-16 education in the UK in 2000, the A level has been a modular qualification which normally takes two years to complete, with the first year of study leading to an Advanced Subsidiary qualification (AS level). Students may either study only the first half of the course and gain an AS level, or proceed to complete the remainder of the course (A2) for the award of an A level. Students normally select to study between four or five subjects at AS level and then drop some subjects to complete 3 or 4 A levels. Students with an interest in mathematics can therefore choose to study for either an AS or A level in mathematics and also an AS or A level in FM.

Immediately following the qualification reforms in 2000, the number of students studying both mathematics and FM declined substantially. The decline in participation in FM has been linked to the expectation that in the post-2000 system students would study four or five subjects to AS level, when previously students normally only studied three or four subjects. This created timetabling problems for schools, leading to a decline in the number offering FM (QCA, 2007a). Although the knowledge and skills acquired when studying FM are valuable for studying STEM degrees, UK universities at that time tended not to demand the FM A level in the interest of fairness, as not all post-16 schools/colleges offered the qualification.

In contrast, participation in mathematics A level is now increasing and mathematics is currently the most popular A level choice in the UK, and has been the most popular AS level choice since 2011 (JCQ, 2016). Indeed, following the creation of FMSP and FMSPW, participation in FM is also increasing. The increase in the numbers of students studying both mathematics and FM is illustrated in Table 1.

Whilst FM is an increasingly popular subject choice, it remains a relatively small subject in terms of student numbers. Due to the relatively small class sizes, some schools struggle to justify financially a teaching provision for the FM A level similar to that for other A level subjects. Some schools also struggle to recruit staff with sufficient mathematical knowledge to teach the syllabus; for instance, 24 per cent of mathematics teachers in

**Table 1. Increase in the number of students receiving AS and A level mathematics and FM qualifications in England and Wales 2003–2015 (JCQ, 2016)**

| *Qualification* | *England* | | | *Wales* | | |
|---|---|---|---|---|---|---|
| | *2003 exam results* | *2015 exam results* | *% increase* | *2003 exam results* | *2015 exam results* | *% increase* |
| A level mathematics | 46,022 | 85,648 | 186% | 2,423 | 3,735 | 154% |
| AS further mathematics | 3,189 | 26,327 | 826% | 78 | 471 | 604% |
| A level further mathematics | 5,039 | 14,298 | 284% | 147 | 514 | 350% |

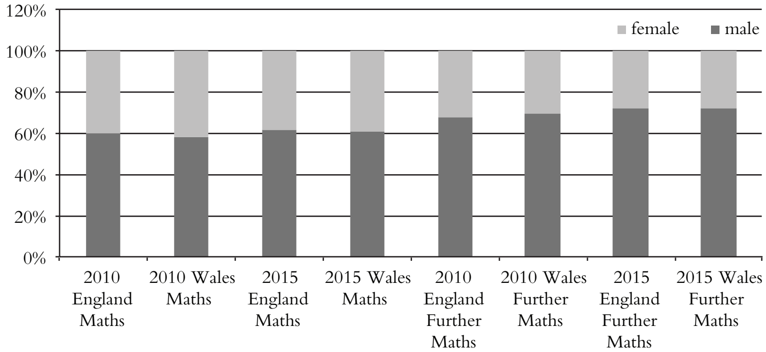
England do not hold a relevant post-A level qualification (DfE, 2015). There is a wide range of support levels provided by schools for students taking a FM course, from a fully timetabled course similar to any other A level, a partially timetabled course with support from both teachers and FMSP/FMSPW in breaks during the day or evenings and weekends, or a course entirely run through distance learning via FMSP/FMSPW at evenings and weekends. When taken through FMSP/FMSPW, FM is taught in reduced hours and there is an emphasis on self-study and independent learning.

As the number of FM students has revived, more UK universities now mention FM qualifications in their entry requirements (FMSP, 2016). Indeed, both mathematics and FM are regarded as facilitating subjects by the Russell Group universities. Some university courses now require FM, while others give FM students lower offers. This not only applies to mathematics degree schemes, but also to mathematically related schemes at some universities, including subjects such as economics, engineering and physics.

Analysis of the JCQ data shows a few notable trends in the uptake of both the mathematics and FM A level qualifications. As Figure 2 illustrates, the proportion of male and female students has remained static over the last five years with around 60 per cent and 40 per cent for A level mathematics and around 70 per cent and 30 per cent for FM, although both England and Wales have shown a slight drop in the proportion of girls taking FM since 2010.

