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WIDENING AND INCREASING POST-16 MATHEMATICS PARTICIPATION: PATHWAYS, PEDAGOGIES AND POLITICS

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ABSTRACT. This paper explores the potential impact of a national pilot initiative in England aimed at increasing and widening participation in advanced mathematical study through the creation of a new qualification for 16- to 18-year-olds. This proposed qualification pathway—*Use of Mathematics*—sits in parallel with long-established, traditional advanced level qualifications, what we call 'traditional *Mathematics'* herein. Traditional *Mathematics* is typically required for entry to mathematically demanding undergraduate programmes. The structure, pedagogy and assessment of *Use of Mathematics* is designed to better prepare students in the application of mathematics, and its development has surfaced some of the tensions between academic/pure and vocational/applied mathematics. Here, we explore what *Use of Mathematics* offers, but we also consider some of the objections to its introduction in order to explore aspects of the knowledge politics of mathematics education. Our evaluation of this curriculum innovation raises important issues for the mathematics education community as countries seek to increase the numbers of people that are well prepared to apply mathematics in science and technology-based higher education courses and work places.

KEY WORDS: curriculum, mathematics, policy, qualifications, widening participation

Introduction

Mathematics is centrally important in the study of many university first-degree courses, and therefore, curriculum design, teaching and learning of the subject is of particular concern in the upper years of secondary education. Of course, for those students wishing to progress to study (and work) in science, technology, engineering and mathematics (STEM), preparation in mathematics is essential. However, these students can have very different needs. The problem of how education systems can meet these diverse requirements of students, future courses and employers is at the heart of this paper. Although this is not a problem unique to England, we present the findings from this large-scale pilot and evaluation as a national case in order to explore some of the challenges of developing a wider range of curriculum *pathways*.

In England, unlike in many countries, there is no expectation that young people continue their studies of mathematics beyond the age of 16,

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and the long-term decline[1] in the proportion of students participating in pre-university mathematics in England has been well noted (Roberts, 2002; Royal Society, 2008; Smith, 2004). This mirrors concerns throughout the developed world about the supply of mathematicians, scientists and technologists (Gago, 2004; National Academies, 2007; Rocard, 2007). A review by the Qualifications and Curriculum Development Authority (Matthews & Pepper, 2007) highlighted a common view in England, namely that post-16 advanced level mathematics is largely for a 'clever core', resulting in approximately only one tenth (~70,000) of each annual school cohort of 16-year-olds in England progressing to post-16 study on the traditional *Mathematics* course. This compares with, for example, Japan where the proportion in post-16 study of mathematics is nearer to 50%.

The Qualifications and Development Authority in England has coordinated attempts at a national reform of 14 – 19 mathematics qualifications in the period from 2005 to 2010. This project followed the publication of the influential Smith report (2004) which recommended that the Government act to develop new models of mathematics learning *pathways* for all young people in the 14 – 19 age range. At the core of the proposed reforms was a recommendation that a range of *pathways* should be developed that better cater for groups of students with different mathematics needs at all levels. However, agreeing what these needs are is not straightforward. Indeed, school mathematics has a variety of possible purposes (Ernest, 2004; Noyes, 2007), and as a result, the curriculum and its assessment are contested by those with particular interests and influence, especially at times of significant transition (Ernest, 1992). Such attempts at curriculum reform expose the ongoing struggles over the mathematics curriculum and its assessment and, to a degree, the subject itself. The proposal and development of radical reforms has resulted in various special interest or lobbying groups and 'think tanks' moving to protect the interests of the stakeholder groups that they represent. This has parallels, albeit on a different scale, to the Math Wars in the USA (Restivo & Sloan, 2007; Schoenfeld, 2004). In this paper, we consider some of the difficulties of attempting to extend provision to open multiple mathematics learning *pathways* that potentially cater to different students by introducing different epistemologies of mathematics.

As authors who have led a major, three and a half-year research evaluation[2] of this initiative, we draw on a complex and extensive database to explore the impact of developing an alternative mathematics *pathway* upon participation, learner engagement and outcomes. The evaluation included visits to over 100 schools and colleges, some of them on several occasions. These visits incorporated interviews with senior staff, heads of mathematics, student focus groups and classroom observation. We also conducted four online and/or paper surveys in pilot centres (of staff and students) and detailed systematic scrutiny of a large number of pilot and non-pilot examination papers, as well as student scripts, across the 14 – 19 age range. The final strand of the work included interviews with a range of stakeholder organisations including those inside and outside of the education sector (for example, employer representatives). Qualitative data (field notes and interview transcripts) were imported to NVivo and analysed using an initial coding framework that was further developed as analysis and further data collection continued.

