Time for curriculum reform: the case of mathematics

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Abstract

Mathematics education is rarely out of the policy spotlight in England. Over the last ten years, considerable attention has been given to improving 14-19 mathematics curriculum pathways. In this paper we consider some of the challenges of enacting curriculum change by drawing upon evidence from our evaluation of the Mathematics Pathways Project. From 2004-10 this project, which was directed by England's Qualifications and Curriculum Authority, aimed to improve the engagement, attainment and participation rates of 14-19 year old learners of mathematics. Our particular focus is upon the temporal problems of piloting new curriculum and assessment and we draw on Lemke's discussion of time-scales, heterochrony and the adiabatic principle to consider the interlocking and interference of various change processes.

Keywords: curriculum, mathematics, time-scales, GCSE, reform

Introduction

As education and politics have become increasingly entangled, mathematics is arguably the area of the curriculum which is subjected to the most scrutiny; by policymakers, think-tanks, stakeholders and the media. Language (in our case English) and science also receive a great deal of policy attention but school mathematics is uniquely political for several reasons: 1) there is a popular belief that it is culture-neutral and is therefore valuable in making international comparisons of the effectiveness of education systems; 2) it is of foundational importance to the 'STEM agenda' (Science, Technology, Engineering and Mathematics) and associated arguments around future economic productivity and security, and 3) the sheer number of stakeholders with vested interests in school mathematics, particularly in the 14-19 age range[i] . However, the mathematics education literature rarely considers issues of policy, and education policy literature rarely focuses on mathematics education. This dearth of research on mathematics education policy is due, in part, to the historical development of the fields of mathematics education and policy studies, with their generally non-intersecting values, interests and theoretical points of reference.

In this article we consider the challenge of making substantive changes to complex education systems by focusing on a national curriculum development project undertaken by the Qualification and Curriculum Authority (QCA) in England from 2004-10. The Mathematics Pathways Project (MPP) aimed to improve the levels of engagement, participation and attainment of 14-19 year old learners of mathematics. Despite the substantial resources invested in the MPP very little came of it. As project evaluators, we were in a unique position to analyse what happened and here we focus in particular upon issues of temporality. That is not to say that a temporal analysis is *sufficient* to explain the failings of the project but we argue that it is a *necessary* component.

This paper focuses specifically on the attempt to reform the General Certificate in Secondary Education (GCSE) in Mathematics, a programme studied by around 1.2 million 14-16 year olds at any one time. In order to understand the context we devote some space to the relevant piloting and policy processes but first we introduce the key ideas in Jay Lemke's (2000) work on 'the scales of time'.

Thinking about time-scale

Lemke argued that in order to understand the dynamics of complex systems, one should view each component of that system, for example individuals or institutions, not in terms of their stable, time-invariant properties (if such exist) but rather as clusters of actions, processes, social practices, etc., each of which takes place over different timescales.

> Each scale of organization in an ecosocial system is an integration of faster, more local processes…into longer-timescale, more global or extended networks. It is relative timescale that determines the probability and intensity of interdependence (according to what I call the adiabatic principle), and it is the circulation through the

> network of semiotic artefacts…that enables coordination between processes on radically different timescales. (p. 275)

Lemke's overarching question was about how moments add up to larger time units and ultimately lives. Our usage is a little different but takes up the same ideas (admittedly without the attention to semiotics) and recognises the fractal nature of such analyses: moments do not simply 'add up' to lives and complex policy processes cannot be simply broken down into elemental units. Rather, classroom or policy events are always complex, fractal (Davis & Sumara, 2000), networked and multi-scalar (Noyes, 2013, in press). This issue of how processes are connected across timescales is of particular relevance in making sense of policy and understanding the evolutionary change of classroom practice and school curricula.

Lemke outlines the adiabatic principle and heterochrony, both of which are pertinent to this discussion and are explained briefly below. Drawing on the physical sciences, in particular thermodynamics, he explains how, under the adiabatic principle, "a very fast and a relatively much slower material process cannot efficiently communicate with one another, cannot efficiently transfer energy" (p.279). In other words, if a complex dynamic system incorporates various processes happening over quite different timescales, very quick processes generally appear to have little effect upon much slower processes; their impact or energy doesn't get through the adiabatic boundary. This metaphor has some potential for understanding how the quick processes of policymaking, the somewhat slower processes of education and very slow culture changes (e.g. societal attitudes towards mathematics) interact.