As shown in Table 2, a high proportion of students achieve the top A* grade in mathematics and FM when compared to other A level subjects.

**Figure 2. Percentages of A level mathematics students in England and Wales by gender (JCQ, 2016).**




The fact that FM is considered by many to be the hardest A level of all, and yet 56 per cent of all grades are A or A*, is generally attributed to the higher-than-average performance of those students who take FM. This 'clever core' effect (QCA, 2007b) can be seen as a result of a system that encourages a successful core of students to progress through the mathematics stream of the education system to reach the A level mathematics courses. Indeed, a recent analysis of the UK government Department for Education's National Pupil Database revealed that in 2010, 85 per cent of students with a top grade (A*) in GCSE mathematics proceeded to study A level mathematics, whilst only 56 per cent of those with an A grade, 18 per cent of those with a B grade and 1 per cent of those with a C grade did so, creating a 'pipeline' of successful students flowing towards studying FM (Noyes and Adkins, 2016). While attainment in A level mathematics is approximately the same in England and Wales it differs substantially in FM where Wales has an even higher proportion of A* grades than England. This can be explained by the small number of Welsh students taking FM, exacerbating the 'clever core' effect.

While boys outperform girls in A level mathematics, the attainment for both genders is approximately the same in FM. The data for 2015 for England and Wales is illustrated in Figure 3.

**Table 2. Cumulative percentages by subject for England and Wales for 2010 and 2015 (JCQ, 2016)**

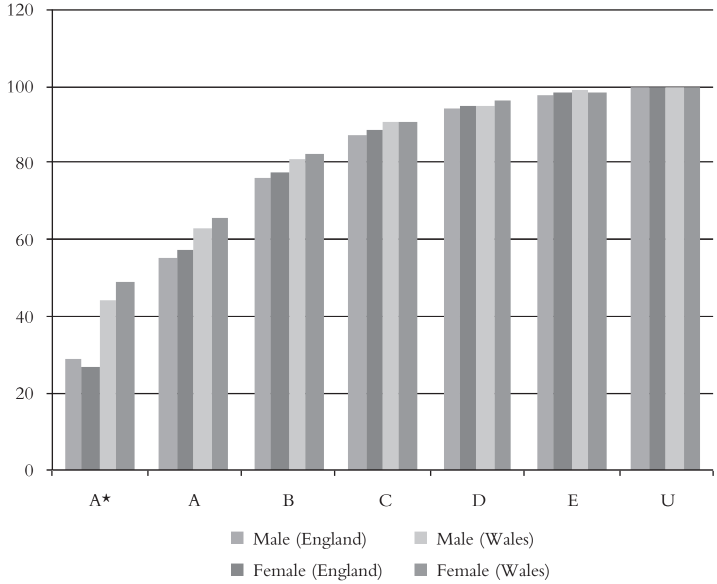
| *A level and country* | *A** | *A* | *B* | *C* | *D* | *E* | *U* |
|---|---|---|---|---|---|---|---|
| Math 2015 England | 17.8 | 41.5 | 63.3 | 79.4 | 90.6 | 97.2 | 100 |
| Maths 2015 Wales | 19 | 43.3 | 65 | 80.7 | 90.9 | 96.7 | 100 |
| Maths 2010 England | 17.2 | 44.5 | 66 | 81.4 | 91.4 | 97.4 | 100 |
| Maths 2010 Wales | 13.1 | 44.2 | 67.5 | 82.9 | 92.8 | 97.2 | 100 |
| Further maths 2015 England | 28.1 | 56 | 76.2 | 87.5 | 94.3 | 97.8 | 100 |
| Further maths 2015 Wales | 45.5 | 63.8 | 81.3 | 90.7 | 95.1 | 98.8 | 100 |
| Further maths 2010 England | 29.5 | 58.6 | 78.6 | 89.8 | 95.4 | 98.4 | 100 |
| Further maths 2010 Wales | 40 | 58.3 | 77.9 | 87.5 | 92.5 | 96.3 | 100 |

## *Methodology*

In phase one, a bilingual questionnaire on the attitudes of students to studying mathematics after GCSE was prepared. The questionnaire consisted of questions on the background of the respondent, a series of attitude statements on the respondent's reasons for choosing to study mathematics beyond GCSE and some free text response questions. The attitude statements used a 5-point Likert scale from strongly disagree to strongly agree. The free text questions asked the respondents to offer advice to other students on choosing to study mathematics at A level and beyond.