In this paper, we mainly draw on our cross-case analyses of schools' conceptualisations of the two *pathways* and some exploratory statistical analyses of how the qualification is impacting upon patterns of participation in traditional *Mathematics* and also in *Use of Mathematics*. Despite the weaknesses of presenting the development before the pilot is completed, we think it important to capture the emergence and resolution of tensions and difficulties that arise when a significant change is introduced in the curriculum offer made to students. This allows us to explore aspects of the 'knowledge politics' (Apple, 1993, 2004) in respect to this new qualification in order to better understand how to negotiate future curriculum changes. For example, a stakeholder group (Educators for Reform) publically denounced the new qualification in July 2009, and examining their criticisms enables us to consider some of the different values and epistemologies that get mobilised in curricula change.

Background

In England, young people complete their compulsory schooling at age 16 (Year 11) with the General Certificate of Secondary Education (GCSE) qualifications that separately assess the nationally defined curriculum across each of a range of traditional subjects such as mathematics, sciences, English, history, geography and so on. Obtaining five or more higher grades (A* – C), including mathematics and English, allows students access to a wide range of further educational opportunities. The majority of those achieving this level at GCSE proceed to the traditional academic track of advanced level courses (A levels). These are the standard university entrance qualifications, and most students study three or four subjects over the following 2 years, up to the age of 18 (Year 13). In practice, in one of the four subjects, many students might complete only half of one of these 2-year, modular A level courses and receive an Advanced Supplementary (AS) award. Success in the traditional A level *Mathematics* is currently a prerequisite for most STEM courses in higher education. However, this qualification needs to act as preparation for study of degrees in mathematics itself as well as in a range of science/technology subjects, some of which are very applied in nature. The focus of traditional *Mathematics* reflects its historical development, led by the higher education mathematics community, presenting mathematics as an abstract, primarily algebraic, pursuit situated in the world of mathematics itself with calculus at its core. In pursuit of an alternative pathway that might prove more appealing to a wider range of post-16 students, but with little dilution of subject content, a new *pathway* was designed: *Use of Mathematics*. This *pathway* offers an alternative approach with applications/modelling (and consequently a range of process skills) at the core.

Use of Mathematics had previously been available since earlier changes to post-16 mathematics provision in 2000, but only as an AS qualification and had only been taken by a relatively small number of students (just over 1,000 per year) due to the relatively low status of AS awards in comparison to a full, 2-year, advanced level award. This qualification was initially designed to support students following a range of mathematically dependent pre-vocational post-16 courses, such as those in engineering, construction, science, etc., in an attempt to make the mathematics in such courses visible and to rationalise provision of mathematics. Consequently, applications of mathematics and mathematical modelling were central to each constituent module. Part of the assessment required students to provide portfolio evidence of their use of mathematics in solving substantial problems in their other studies or in areas of interest to them. In addition, the appropriate use of technology was a requirement of the assessment process throughout the course and is an integral part of the texts that support teaching and learning. In general terms, the *Use of Mathematics* approach might best be conceptualised as encapsulating the ‘realistic mathematics education’ approach of Freudenthal and colleagues (see, for example, Treffers 1987; Van den Heuvel-Panhuizen 2001). That is, the design of the assessment and supporting materials situates both mathematics learning and its application as a problem-solving tool in the realisable, if not real, world. Thus, the vision for the resulting course was that it would result in a different mathematics learning experience that prioritised modelling and applications and which would make much greater use of a range of technologies than would usually be the case in traditional *Mathematics* courses at this level. This approach also recognises that transition to study mathematics at university results not only in ruptures in mathematical content (Gueudet, 2008) but also, necessarily, in the way it is learned as students move from the study of the subject itself to its application (Wake, 2010). This provides challenges for curriculum design and implementation. The aims for the *Use of Mathematics* course include widening participation in the study of mathematics by supporting learners to whom traditional *Mathematics* proved either unattractive or difficult.