Although Lemke argues that the adiabatic principle generally holds true, there are instances where short-timescale processes can produce an 'avalanche of consequences' which can have major long-term effects on much larger systems (a butterfly effect). One example of this in England was the ministerial decision in 2008 to include GCSE mathematics and English in the headline school performance measure (% of students attaining 5 or more A* to C grades at GCSE, including English and Mathematics). These measures are published as 'league tables' and are critically important for schools as accountability measures. Generally speaking, ministerial pronouncements have little immediate, direct impact upon classrooms. However, in this case, there was a relatively quick shift in school management processes (e.g. extra resources were focused on students at the C/D borderline) and the culture of mathematics classrooms by ramping up the pressure for teachers (and their students) to perform, in order to maximise the chances of getting a grade C. The impact was quick and had a damaging impact upon classrooms and learners (ACME, 2011).

So, although processes operating at similar timescales are most likely to impact upon one another, there are these instances where very different time-scales can interact powerfully. Lemke highlights the special case of heterochronicity, in which it is the imperceptibly slowly changing social processes that can suddenly have an effect in a process of much shorter timescale. We return to these ideas below but introduce them here to signpost our direction of travel. Next we provide some background to the policy problem and introduce the Mathematics Pathways Project (MPP) and the Evaluating Mathematics Pathways (EMP).

Post-14 mathematics education: a policy problem

There is much concern around the world regarding the supply of sufficient numbers of suitably educated/qualified STEM workers at all levels (Gago, 2004; National Academies, 2007; Roberts, 2002). This globalised policy discourse (Rizvi & Lingard, 2010) is predicated upon the belief that future economic growth and security can only be secured through scientific and technological innovation. The political strategy that Lord Sainsbury's (2007) report called 'the race to the top' aims to position the UK as a world-leading producer of highly-educated STEM workers and innovators, which in turn will mitigate the ill effects of anticipated future economic turbulence. Hence the privileged position of STEM in UK education policy, for example as seen in the ring-fencing of STEM funding to UK universities at a time of massive public cuts (HM Treasury, 2010).

The centrality of mathematics within global education policy discourses is fuelled by international comparisons such as TIMSS[ii] (Sturman, Ruddock, et al., 2007) and PISA[iii] (OECD, 2010). The latter has been taken up by the UK's coalition government in its calls for (mathematics) education reform (Gove, 2011). The results of such comparisons, which are often uncritically presented and received as 'truth', are used to legitimate various policies despite their statistical unreliability[iv]. International ‘cherry picking’ of education policy ideas is not new (e.g. by Brown (1998)) and the selective use of data continues to frame education reform efforts.

The specific policy concern that the MPP was designed to address was the growing disquiet around the turn of the millennium regarding the long term decline in participation in post-compulsory (i.e. 16+) mathematics in England. This remains a concern (Hodgen, Pepper, et al., 2010; Matthews & Pepper, 2007; Royal Society, 2008) and continues to exercise government. Curriculum 2000, which heralded a major change to the structure of academic qualifications for 16-18 year olds, had a “disastrous” impact (Smith, 2004) upon mathematical participation. The new curricula and assessment regime exacerbated a gradual downward trend in participation from the late 1980s (Savage & Hawkes, 2000) and a chorus of appeals from influential stakeholders and lobby groups for political action to stem this decline culminated in several high profile reports, in particular the influential Roberts review ‘SET for Success’ (2002). Close on the heels of ‘Roberts’, and in response to the government spending review of July 2002 (HM Treasury, 2002), the government commissioned an inquiry into post-14 mathematics education. Two years later Making Mathematics Count (Smith, 2004) was published and resulted in a flurry of policy activity. A central concern of the Smith report was to raise the profile of mathematics and in doing so to increase student participation and the fitness-for-purpose of curriculum and assessment. The report led to the multi-million pound Mathematics Pathways Project (MPP), whereby the then Department for Education and Skills (DfES) commissioned the Qualifications and Curriculum Authority (QCA) to develop new models for 14-19 mathematics curricular pathways, followed by a national pilot and evaluation of these models.

The mathematics participation crisis and attempts to address it have not happened in isolation. Post-14 education more generally has been under considerable scrutiny; the Tomlinson Report (DfES, 2004) proposed radical changes to the structure of 14-19 education in England. The report advocated the reform of learning pathways and part of this was a focus on the development of core or key skills, which were to be rebadged as ‘functional skills’. Although ‘Tomlinson’ was too radical for the government of the day, functional mathematics, together with functional English and ICT, were taken up enthusiastically by policymakers in response to repeatedly expressed, and increasingly vociferous, employer concerns about young people's unpreparedness for work.

The Mathematics Pathways Project

One of the central ambitions of the Smith report was the development of "a highly flexible set of interlinking pathways that provide motivation, challenge and worthwhile attainment across the whole spectrum of abilities and motivations" (p.8). It was argued that this could only be achieved through the careful development of curriculum models followed by well-funded national pilots. Two academic-led teams were contracted to develop models in 2005-6 and by the following year three awarding bodies had begun trialling new assessment items.