A sample of schools was chosen, primarily in Wales, but also including some English schools. Two Welsh further education colleges were also selected and from these colleges fourteen students participated. The questionnaire was given only to students who had chosen to study for at least AS level mathematics. The sample of Welsh schools was chosen based

**Figure 3. Cumulative percentages of grades awarded in FM in 2015 by gender (JCQ, 2016)**




on the Welsh Government's national school categorisation system which divides institutions into four standards groups graded from 1 (best) to 4 (worst) (Welsh Government, 2016a). Two schools were selected from each of groups 1, 2 and 3 with three schools selected from group 4. Three schools from England were also selected based on an opportunity sample. The combined sample stratified by GCSE results of each school is shown in Table 3. For comparison, across all state-funded schools in England in 2015, 57 per cent of students achieved 5 GCSEs at grades A*–C including English and mathematics.

Thus the overall sample consisted of 158 respondents split between fourteen institutions. The sample had a gender balance of 65 per cent male to 35 per cent female reflecting the overall split of A level mathematics students across England and Wales. Amongst the respondents 36 per cent indicated that they were participating in some form of FM course (AS or A level). The gender balance in the groups studying FM and those not studying FM were both in line with the overall sample (67:33 and 65:35 respectively).

**Table 3. Sample of English and Welsh schools included in the questionnaire (DfE, 2016; Welsh Government, 2016b)**

| *Students achieving 5 GCSEs A*–C including English/ Welsh and maths* | *Schools* | | | *Respondents* | | |
|---|---|---|---|---|---|---|
| | *Total* | *Welsh* | *English* | *Total* | *Welsh* | *English* |
| 30%–39% | 2 | 1 | 1 | 24 | 14 | 10 |
| 40%–49% | 2 | 2 | 0 | 30 | 30 | 0 |
| 50%–59% | 4 | 2 | 2 | 44 | 16 | 28 |
| 60%–69% | 3 | 3 | 0 | 33 | 33 | 0 |
| 70%–79% | 1 | 1 | 0 | 13 | 13 | 0 |
| Total | 12 | 9 | 3 | 144 | 106 | 38 |

In phase two, sixteen students from a selection of seven Welsh schools and one Welsh college were chosen for interview. The schools were again selected according to the Welsh Government standards groups with two schools chosen from each of groups 1, 2 and 4, and one from group 3. The institutions involved in phase two were not all involved in phase one. Interviews were conducted at the student's school or college and were structured to cover an agreed list of questions and topics on student attitudes to studying mathematics. Seven students interviewed were not studying FM while nine students were, with both groups having an even gender balance. All students interviewed were studying A level mathematics and planning to go to university.

Ethical approval for both the use of the questionnaire and the interviews was sought and given by University of Wales Trinity Saint David prior to the commencement of the study. Free and informed written consent was sought from all participants. The research was conducted in accordance with BERA guidelines (BERA, 2011).

## *Results*

The results we present here look to highlight trends contained within the questionnaire data. Where comparisons are made between groups such as gender, or between those studying FM and those not studying FM, details of the statistical significance and size of effect are given. As the data from the Likert scale was ordinal, non-parametric tests (Mann-Whitney) were used. The estimate of effect size 'r' is calculated using the formula $r=Z/\sqrt{N}$ where N denotes the sample size (Cohen, 1988; Fields, 2005). All results are based on the sample of 158 students drawn from the stratified sample described earlier who had all chosen to study mathematics at A level.

Of the students who responded to the questionnaire, only 20 per cent were in schools, which they described as not offering FM. The remainder were in schools which either fully timetabled the subject (41 per cent) or used a combination of school lessons, lunchtimes and FMSP (39 per cent). The interviews confirmed that when FM is offered as a fully timetabled option, the choice is less of a dilemma for the students, and if they enjoy mathematics they are likely to take FM.

The vast majority of questionnaire respondents had a very positive attitude to mathematics, with 90 per cent agreeing that they enjoyed mathematics. For the majority of respondents, it was the certainty of mathematics that they enjoyed (77 per cent). For some of the interviewed students this sense of enjoyment came from finding the subject easy, 'once I've grasped it, I can do it easily', whilst for others it was the challenge as 'when you get good results it encourages you to do more'. Two of the interviewees noted that it was when they were allowed to drop other subjects at the start of their GCSE courses and were able to concentrate more on mathematics that they became passionate about mathematics. This sense of enjoyment also drove some students towards FM with one interviewee remarking that 'for me it feels that Maths on its own would not be enough, Further Maths is a completing part'.