The *pathways* project development introduced a full, 2-year A level *Use of Mathematics* so that for the first time at advanced level, students of mathematics would have a choice: traditional *Mathematics* or *Use of Mathematics*. Here, therefore, we explore how these two courses with their different epistemologies and underpinning values get taken up by schools and colleges and get supported or critiqued more widely. We are using this development in England to explore how one national education system is working on the critical issue of supporting students for progression to STEM in higher education. In particular, we explore the concern raised by some stakeholders that students might be dissuaded from following the traditional *Mathematics pathway* in favour of this more applied qualification. Although these fears have no warrant from our evaluation data, this argument is a persuasive one to some policy makers.

Two Pathways: Hierarchical or Parallel

A small number of schools/colleges (29) piloted the new *Use of Mathematics* qualification and analysis of our case study data from visits to over half of these centres indicates that they have conceptualised the relationship of the new qualification with traditional *Mathematics* in two broadly different ways: hierarchical or parallel. This heuristic, which was developed using a grounded approach from interviews with teachers and student focus groups, is of course a simplification as different teachers and students in the same school sometimes expressed divergent views on *Use of Mathematics*. Generally, most schools fell into one or other of these categories (more often hierarchical), but interestingly, a small number of schools started with a hierarchical model and then shifted to a more parallel view as their understanding of the structure, aims and value of the *Use of Mathematics* qualification changed.

- Hierarchical: Traditional *Mathematics* is privileged over *Use of Mathematics*; more highly qualified students should do *Mathematics* with those less able doing *Use of Mathematics*.
- Parallel: Students are advised by teachers as to which is more suitable for their particular needs, taking into account prior attainment, current studies and future aspirations and plans.

Although it is a simple model, it highlights one of the main concerns raised by the opponents of *Use of Mathematics*, namely the perceived relatively lower level of difficulty of the new course. The two models present quite different *pathway* options for students and might have different long-term effects. In most centres, the introduction of *Use of Mathematics* has widened and increased participation in advanced mathematical study—we explore this in more detail below. In the parallel model, in particular, there is the express intention of tailoring mathematics learning to the particular needs of students. However, it does rely on the quality of advice given by teachers. By way of fleshing out these two models, we present two sketches.

Albany—A Parallel Pathway Model

Albany is a large further education college[3] in competition with local selective schools and has a clear sense of how mathematics pathways might emerge from the creative deployment of *Use of Mathematics* units alongside the traditional route. Mathematics education is located in a School of Advanced Education that offers a range of courses as well as 'servicing' the vocational schools within the college. Carole, the head of department, recognises that there is an outstanding need to integrate mathematics learning across the college with the mathematics team providing support for those teaching mathematics who are themselves not mathematicians.

Within the college, they offer a wide range of mathematics courses and have run the original AS *Use of Mathematics* for several years. Carole had been eagerly waiting for *Use of Mathematics* to become a full A level, describing it as being different rather than easier:

> It's [*Use of Mathematics*] more successful because it's entirely practical. You don't go off developing the theory of whatever, you know, functions, it's all very practical. If you stick to the ethos, which is analysis of real data, techniques for analysing real data, we find they're very successful. And you give them loads of IT and you let them sit down with spreadsheets and graphing software and let them work their way through the problems… we don't do twenty examples we give them a project and then let them get on with it!

The college has a policy that all science students who have not chosen to study advanced mathematics should follow one of the relevant *Use of*

Mathematics units. There is also a plan to encourage social scientists to study relevant mathematics units from the *Use of Mathematics* course. As *Use of Mathematics* allows for some choice during the first year, Carole intends to orient the curriculum towards data handling, which has proven particularly successful for social and life scientists working with data from their other subjects.

Being in a mathematics department, Carole and colleagues are trying to conceptualise the two routes as different, with each being better suited to the needs of different cohorts of students.

I am suggesting that to make the *Use of Mathematics* work better … anyone who is signing up for (traditional) maths who doesn't want to be a physicist, mathematician or an engineer does the *Use of Mathematics* … They will do statistics which supports their other subjects. So, unless they got an A* at GCSE I'm going to say—they should do that.

They will recommend *Use of Mathematics* like this as they believe it is more engaging and so students will get higher grades. There is a genuine attempt to steer students to particular pathways. She adds, "My key interview question is, 'How do you feel about algebra? About trigonometry?' And if the answer is not, "I love it", then, "Are you sure you want to do Mathematics?"