The MPP swung into full-scale pilot mode with around 300 schools and colleges in the autumn of 2007 and ran until the summer of 2010. The schools were piloting a range of new qualifications for 16 and 18 year olds but for the purposes of this paper we focus our attention on the national examination for 16 year olds; the General Certificate of Secondary Education or GCSE. The project encountered a number of difficulties. One of the reasons for these was the turbulent policy context for the pilots [Ball et al. (2011) report cases where schools in England were working with 170 different policies at any one given time].

Two key elements of the pilot models were the introduction of more mathematical problem solving, which reflects an international trend, and a focus on 'functional mathematics' as a mode of quantitative literacy (Steen, 1990). Since the introduction of GCSE in the late 1980s, students typically completed one GCSE in mathematics at the age of 16. Respondents to the Smith inquiry identified what they considered to be a disparity in status with English (with its two GCSEs: Language and Literature) and Science (which was at that time a 'double GCSE'). One of the recommendations of the Smith report was therefore that GCSE Mathematics should become a 'double award'. Accordingly, the pathway models included two mathematics GCSEs, based on the same Programme of Study but with the second – *Additional Mathematics* – to be more focused on mathematical problem solving. Functional mathematics was to be incorporated into the first mathematics GCSE but would be accredited separately.

Importantly, the high status of functional skills in the policy rhetoric of the day resulted in the ministerial proposal that functional mathematics would act as a *hurdle* to obtaining a higher grade GCSE pass (i.e. C or above). This would mean that some students would gain an all-important grade C on the GCSE paper but not pass the functional mathematics assessment and therefore not receive the certification for GCSE. From the outset this positioned policymakers 'between a rock and a hard place'. Either the *hurdle* would be too high, which would satisfy employers seeking better mathematics qualifications but lead to a drop in GCSE attainment and the potential for media accusations of a fall in standards. Alternatively, the *hurdle* would have little discriminatory power, with most students clearing it, thus rendering it of little value as a credential.

The Evaluating Mathematics Pathways Project

The Evaluating Mathematics Pathways project (EMP[v]) was a large-scale, multi-institutional study conducted from 2007-10 which adopted a mixed-methods approach to evaluate the impact of the MPP (Noyes, Drake, Wake and Murphy, 2010). The empirical work comprised three strands: 1) school-based case studies and surveys; 2) scrutiny of assessment items, qualifications and pathways; 3) liaison and interviews with professional bodies and stakeholders. The school 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). Detailed and systematic scrutiny of a large number of pilot and non-pilot examination papers, as well as student scripts, across the 14 – 19 age range was undertaken. The final strand of the work included interviews with a range of stakeholder organisations both inside and outside of the education sector (for example, employer representatives). Importantly, regularly interviews were undertaken with project leads in the awarding organisations. Qualitative data (field notes and interview transcripts) were imported to NVivo and analysed using an initial coding framework that was iteratively developed as analysis and data collection continued.

Our focus herein is on 14-16 year old learners completing the GCSE. Transforming student experiences in this age range is critical to increasing participation post-16 (Brown,

Brown, et al., 2008; Nardi & Steward, 2003). A total of seventy-eight schools from around England that were piloting the new GCSEs were visited as part of the fieldwork, some of them on several occasions. This sub-sample of in-depth cases included a representative range of school types, awarding organisations, social contexts, etc. There was some turnover in the sample as schools left or joined the project and as the funder shifted their evaluation priorities. The evaluation team, which ranged in size from 15-30 at different stages of the evaluation, was involved in various forms of analysis in an iterative way that informed future data collection and the writing of several interim reports. The data informing the analysis in this paper combines case study material with research on awarding organisation processes, records of the evolving educational context and the wider policy activity of the period.

Interlocking timescales

In order to discuss the temporality issues we present an abridged timeline for the MPP (see Figure 1) and a vignette that serves to illustrate some of the key events and processes from a school perspective. The grid-like arrangement appears overly structural, fixed and laminar – such are the limitations of the printed page. We are mindful of Bourdieu's (2004) analysis of the scientific field with its 'structural interlockings' as we think about the temporal interlockings and dissonance between the different timescales represented in the diagram. The notion of interlocking points to the interdependence of the layers, that is the constraints of them rubbing against one another, an idea that is helpful in our broader analysis of the processes of change.