The 'pipeline' of students creating the 'clever core' can be seen clearly in the questionnaire with 79 per cent agreeing that they had found GCSE maths easy. In terms of the students' perceptions of their own ability, there were some differences between those studying FM and those not, with small to medium effect sizes ($r=0.2$ small effect, $r=0.5$ medium effect, $r \geq 0.8$ large effect; Cohen, 1988). Students studying FM were more likely to describe themselves as gifted at mathematics (82 per cent) than those not studying FM (54 per cent) ($Z=3.665$, $p<0.001$, $r=0.29$). Students studying FM were less likely to say that they found AS level mathematics hard (5 per cent) compared to those not studying FM (38 per cent) ($Z=4.485$, $p < 0.001$, $r=0.36$). Fewer students studying FM felt that mathematics was not their best subject (7 per cent), compared to those not studying FM (40 per cent) ($Z=4.981$, $p<0.001$, $r=0.40$).

There does appear to be a substantial pool of untapped talent amongst those who are not currently taking FM, with 24 per cent of these students stating that they felt they were good enough to study FM. Even amongst those who were not studying FM, 32 per cent wanted to continue studying maths to the highest level they could, and only 11 per cent agreed that they were not good enough to study maths at a higher level. Indeed 59 per cent of all the students felt that hard work is more important than ability in mathematics.

There was a clear feeling amongst students that there is a step up in difficulty at the start of A levels with 80 per cent identifying a jump from GCSE to AS level. There also appears to be a perceived difficulty barrier to beginning FM, with 41 per cent of all students agreeing that FM should only be studied by those gifted at mathematics. Some of the students interviewed who had not chosen to study FM reported that they had been told that the subject was difficult and some were unsure about their own mathematical abilities. Some were unaware that FM can be taken as an AS level to make it easier. Overall 53 per cent of students felt that there was a step up in difficulty from mathematics to FM. In interviews this was perceived by students as a serious hurdle with the first module of FM being difficult as 'matrices and complex numbers blow your mind'. On the other hand, students also enjoyed the challenge of the new topics. As one boy noted, 'there are no boundaries in maths' using complex numbers as an example of this. As another student noted: 'Further Maths gives maths more of an identity and character.'

Another barrier identified is the amount of self-study required in FM, with 44 per cent of students believing it involved more work than other subjects. In some respects, the reality is actually worse than these perceptions with 54 per cent of those studying FM agreeing it involves more self-study. In the interviews students who were attempting to complete the entire FM A level in their second year of A level study felt that they were doing much more work than they had done for their A level in mathematics, with extra lunchtime lessons. A student who studied with FMSP rather than their school remarked on the difficulty of having to ask for help from a teacher who had only taught FM 'years and years ago'. On the contrary those students interviewed, whose classes were fully timetabled, thought that FM 'did not feel different from learning normal maths'. Of the sixteen students interviewed, seven had studied for an additional mathematics qualification before starting their A levels and the qualification made a significant impact on how well they coped with the transition from GCSE to A level. As one student remarked, the additional mathematics qualification 'is like a transition project from GCSE to A-level', which another student said 'helped me to settle in. I did not find it [A level] as much of a jump as others'.

Both parents and teachers play a key role in guiding students to study mathematics and FM with 57 per cent agreeing that their parents thought it was important that they study mathematics in some form and 80 per cent agreeing that their teachers had encouraged them to study AS level mathematics. However, only 14 per cent of students stated that their parents thought it was important for them to study FM and those studying FM were more likely to agree that their parents thought it was important (35 per cent) compared to those not studying FM (2 per cent) ($Z=5.627$, $p<0.001$, $r=0.45$). Three of the FM students interviewed remarked how doing more mathematics courses during their GCSEs had led them to taking FM. One of them commented that doing the additional mathematics qualification before starting his A levels made him aware that there might be more than one A level in mathematics. Two others finished the first module of AS level mathematics whilst completing their GCSEs which 'was enough reason to carry on with doing more maths'. Amongst those who did not choose to study FM, some mentioned that none of their siblings had studied FM and thus they 'had no one to ask about what it would be like'. It is interesting that several interviewees mentioned it was their father and not their mother who helped with their GCSE mathematics and influenced their choice of A level mathematics. Four students mentioned that their older siblings had introduced them to new pieces of mathematics which prompted their curiosity. Several students mentioned that they had decided to study A level mathematics after an elder sibling had studied for a degree, which had used a lot of mathematics. Most of the students did not see a careers advisor and of those who did, the advisor had not mentioned FM in the meetings.