Blakeney—A Hierarchical Pathway Model

Blakeney is a school taking pupils from 11 to 18 years of age serving a small town and its rural surroundings. They have typically had 25 students starting the traditional (A level) *Mathematics* course. The senior teacher leading the introduction of *Use of Mathematics* (Pippa) has a principled objection to the elitist nature of A level *Mathematics* and disagrees with the head of department regarding the higher value of the qualification. Students at Blakeney need to have an A grade at GCSE to start traditional *Mathematics*, and so without the *Use of Mathematics* option, there would be no mathematics provision post-16 for the majority of students who obtained grade C or higher at GCSE.[4] It is the intention that *Use of Mathematics* will not threaten traditional *Mathematics* recruitment as they have a tiered approach. High attaining students do the traditional course, with Pippa believing that *Use of Mathematics* will provide a good preparation for some higher education programmes.

Pippa is convinced that there would be benefit for all learners in adopting some of the *Use of Mathematics* teaching and learning approaches:

My knowledge of mathematics has been enhanced hugely through teaching it. I always say to students that with the traditional A level course you are taught techniques, conjuring tricks almost if you like, and then at the end of the exercise, if you get that far, there's a sort of pseudo in-context, real life example to work out. And I say that with Use of Mathematics it's completely the other way around. Here's some data … lets draw a graph … and 'Look, it makes a funny curve there', let's learn some more maths about this curve. Oh it's a quadratic and then see what extra information we can deduce to apply it to the situation.

Pippa is also a strong advocate of the use of technology which is central to the *Use of Mathematics* as a means of enhancing student learning. She believes that *Use of Mathematics* is encouraging new participation in advanced level mathematical study, and although the programme is in some ways narrower, it is no less difficult. She explains that at the outset, most *Use of Mathematics* students have relatively low self-confidence and so need considerable encouragement. Her underpinning philosophy is one of inclusion.

Albany and Blakeney have approached the piloting of the *Use of Mathematics* in quite different ways. Teachers and departmental cultures in the different institutions reflect a range of values and beliefs that get realised in the different ways that they construct the relationship between these two advanced mathematics pathways. These distinctions raise at least one important question for the future. If schools/colleges conceptualise the courses differently, either due to economic necessity (i.e. not enough students to give choice) or philosophic positions (parallel or hierarchical), then it seems that students could be presented with quite different opportunities in their different schools/colleges. These questions are a cause for concern and are taken up by those with a more conservative approach to curriculum change. We now turn to consider participation data from a range of our case study sites.

Recruitment to *Use of Mathematics*

The beliefs, commitment, experience and skills of the teachers leading the development of the course make a real difference to student engagement and success. The idea that grade C GCSE students can make good progress with advanced level mathematics is central to these beliefs, and this can have a transformative effect on the attitudes of learners to the subject:

One thing that gives me the most pleasure out of teaching [Use of Mathematics] is that you start off with kids who have not been the highest achievers in mathematics … and realising that by Christmas, if you gave them any function of the form $a\sin(\omega t+\alpha)$ they can tell you exactly what each of those parameters does to that sine wave. They know exactly how a sine wave has been transformed. They can tell you in the context of … tides, roller coasters; they can tell you what's happening to that pod on a roller coaster. They know exactly where it is in time and space. And they amaze themselves. And they feel really pleased with their ability. One girl … she said to me at the end of one lesson a couple of weeks ago, she said 'Do you know … I really love this. And I've never liked maths before'. (*Use of Mathematics* teacher)

There is clear evidence that uptake of *Use of Mathematics* has increased in centres already using this qualification, and many report a lower dropout rate, particularly in comparison with traditional *Mathematics*. We found that a large proportion of *Use of Mathematics* students we spoke to would not have chosen, and indeed would not have been allowed to study, traditional *Mathematics*. These form a new population of advanced level mathematics learners.

One of the most striking features of focus group discussions is students' enthusiasm for a course which they feel has some relevance to real life. It is not always clear the extent to which this is merely a perception, but the effect is that many report finding the course more engaging than previous mathematics learning, and this helps keep them motivated and enables them to persevere when things get tough. The following Year 12 student explains that

Before, maths used to be boring in the GCSE and you're doing the questions thinking 'how is this going to affect me in life?', but *Use of Mathematics* you learn about business, you learn about sine waves, you learn about everything. If you see something you think 'Oh, I've learnt this in maths', I can actually use it and integrate it. (*Use of Mathematics* student, aged 17)

There are multiple accounts of students with GCSE mathematics grades C and B feeling more confident about their mathematics as they progress in the *Use of Mathematics* course. In many schools, these students would not be allowed to start traditional *Mathematics*. In one centre, several of the *Use of Mathematics* students explained how they ended up doing the course as an afterthought. Having completed nearly a year, it is now one of their top choices and they are eager to continue.