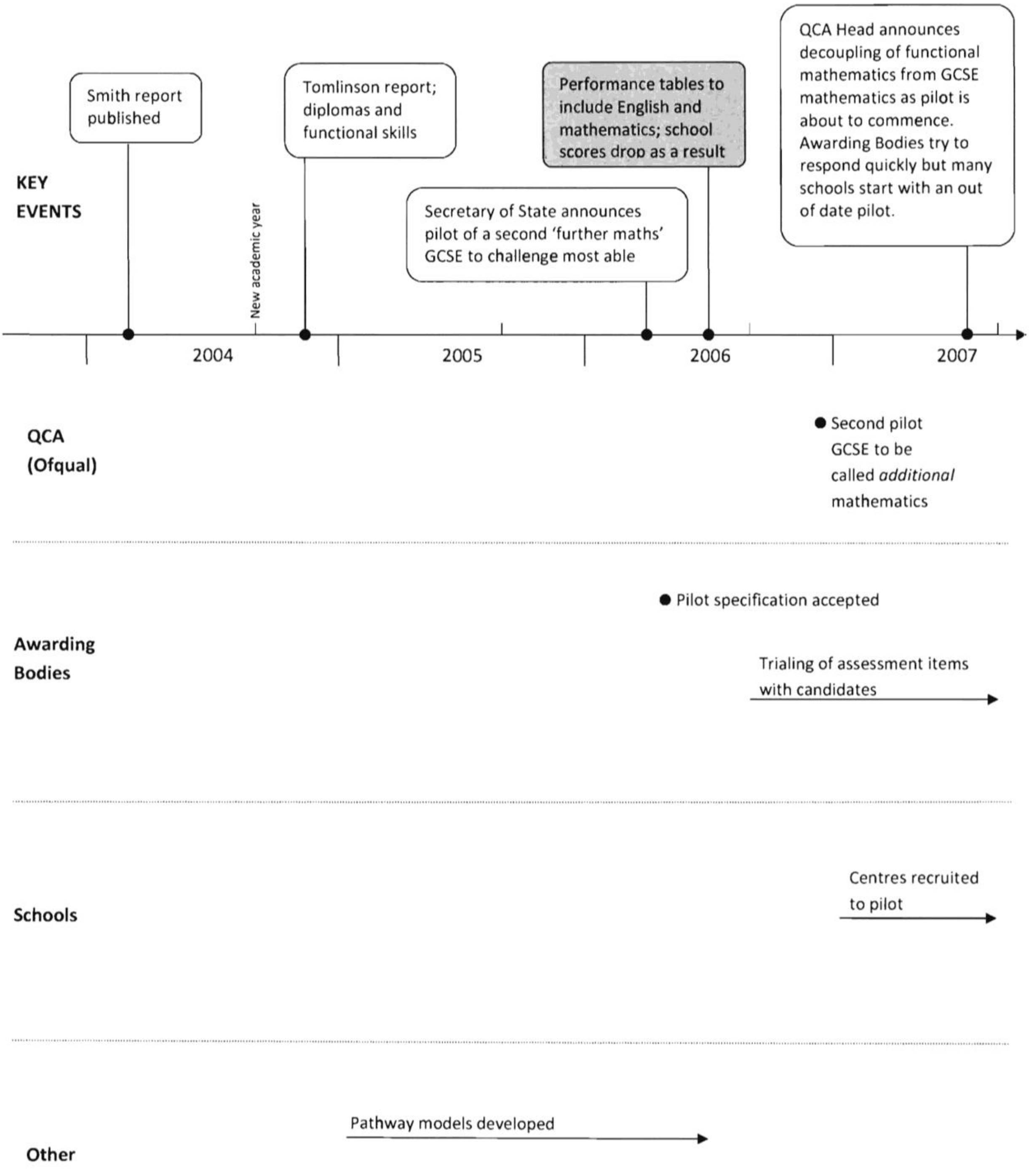
The Figure demonstrates the periods of time over which some of the processes took place. For example, from initial drafting of examination paper items to the validation (QPEC), sitting, marking and analysis of results is around 18 months; a national consultation lasts for 3 months; a ministerial decision emerges and is made in a matter of weeks and critical regulatory decisions often appear without warning. Despite the limitations of the figure, it does usefully expose some of the critical incidents and fracture points in the timeline. Some of these problems were due to the insufficient duration of the study. However, some of the specific events could not have been foreseen, although with the benefit of hindsight they are quite understandable. It is too simplistic to point to the different timescales of policy generation and pronouncement, qualifications development and teacher change to explain the limited progress. Some important changes happened quite quickly and unexpectedly during this period and it is important to be able to distinguish these.

Figure 1 includes the activity of one of the three national awarding organisations that was involved in the pilot. The grey boxes are events that were not part of the MPP but had a significant impact upon schools during the period in question. In addition to the diagram and in order to illustrate some of what happened during the pilot period from 2007-2010 we present a short vignette of a composite pilot school. Thomson (2002) used a similar heuristic device in her work and we consider this to be an appropriate way to explore some of the issues in this context (see also the work of Lawrence-Lightfoot & Hoffmann Davis, 2002). The external events in the vignette are real and the internal experiences in the school are typical of many of the schools involved in the evaluation.