The vast majority of students were clear that having at least an AS level in mathematics would help them get into a university (82 per cent). There was, however, a clear split about the usefulness of FM with those studying FM more likely to agree that it would help get them to a better university (75 per cent) compared to those not studying FM (47 per cent) ($Z=4.098$, $p<0.001$, $r=0.33$), with a similar split over whether FM would help them get a job (72 per cent versus 42 per cent, $Z=3.996$, $p<0.001$, $r=0.32$). In the interviews several students, whose schools did not offer FM directly, said that they had first heard about FM from universities. Other students who had already decided to take FM felt reassured in their choice by university entry requirements. As one student remarked about entry requirements, 'I went to a UCAS convention. A* in Maths, A in Further Maths and another A was a general answer.' Some students who decided not to study FM also felt their decision was supported by their choice of a career or university course. Of those not studying FM, 47 per cent agreed that it was more important for them to study a range of subjects rather than to study FM. As one student remarked, some university courses 'do not like students taking double Mathematics as it shows too much of one subject'. One student interviewed expressed regret at not having chosen FM as this had limited her choice of universities even though she wanted to study an economics-based course.

Interestingly there were few statistically significant gender differences in the questionnaire results. The few differences that were observed were all small effects (Cohen, 1988). Boys were more likely to see FM as a route to a better job (B=57 per cent, G=43 per cent, $Z=2.707$, $p=0.007$, $r=0.22$) or university (B=66 per cent, G=43 per cent, $Z=2.899$, $p=0.004$, $r=0.23$) than the girls; girls were less likely to be planning to study mathematics the following year (B=85 per cent, G=70 per cent, $Z=2.743$, $p=0.006$, $r=0.22$) and the girls tended to like the certainty of mathematics more (B=71 per cent, G=87 per cent, $Z=2.126$, $p=0.034$, $r=0.17$).

Interestingly, the girls were less likely to consider that there was a big step up in difficulty from mathematics to FM (B=48 per cent, G=30 per cent, $Z=2.031$, $p=0.042$, $r=0.17$) and that only the gifted should do FM (B=48 per cent, G=30 per cent, $Z=2.644$, $p=0.008$, $r=0.21$). In each case, these small effects were based on the sample of 158 students drawn from the stratified sample described earlier who had all chosen to study mathematics at A level.

## *Discussion*

First we should remark that the lack of more substantial gender differences in the results of the questionnaire was a surprise, particularly given the clear gender divide in the uptake of both A level mathematics and FM. This may be explained by our sample which only considered students who had already chosen to study mathematics at A level, but it is interesting that there were few gender differences within such a sample and that those that did exist were small effects. There is, of course, a separate issue of the gender divide in choosing to study mathematics in the first place, but we are not investigating that matter here. Our results indicate that once girls have decided to study mathematics their attitudes to mathematics and to FM seem remarkably similar to those of boys.

Turning to FM, the evidence here shows that there is a pool of students who do not currently study FM but clearly feel they could have taken it. For many of these students taking FM could open up more options for courses at highly selective universities. The question is how these potential FM students might be converted into actual FM students.

In terms of exploring how students come to a decision to choose whether to study FM it is important to understand how they also reach a decision about studying mathematics in the first place. Clearly in our results the influence of parents and teachers shine through.

Teachers influence student choice by encouraging participation, but also influence students directly through their teaching. In this respect both the mathematical knowledge and the pedagogical knowledge of the teacher are important. As one student responded to the questionnaire, 'Make sure the teachers are good, bad teacher = hard course, good teacher = easier.' Whilst several interviewed students described how they found FM difficult, this was significantly helped by having a good teacher. As another student explained in interview, 'the first few lessons were pretty difficult but then my teacher who was really good helped me and I got over it'. Given the advanced nature of some of the material included in FM, it is therefore imperative that schools have access to suitably qualified teachers who have a good understanding of advanced mathematical topics.