These and other examples of changes in attitude to mathematics are striking. It is worth repeating that some of this is no doubt due to the quality of the teaching experienced, but this is within the framework of a qualification which encourages different teaching and learning styles from those previously encountered. It does appear that *Use of Mathematics* attracts many students who are not very clear about their future aspirations. Often they would like to do some mathematics, but have no interest in the traditional *Mathematics* course.

Will *Use of Mathematics* Change Participation in Advanced Level Mathematics?

One of the expressed concerns of the critiques is that the new course will draw people away from the traditional *Mathematics* course, and this would, it is argued, be a disaster for the supply of mathematically well-qualified undergraduates. So here, we use entry data for traditional *Mathematics* and *Use of Mathematics* students at the end of their first year of study in pilot centres in the summers of 2008 and 2009 to consider whether this is likely to occur. We focus on the entries at the end of the first year of study (Year 12) for simplicity as patterns of retaking course examinations can confuse matters. This enables us to compare the two cohorts (2008 and 2009) on the two *pathways* (traditional *Mathematics* and *Use of Mathematics*).

Firstly, we compare the entries in 26 centres piloting the new *Use of Mathematics* (Table 1, below). This compares 2008 entries for the old qualification which lasted 1 year and 2009 entries for the first year of the new 2-year *Use of Mathematics* qualification. These cohorts are not like for like in terms of units studied, but it serves to show whether or not entry patterns are changing. Schools/colleges entered between 5 and 132 students for *Use of Mathematics* in Year 12 over the 2 years. The entry in these 26 centres has increased by over 60%. However, it is worth noting that this increase is higher for females (100%) than for males (45%). The ratio of boys to girls drops from about 2.2 to 1.6.

Due to the number of students for whom prior data are not available, it is not easy to draw conclusions about the general prior attainment of the two cohorts, but it does appear that there has been a change in entry patterns in the female population between 2008 and 2009, with nearly 50% having a grade B in 2009 compared with 40% in 2008. Ignoring those for whom prior data are not available, this becomes more striking if A and B GCSE grades are taken together. There is an increase from 42% to 55% of the female cohort with grades A and B at GCSE, whereas for males, it remains constant at 42%. We note this with caution at this stage, for it is not entirely good news if able girls are lured by what are currently less prestigious qualifications, and the criticisms of *Use of Mathematics* discussed below aim to position the new qualification as lower status than the traditional *Mathematics* course.

The question remains as to whether or not this is an overall increase in total numbers taking mathematics or merely a transfer of entries from traditional *Mathematics* to *Use of Mathematics*. So we move to consider this question. To shed some light on this, consider data from eight centres that entered students for both *pathways* in the 2 years (one centre had no

TABLE 1

GCSE grade profile of AS *Use of Mathematics* students entered in Year 12, 2008 and 2009

Year		GCSE grade						
		*A**	*A*	*B*	*C*	*D*	*X*[a]	*Total*
2008	F		2 (2%)	39 (40%)	44 (45%)	0	13 (13%)	98
	M		2 (1%)	87 (40%)	89 (41%)	1 (1%)	38 (17%)	217
	Total		4 (1%)	126 (40%)	133 (42%)	1 (1%)	51 (16%)	315
2009	F	1 (1%)	12 (6%)	95 (48%)	55 (28%)	1 (1%)	33 (17%)	197
	M	0	12 (4%)	116 (37%)	149 (47%)	3 (1%)	35 (11%)	315
	Total	1 (1%)	24 (5%)	211 (41%)	204 (40%)	4 (1%)	68 (13%)	512

[a]Prior attainment not available

Use of Mathematics entries in 2008, but it is included here to help explore the impact of the introduction of the new qualification; Table 2).