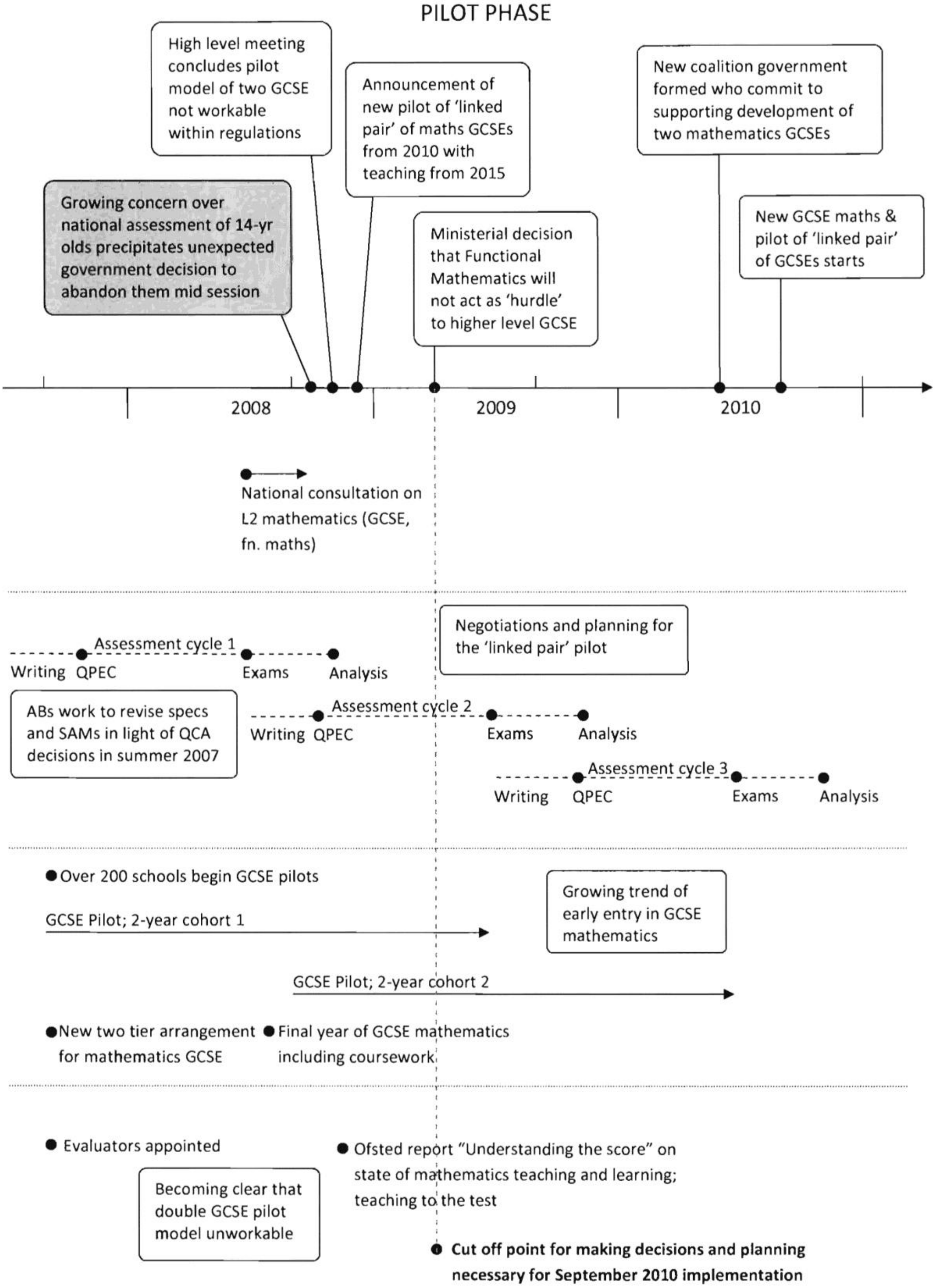
The view from a pilot school

Having been recruited to the pilot in the spring of 2007, Swarkstone School began the autumn term of 2007 with a cohort of two hundred and twenty 14-year-olds embarking on a new two year programme of double GCSE mathematics and functional mathematics. The previous summer's school leavers had only completed a single qualification in mathematics but this cohort would leave school with three awards: GCSE Mathematics, GCSE Additional Mathematics and Functional Mathematics. Although that meant a lot of exams, the school's senior management team had been keen to support the pilot, not least because students would be getting two GCSEs and many of the borderline C/D students that are so critical to the school performance measure would get two attempts at getting that all important C grade. There was also the hope that functional mathematics might be more motivating and meaningful for the lower attaining students and that the new emphasis upon problem solving would prove motivating for all, including the teachers. The awarding body had not made dramatic changes to the assessment for the pilots, at least in the sample assessment materials (SAMs), as they knew that recruiting centres in an inherently conservative and highly competitive assessment market can be a high risk strategy. Moreover, because the two GCSEs were both based on the