Whilst parents appear to influence students' decisions to study mathematics, this is not apparent with FM. This may be explained by a simple lack of information, knowledge or experience amongst parents about FM. Similarly, it is clear that their peers influence students in their decision, be they school friends or members of their extended families. Given the small numbers of students involved in FM compared to other A level subjects it is no surprise that many students do not encounter anyone amongst their peers who has studied FM. Perhaps if more information was provided and FM more widely promoted in schools there would be a greater take up. For instance, encouraging existing FM students to become FM champions could facilitate this.

Another result here is the importance of communicating that FM exists and why it might be chosen at an earlier age. For instance, students who study additional mathematics whilst studying for their GCSEs became aware of the existence of mathematics qualifications beyond the standard ones.

One of the barriers highlighted in our results is the perceived difficulty of FM when compared to the mathematics A level, which one can reasonably expect is compounded in students' minds by the step up from GCSE to A level. To a certain extent this step up will always exist, particularly given that so many of the students who study A level mathematics found GCSE mathematics easy. As one student remarked on the questionnaire, 'You cannot sleep in lessons like at GCSE and expect to pass.' However, as has been noted earlier, students taking the additional mathematics qualification before starting their A levels can ameliorate this step up. The students interviewed felt a clear benefit here, particularly in terms of their improved skills in algebra, manipulating indices, simultaneous equations and factorising quadratic polynomials. They also had a clear advantage in having previously seen the basic calculus of differentiation and integration. As one girl noted, not having had the opportunity to study additional mathematics was: 'a big regret. In A-level maths lessons I often hear from other students "we did this and that in Additional Maths lessons". So I think having it would have given me an extra strength.'

For schools where this provision is not possible, FMSP and FMSPW have stepped in to fill a teaching void. However this solution is not ideal. It is clearly more difficult for students to engage with FMSP/FMSPW teaching outside the normal school timetable. One student explained that although the FMSPW tutor came regularly to the school, these visits were simply not enough. This should be contrasted with schools that are able to fully timetable the subject, making it feel like a normal part of the school curriculum. In the interviews, students experiencing this model of teaching felt that the workload was far less onerous, and saw FM as simply carrying on from mathematics.

These issues are related to the model of delivery offered by FMSP/FMSPW and are of particular interest to us. The authors have been working with the FMSP Wales and one author is involved in running the programme in south-west Wales. Thus we felt it is appropriate to include our views on the issue above from the FMSPW perspective. The comments from FMSPW students, teachers, parents and FMSPW tutors regularly emphasise that workload is an issue. Although the return of the subject as a fully timetable option would be the straightforward solution, in reality this is unlikely to be achievable in the near future. Lack of funding, appropriately qualified staff, small size groups form a vicious circle leading to difficulty to timetable the subject. MEI has been running programmes to support the teaching and learning of FM since 2003, and the need for such support has not diminished. The FMSPW experience suggests that the most effective mechanism to return the subject on timetable is to increase the size of the FM class. But even this may be challenging if the funding is being cut in a school or college. Thus, for the moment, we need to look for the solutions within the FMSP/FMSPW model of delivery, which opens room for further research.

## *Conclusion*

We suggest that it should continue to be an entitlement for students in England and Wales to choose to study FM at A or AS level. In view of the coming reforms of A level mathematics and FM in England and Wales every possible care should be taken to prevent decline in the numbers of students taking FM as happened after the last reform in 2000. The new reforms represent a challenge but can also provide opportunities to ease the access to FM if carefully thought through.

However, entitlement must mean more than simply the right to take an examination. As the present research confirms, the false perception persists that FM is harder than mathematics and only suitable for the most talented mathematicians. The existing models of delivery unfortunately add to this misconception. Students are often offered the option of FM through additional lessons and self-study outside the normal curriculum. FMSP and FMSPW have been very successful in supporting FM students in such contexts, but it is expecting a great deal of a student with no peer group or sibling knowledge of FM to choose to follow such a path. We suggest that efforts should be made to facilitate the return of the subject as a fully timetabled option and FMSP/FMSPW should evaluate how their students perceive the workload and the challenges it represents.

Teachers and parents influence students in their choices, but their peers and older siblings also influence them. There is a vicious circle here: if there is no tradition of FM within a school or college, parents, teachers, peers and older siblings will not have the personal knowledge and experience to influence that choice. We suggest that a comprehensive programme of professional development for teachers is available alongside promotional materials for students, teachers and parents, explaining the benefits of studying mathematics beyond GCSE. A programme of student

FM champions should be developed to help to tap the pool of potential FM students in schools and colleges. It is important that qualifications such as additional mathematics are offered to the GCSE students to help with the transition from GCSE to A level mathematics, which clearly contributes to succeeding with studying mathematics and FM at A level.