The first thing to note is that in this small sample of centres, there has been nearly a threefold increase in the *Use of Mathematics* entry at the same time as an 11% increase in the traditional *Mathematics* entry. However, the increase in *Use of Mathematics* seems to be quite different in the centres, even taking account of the sample sizes. Centres C, E and H, as well as the newcomer, centre G, have all made clear increases in their *Use of Mathematics* entry. The traditional *Mathematics* cohort in H has dropped slightly, whereas in G, it has remained about the same despite a substantial increase in take-up of *Use of Mathematics*. Interestingly, centre C now has a *Use of Mathematics* group that is bigger than the traditional *Mathematics*

TABLE 2

Year 12 entries to traditional *Mathematics* and *Use of Mathematics* in eight pilot centres for 2008 (*Use of Mathematics* non-pilot) and 2009 (*Use of Mathematics* pilot)

Year		Centre								
		A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*Total*
2008	Traditional *Mathematics*	32	14	14	180	165	81	183	164	833
	Use of Mathematics	15	6	4	9	7	15	0	6	62
	Total	47	20	18	189	172	96	183	170	895
2009	Traditional *Mathematics*	40	32	18	201	163	140	191	140	925
	Use of Mathematics	19	1	24	15	20	17	54	25	175
	Total	59	33	42	216	183	157	245	165	1100

group. Drawing conclusions from this table is not easy without having a more detailed picture of the cohort in each school.

From these data, it is not easy to make predictions about the likely take-up of *Use of Mathematics* (and traditional *Mathematics*) if the two routes were available to all students. It is important not to draw inferences from these entry patterns as they might not be typical of other centres and ultimately some centres might only have one or the other of these qualification *pathways* available. However, it does seem likely that overall, there would be a significant increase in participation in advanced mathematics.

Table 3 gives some insight into the prior attainment of students following the two different courses, although again, the number of students with unknown prior attainment makes interpretation difficult. However, there seems to be, as already noted, an increase in the proportion of *Use of Mathematics* students with prior attainment of grades A and B at GCSE. It is impossible to say whether or not these students would have done traditional *Mathematics* had *Use of Mathematics* not been available.

From this brief analysis, it seems very likely that *Use of Mathematics* is both increasing and widening participation in advanced mathematics. In other words, it is not the case that the existing cohort recruited to post-16 mathematics is now being split between the two *pathways*. Although there are variations between centres in the entry patterns for the two *pathways* over the 2 years, there is no compelling evidence of students abandoning traditional *Mathematics* for *Use of Mathematics*, which is one of the central arguments made by the critiques of the new qualification.

TABLE 3

GCSE grade profile of traditional *Mathematics* and *Use of Mathematics* entry for Year 12 students in 2008 and 2009

		GCSE grade					
Year		*A**	*A*	*B*	*C*	*X*	*Total*
2008	Traditional *Mathematics*	152 (18%)	344 (41%)	206 (25%)	19 (2%)	112 (13%)	833
	Use of Mathematics	0	0	17 (27%)	38 (61%)	7 (11%)	62
	Total	152 (17%)	344 (38%)	223 (25%)	57 (6%)	119 (13%)	895
2009	Traditional *Mathematics*	179 (19%)	335 (36%)	258 (28%)	12 (1%)	141 (15%)	925
	Use of Mathematics	0	6 (3%)	53 (30%)	85 (49%)	28 (16%)	175
	Total	179 (16%)	341 (31%)	311 (28%)	97 (9%)	169 (15%)	1,100

Discussion: The Challenge of Reforming Advanced Level Mathematics Curricula

Although there is evidence that the piloted *Use of Mathematics* qualification could lead to both widened and increased participation, there is an uphill struggle to establish the qualification as an alternative pre-university pathway. Mathematics education in England, and elsewhere in the world (see, for example, Gutstein, 2009, in the USA), is guarded by powerful individuals and groups. In our case, there are influential groups and individuals who are suspicious of curriculum innovations that could threaten the ‘gold standard’ of the established traditional *Mathematics*. In an effort to understand how proponents of this alternative curriculum *pathway* are struggling to establish it, we draw upon Ernest’s (1992) discussion of how different interest groups struggled to influence the introduction of a national curriculum in the late 1980s. Ernest identifies five key groups:

- Industrial Trainers: Radical 'New Right' conservative politicians and petty bourgeois
- Technological Pragmatists: Meritocratic industry-centred industrialists, managers, etc.
- Old Humanist Mathematicians: Conservative mathematicians preserving rigour of proof and purity of mathematics
- Progressive Educators: Professionals, liberal educators, welfare state supporters
- Public Educators: Democratic socialists and radical reformers concerned with social justice and inequality

In Ernest’s analysis of the creation of the National Curriculum in England, he suggested that the first three groups managed to dominate the emerging definition of school mathematics. As the contested ground has moved to advanced level qualifications, we identify familiar battle lines being formed with the old humanist mathematicians deploying political lobbyists, e.g. Educators for Reform, to promote their cause. On the other hand, some ‘progressive educators’ (e.g. prominent educationalists on advisory boards) have aligned with the ‘technological pragmatists’ in support of the new qualification. The outcome of the pilot of *Use of Mathematics* will probably be decided by those who hold the greatest power and influence.