PRE-PILOT PHASE



PILOT PHASE


High level meeting concludes pilot model of two GCSE not workable within regulations
Announcement of new pilot of 'linked pair' of maths GCSEs from 2010 with teaching from 2015
New coalition government formed who commit to supporting development of two mathematics GCSEs
Growing concern over national assessment of 14-yr olds precipitates unexpected government decision to abandon them mid session
Ministerial decision that Functional Mathematics will not act as 'hurdle' to higher level GCSE
New GCSE maths & pilot of 'linked pair' of GCSEs starts
2008
2009
2010
National consultation on L2 mathematics (GCSE, fn. maths)
Negotiations and planning for the 'linked pair' pilot
Assessment cycle 1
Writing
QPEC
Exams
Analysis
ABs work to revise specs and SAMs in light of QCA decisions in summer 2007
Assessment cycle 2
Writing
QPEC
Exams
Analysis
Assessment cycle 3
Writing
QPEC
Exams
Analysis
Over 200 schools begin GCSE pilots
GCSE Pilot; 2-year cohort 1
Growing trend of early entry in GCSE mathematics
GCSE Pilot; 2-year cohort 2
New two tier arrangement for mathematics GCSE
Final year of GCSE mathematics including coursework
Evaluators appointed
Becoming clear that double GCSE pilot model unworkable
Ofsted report "Understanding the score" on state of mathematics teaching and learning; teaching to the test
Cut off point for making decisions and planning necessary for September 2010 implementation

existing programme of study there was no extra content to teach, although the Additional Mathematics GCSE did have fewer, longer questions and a greater emphasis on problem solving. This was something new for the department.

As the autumn term was getting underway the school received a letter from the awarding body, explaining QCA's decision that functional mathematics would no longer be accredited as part of the first mathematics GCSE. Instead there were to be separate examinations. This meant that the pilot on which the cohort had just embarked was already obsolete in its current form, although it would still be allowed for the pilot, to comply with student and teacher expectations and teaching arrangements set up for the cohort. There were reassurances from the awarding body that the changes would be made to the assessments and support was offered. The department decided to proceed but some members of the team urged a more cautious 'wait and see' approach, so classrooms looked very similar to the previous year.

At the end of that school year, in July 2008, the QCA began a national consultation on the programme of study for, and structure of, GCSE and functional mathematics. The head of department thought it odd to be piloting new qualifications before consulting on the content and structure of these in the future. Whilst she was attending the Advisory Committee on Mathematics Education's (ACME[vi], an important stakeholder) annual conference she heard that Ofqual, the qualifications regulator, were not going to allow two mathematics GCSEs to be based on assessment of the same programme of study. By the autumn of 2008 this regulation had led to the decision that the pilot would not be implemented. Instead, the head of department heard on the BBC that there would be a different pilot of a 'linked-pair' of mathematics GCSEs starting in 2010. Although the first cohort of pilot students at Swarkstone School was yet to complete the course in summer 2009, they were working on something which was by now well out-of-date.

A few months later, at Easter 2009 and just prior to the final exams for this cohort of 16 year-olds, the government made another announcement. In contrast to what they had been told at the outset of the pilot, functional mathematics would now not act as a hurdle to students attaining higher grades at GCSE. This was not that important as the operating rules for the pilot had meant that this would not be imposed anyway, so the department had not been paying too much attention to it. Two months later in June 2009 this first pilot cohort of GCSE students completed their two-year programme of outdated double GCSEs. Some of them also did functional mathematics. Many of the students were delighted to get two top grades rather than one whilst others had managed a C/D and were similarly elated. The school withdrew from the pilot.

Problematic timescales

At the heart of our analysis are temporality problems. From a project-management perspective there are important lessons that need to be learnt from this pilot. If a substantial national pilot project of this nature is to be properly planned, implemented and evaluated prior to any decisions being made about what should happen as a result, then there needs to be a longer time period committed to the work. This will exceed one parliamentary term and so presents an understandable political problem. The MPP all took place under one New Labour government so the reasons for failure are not as a result of changes in government. However it is safe to say that the MPP would have been terminated early had there been a change of government earlier than 2010.

In the case of the Mathematics Pathways Project, the pilot would need to have been completed and evaluated by the end of 2008 in order that lessons could be learned for implementation of a new curriculum and assessment system from autumn 2010 (see the 'Cut-off point' in Figure 1). Working backwards, this would mean evaluating a pilot cohort completing in summer 2008, starting in 2006 (Figure 1 shows that the first pilot cohort completed after the cut-off point). For this pilot cycle to have benefitted from the findings from an earlier cycle there would have to have been a 2004-6 pilot GCSE cycle. This in turn would have needed at least eighteen months of planning. This would take the process back to 2001, three years before the Smith report. The implication here is that in order to properly plan, implement and evaluate a programme of this type requires around ten years – double that which was allocated - whilst the student experience of it lasts two years or less.