## *References*

BERA (2011). *Ethical Guidelines for Educational Research*. London: British Educational Research Association.

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd edn). Hillsdale, NJ: Erlbaum.

DfE (2015). *School workforce in England: November 2014*. Available at: *https://www.gov.uk/government/statistics/school-workforce-in-england-november-2014* (accessed 10 February 2016).

DfE (2016). *School and college performance tables*. Available at: *http://www.education.gov.uk/schools/performance* (accessed 12 January 2016).

Dolton, P. J., and Vignoles, A. (2002). 'A Return on Post-Compulsory School Mathematics Study'. *Economica* (69), 113–41.

Fields, A. (2005). *Discovering Statistics Using SPSS*. Beverly Hills: Sage Publications.

FMSP (2016). *Universities and Careers*. Further Mathematics Support Centre, MEI. Available at: *http://www.furthermaths.org.uk/universities* (accessed 12 January 2016).

GSR (2014). *Evaluation of Further Mathematics Support Programme Pilot Final Report*. Welsh Government Social Research, Cardiff: Welsh Government.

Hillman, J. (2014). *Mathematics after 16: the state of play, challenges and ways ahead*. London: Nuffield Foundation.

JCQ (2014). *Examination Results*. Joint Council for Qualifications. Available at: *http://www.jcq.org.uk/examination-results/a-levels* (accessed 20 October 2014).

JCQ (2016). *Examination Results*. Joint Council for Qualifications. Available at: *http://www.jcq.org.uk/examination-results/a-levels* (accessed 12 January 2016).

Mendick, H. (2008). 'Subtracting Difference: Troubling Transition from GCSE to AS-level

Mathematics'. *British Educational Research Journal*, 34 (6), 711–32.

Miller, N. (2014). *Evaluation of Further Mathematics Support Programme Pilot: Final Report*. Available at:

*http://gov.wales/docs/caecd/research/2014/140919-evaluation-further-mathematics-support-final-en.pdf* (accessed 12 January 2016).

Noyes, A. (2009). 'Participation in Mathematics: What is the Problem?'. *Improving Schools*, 12 (3), 277–88.

Noyes, A., and Adkins, M. (2016). 'Reconsidering the rise in A-level Mathematics participation'. *Teaching Mathematics and its Applications*, 35 (1), 1–13.

QCA (2007a). *Offering further mathematics as part of the A level curriculum*. Qualifications and Curriculum Authority. Available at: *http://www.furthermaths.org.uk/manager_area/files/Offering_further_Mathematics_as_part_of_the_A_level_curriculum_Final_Report_Dec_07%201%20.pdf* (accessed 12 January 2016).

QCA (2007b). *Evaluation of participation in GCE Mathematics, final report*. London: Qualifications and Curriculum Authority.

The Royal Society (2008). *A state of the nation report: Science and Mathematics education, 14–19*. London: The Royal Society.

Searle, J. (2009). *Evaluation of the Further Mathematics Network: Final Report*. Durham: Centre for Evaluation and Monitoring. Available at: *http://www.furthermaths.org.uk/manager_area/files/FMN_Final_Report_290509.pdf* (accessed 12 January 2016).

Searle, J. (2011). 'Investigating the impact of the Further Mathematics Network'. *Research in Mathematics Education*, 13 (1), 91–2.

Searle, J. (2012). *Evaluation of the Further Mathematics Support Programme Report on Phase Four*. Durham: Centre for Evaluation and Monitoring. Available at: *http://www.furthermaths.org.uk/manager_area/files/FMSP_Phase3_Report.pdf* (accessed 12 January 2016).

Searle, J. (2014). *Evaluation of the Further Mathematics Support Programme: Report on Phase Four*. Durham: Centre for Evaluation and Monitoring. Available at: *http://www.furthermaths.org.uk/manager_area/files/FMSP_Phase4Report_Final.pdf* (accessed 12 January 2016).

Welsh Government (2016a). *National School Categorisation System. Guidance document for schools, local authorities and regional consortia*. Guidance document no: 198/2016. Cardiff: Welsh Government.

Welsh Government (2016b). *My Local School*. Welsh Government. Available at: *http://mylocalschool.wales.gov.uk* (accessed 12 January 2016).