The curriculum reform in schools and colleges that the new qualification would precipitate appears to have mobilised key actors in these different groups either in support of or in opposition. This is perhaps best exemplified by the preemptive attack in opposition to the proposed reform made by the ironically named, right-wing think tank ‘Educators for Reform' (ER) in July 2009. As their report covers most criticisms of the *Use of Mathematics* qualification, we will consider the claims made in the report in light of our evidence. Signatories to the report largely consisted of mathematicians, mostly from research-intensive universities.

One of the critiques' concerns is that students would abandon the traditional *Mathematics* course for this new applied course. However, as our data suggest, at this time, there is no evidence that there would be a significant shift. Rather, our analysis strongly suggests that the introduction of *Use of Mathematics* is likely to result in more students doing some mathematical study post-16. In the pilot schools, these are often students that would be excluded from mathematics due to the difficulty of the course. Our evidence suggests that those opting to study *Use of Mathematics* find it more accessible, and there is evidence that they are more likely to persist with their studies for longer (Williams, Wake, Black, Davis, Hernandez-Martinez, Hutcheson & Nicholson, 2008).

The value of the new *Use of Mathematics pathway* seems to be misunderstood insofar as these academic critiques from élite universities do not prioritise the impetus to enhance mathematical capability and confidence of the wider population. Centres piloting *Use of Mathematics* have generally taken great care to advise their highly attaining students aspiring to STEM-related degrees that they should study traditional *Mathematics*. There is also a concern raised that schools and students will follow *Use of Mathematics* as an apparently easier option. Although we recognise that choices are made in a qualifications market, there is no clear evidence from pilot schools to suggest that students and teachers are cynically choosing the 'easy' option (although the discussion of hierarchical and parallel models is pertinent here), particularly where the exchange value of traditional *Mathematics* is fully understood by teachers and students.

The ER report says that 'a significant expansion of participation in post-16 maths will only be achieved by improving the GCSE and making A level [i.e. traditional *Mathematics*] more interesting, challenging and attractive.' (p. 1). It seems misguided to think that a more challenging, one-size-fits-all course would increase numbers. Apart from supplying university mathematics departments, students study advanced mathematics for many reasons. As has been reported to us, some *Use of Mathematics* students started by taking the course as a fourth option and later find it to be their most enjoyable course. There is evidence that such students, who have not been the most successful learners of mathematics, and who would normally not study traditional *Mathematics,* enjoy the approaches to learning offered by *Use of Mathematics* and grow in confidence as learners.

A further criticism, reflecting the tension between the 'technical pragmatist' and 'old humanist' positions, is that in *Use of Mathematics*, 'curriculum time is taken up with practical activities—such as using technology as an exploratory tool for developing mathematical understanding—rather than developing the advanced mathematical understanding that is required for higher education' (p. 2). This seems a rather peculiar assertion given the ubiquity of increasingly powerful technologies in all areas of life, including work (Hoyles, Noss, Kent, & Bakker, 2010). Many higher education courses in mathematics and applied sciences as well as in the social sciences use technology both as a tool for doing and for learning mathematics. There is evidence that such pedagogies appeal to students who take *Use of Mathematics* (Williams et al., 2008).

We understand concerns about threats to the existing population of traditional *Mathematics* students. However, our evidence allows us to be more nuanced in differentiating post-16 populations and *pathways* in mathematics. If *Use of Mathematics* does not continue beyond the pilot, this could be the closing of a door to advanced mathematical study for a substantial group of students who would otherwise not have studied mathematics post-16. It must be said that not all groups are in support of the ER report's criticisms. However, this episode reminds us that the mathematics curriculum is not politically neutral; it is a contested curriculum. Of course there remains a need to consider the possible unintended consequences of curriculum developments, but our evidence suggests that *Use of Mathematics* would not threaten the existing traditional *Mathematics* route and would in all likelihood widen and further increase participation in advanced mathematical study.