A second temporal issue that is arguably more complex and problematic for those interested in education reform is the multiple timescales over which political, educational and socio-cultural changes take place. This brings us back to Lemke's thinking around time-scales. Policy decisions can create a flurry of activity which might or might not lead to some changes in educational practice and impact upon learning. Conversely, societal attitudes to education, in our case mathematics, are notoriously difficult to change and tend to be reproduced across generations. We are interested in how these scales of time interact to a greater or lesser extent and what can be learned about how to lever lasting change. We have already employed Lemke's ideas in the context of the MPP through the structuring of Figure 1. There are moments (ministerial decisions, reports published, etc.) which are intended to have impact upon learners but get mediated through the various processes and artefacts of QCA, the awarding organisations, schools and classrooms.

The political, regulatory and assessment domains are not mutually exclusive but are rather networked through the activities of key groups and individuals (e.g. Ball and Exley's (2010) 'policy interlockers'). It is the historical alliances and rifts that have been sedimented over decades that are arguably the most influential and at the same time the most difficult to see and understand: it is both timescale and *who you know* that is important. This is the heterochronic dimension of the reform process, namely that the longstanding agents and interlockers in the field of mathematics education, each positioned with different interests and influence by virtue of historically accrued social capital are suddenly mobilised to protect group interests. Although the authors had access to many of the stakeholder groups and their representatives, and indeed were insiders to some of these, understanding the amalgam of between- and behind-the-scenes processes that combine in policy work is far from straightforward. That said, despite the appearance of policymakers' regulatory power and the shadowy worlds of the interlockers and policy networkers, the momentum – at least in terms of what happens in lessons - remains with the 3,500 schools, 20,000 teachers and the 1,200,000 students who comprise the cohort studying GCSE up to age 16. Changing pedagogy, attitudes and outcomes is notoriously difficult and, as some sociologists have argued (e.g. Bourdieu, 1989; Bourdieu & Passeron, 1977), education is a powerful means of social reproduction and is therefore inherently conservative. Given the role of mathematics in society, this tendency is particularly acute in the 14-19 mathematics arena where school, higher education, industry and commerce meet.

A temporal analysis implies that for effective implementation of policy ideas - especially the ones that hope to have a long term transformative effect on learner attitudes and outcomes - more careful attention would need to be paid to understanding the adiabatic principle whereby policy 'energy' transfers across the various timescales involved in this dynamic educational system. In the MPP much of this energy was dissipated before it reached schools, with all that remained being the attraction of more GCSEs and higher grades. The initial energy for the initiative was dampened as it passed to regulator and curriculum authority, then to awarding bodies, before reaching schools. The damping was partly systemic and due to the poor temporal alignment of various processes. It was also deeply cultural with endemic performativity producing unintended consequences. This damping process can be seen in the following account as well as in Figure 1 and the vignette of Swarkstone School:

- The Smith Report acknowledges over-filled curriculum for high attaining students, proposes second GCSE for 'most able'; a double GCSE model akin to science (2004);
- Announcement of 'tough new GCSE' (then called further mathematics) to 'stretch' the 'brightest pupils' announced by the then Secretary of State (2006);
- Awarding bodies design double GCSE for 'more able and more motivated'. However, it needs to cover the whole grade range as this is a GCSE regulation (2007);
- Assessment design moves slowly in risk-averse market so schools do not change curriculum much, if at all;
- Schools mostly motivated by opportunity to get 'two for the price of one', especially for students around the C/D borderline, and thereby enhance their position in performance tables;
- More regulatory shifts scupper double GCSE model completely;
- Little change in classrooms as a result of the MPP.

On this last point, it needs to be said that considerable change did happen during the MPP but not as a result of this particular intervention. Two decisions that had a major effect upon young people's experiences of mathematics at GCSE were a) the inclusion of mathematics in the school performance measure (2006) which has already been discussed and b) the cessation of national testing of 14-year-olds (2008). These two decisions were the result of different events and trends and had a quick impact upon teachers and learners. The decision to drop national assessments for 14-year olds part way through the 2008-9 academic year could have reduced the performative pressure (Ball, 2003) on both teachers and students, thereby opening a space for curricular enrichment and innovation. However, within weeks of the announcement, heads of mathematics departments were reporting school decisions to commence GCSEs early. They were also planning to enter students early for mathematics and English, thereby making space in the curriculum for more GCSE subjects and more strategic, targeted interventions to raise attainment. So, some decisions can have almost immediate effects whilst programmes that seek to sustain gradual change and development are all too prone to being derailed by the exigencies of political decision making.