Concluding Comments: Curriculum Reform for Stem—Potentials and Challenges

The *Use of Mathematics* qualification has the potential to offer an alternative mathematics learning *pathway* through which potentially large numbers of additional 16- to 18-year-old students might be attracted to further engagement in mathematical studies. Our case study evidence suggests that for the substantial cohort of 16-year-olds (~240,000) who obtain a high grade at GCSE and who elect not to continue with any study of mathematics post-16, *Use of Mathematics* would provide a course of study which appears to be motivating and attractive. *Use of Mathematics* also offers new approaches to teaching and learning, which our evidence suggests can be motivating for, and effective in, keeping students engaged with mathematics. Ultimately, however, the success or otherwise of the introduction of different mathematics learning *pathways* seems to be at the mercy of a battle over who controls mathematics, with the 'old humanist' mathematicians flexing their muscles in an area that they see as much closer to their own concerns (e.g. university recruitment).

Our analysis of this national reform of 14 – 19 mathematics education which aims to create new *pathways* into STEM illustrates the complex challenges facing those seeking to effect systemic change. The *Use of Mathematics* qualification privileges a different epistemology and values from those associated with the traditional *Mathematics* alternative. This provides opportunities and challenges at all levels of the education system and particularly for learners and their teachers. We see parallels here with another area of recent reform in mathematics education that has been contentious in England: 'functional mathematics'. This initiative has come in response to employer concerns about the general mathematical competence of workers at all levels, a debate that has been rumbling on in the UK and elsewhere for many years. Previously, this debate has called for 'core' or 'key' skills, and these are in some sense related to notions of mathematical literacy (Steen, 2001, Wake, 2005).

Central to all of these curriculum innovations is the increased status of process skills over mathematical content, although *Use of Mathematics* pays due regard to mathematical content despite its emphasis on application, problem solving and modelling. This is encapsulated in the *Use of Mathematics* specifications for the qualification (AQA, 2010) and the texts supporting some of the modules (Haighton, Haworth & Wake, 2003a, b; Haighton, Haworth & Wake, 2004). As we have argued earlier, this approach, informed by the work of Hans Freudenthal and colleagues, appears to have the potential of providing an alternative *pathway* to STEM that could increase and widen participation. However, it is clear that any new mathematics curriculum provision presents teachers with considerable challenges as they develop new pedagogies and modes of learning. *Use of Mathematics* requires something different from teachers and learners and consequently challenges the status quo in classrooms. This is no bad thing, but also surfaces the values and epistemological positions of key stakeholders, including teachers such as those at Blakeney. All of this raises important questions about how we can introduce an applications/modelling curriculum which might challenge the hegemony of the traditional *Mathematics* where the application of important mathematical ideas is seen as something of an adjunct to the study of mathematics itself.

The problems that we have documented here from our evaluation of curriculum innovation and the development of alternative *pathways* in mathematics are not dissimilar to those encountered in the application of mathematics in engineering courses in universities. Cardella (2008), for example, argues that to support students in applying mathematics in engineering at university, we need to consider a broader notion of mathematics learning that encompasses a mathematical knowledge base as well as problem-solving skills, effective use of resources, beliefs and affects and mathematical practices. It seems that whenever and wherever attempts are made to challenge the dominance and exclusivity of traditional, 'pure' mathematics, there is a conservative resistance that means reform is likely to encounter significant, if not insurmountable, challenges. Nowhere is this struggle more keenly engaged in than at the intersection of schooling, higher education, vocational education and work, e.g. the 14 – 19 curriculum in England. These generally under-researched political dimensions of mathematics education require careful attention. The kind of struggle that we have outlined herein presents the mathematics education community worldwide with a difficult challenge as more and more economies align themselves in ways that necessitate increasing participation in the study of mathematics in support of science and technology. We hope that this paper, a case of such a struggle in England, can contribute to debates about the kinds of mathematics education that are currently available to young people internationally.

NOTES

[1] This downward trend is showing signs of reversal but the nature of the published statistical reports makes a clear quantification difficult.

[2] www.nottingham.ac.uk/EMP.

[3] Further education colleges have a wider range of provision for post-16 learners than schools and sixth form colleges, often offering both pre-vocational and academic courses for 16- to 19-year-olds and also providing opportunities for vocational, adult and community learners.

[4] Typically, some 15% of the cohort in England obtain a grade A or A*, a further 15% a grade B and approx. 25% a grade C, leaving 45% of students who do not obtain one of the grades counted as 'higher'.

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