Concluding comments

This paper focuses on the failings of a major curriculum and assessment pilot during the period 2005-10. Since then, and with the election of a conservative-led coalition government, there has been an unprecedented amount of education reform proposed in England. Within the last year (2012-13) the government announced its plans for reforming A levels in England by 2015; a consultation on the new National Curriculum has been undertaken; a new English Baccalaureate Certificate has been announced and the reforms of GCSE for 2015 continue apace. There have been full or partial U-turns on some of these pronouncements but what remains clear is that there is considerable political will to make major system level changes in the school curriculum and assessment. This is particularly keenly felt in 'core' subjects such as mathematics who are normally in the vanguard of any change. Ministers want quick change and seem to think that all change can be made quickly.

At various national consultation meetings on the new qualifications attended by the authors, contributors have made the case for pilot work to be undertaken to inform such developments. Our analysis suggests that there would be little benefit in piloting qualifications on a national scale unless the conditions for the successful conduct of such pilots could be established, namely a sufficiently long period of relative stability. This is unlikely to happen soon. Even if there was a period of stability in which piloting could be undertaken, curriculum developments would nonetheless be contested and remain contingent upon what has gone before and what is now happening.

The Mathematics Pathways Project did not meet its primary objective, namely the development of a range of flexible learner pathways in 14-19 mathematics education starting with a reformed, 'double GCSE'. That vision has subsequently been taken up with the aim of getting two distinct mathematics GCSEs into the catalogue of qualifications and this in turn has been superseded by the government's proposal to do away with GCSE altogether. If future curriculum developments are to include serious attempts to learn from piloting they might be more effective if the following two conditions were met.

Firstly, the timescale required for qualification and assessment development, and for meaningful pilot work, would need to be something in the order of double the length that had originally been allocated, i.e. ten years. Given that it seems unlikely that such ten year projects would be condoned by politicians, the case for the value of large-scale pilots and the possibilities for planned, developmental change are only weakened. Secondly, we need better understanding of the practical consequences of the adiabatic principle whereby policy 'energy' tends to get dampened across the range of 'structural interlockings' (Bourdieu, 2004) of the education field. In a large and complex system such as that in England, the spatial distance (i.e. degrees of separation or network distance) between policymakers and teachers is large. However, the temporal distance between policy pronouncement, enactment and realisation is equally, if not more, complex and yet little understood.

Having argued that large-scale pilot projects are unlikely to be successful in the current climate, it is also clear from the timeline in Figure 1 that real change in classrooms can be effected reasonably quickly in a heterochronic way. For example, over several years the gradual and insidious influence of neoliberal education policies has combined with the growth of international comparisons and perceptions that schools were *gaming* the league tables. Suddenly this precipitated a decision to include maths in the performance measure, although with the benefit of hindsight it was an obvious move. Those changes to the composition of performance tables did lead to changes in the way that young people were taught in preparation for GCSE examination (Ofsted, 2008) and have no doubt helped to squeeze up GCSE performance a little further.

The MPP aimed to achieve a cultural change in the kinds of mathematics being learnt, the ways in which it was assessed and the attitudes of young people to post-16 study. In contrast, policy decisions were intended to yield quick results, and were effective at overriding something of the adiabatic principle whereby different activity timescales do not effectively interact. The issue that this raises is whether there are only certain types of action that can result in quick changes in classrooms. Performativity (e.g. enhanced GCSE attainment) is arguably easier to engender than is an improvement in the quality of teaching and learning (e.g. evidenced by expertise in the teaching of problem solving). If policy makers are interested in making quick gains – 'raising standards' – certain kinds of pronouncements can have a relatively immediate response. The same is probably not true if the goal is to develop a professional development strategy for teaching, for example. So, there are leverage strategies available to ministers that seem to have an effect of sorts, but it is safe to say that managerialist accountability technologies (Ball 2003) do not work well for effecting the longer term culture changes that educationalists often work towards in classrooms. Indeed, if politicians really want deep and long lasting change in schools and classrooms, it will take time and there is a need to understand how these quick and slow political and educational processes interact and counteract one another.

In our analysis we have explored why the MPP process fell far short of meeting its original goals, largely focusing on the problems of time: poorly understood development timescales, the adiabatic principle and heterochronicity. The MPP offered the opportunity to develop new programmes and learner pathways that would be more attractive and engaging to a wider range of young people. Clearly, the challenges have not just been temporal. Attempts to add new programmes and pathways have been resisted by some stakeholders and interlockers (Noyes, Wake & Drake, 2011) but the agency of individuals and groups has not been explored herein. Our analysis needs to be considered alongside critiques of the mathematics education field (e,g, Noyes, 2011) in order to engineer conditions for reform that might lead to wider participation in mathematics.

So, in sum, we have argued for the development of thinking around the pragmatic and theoretical aspects of temporality in policy enactment and curriculum development, exemplified through the case of the Mathematics Pathways Project conducted in England between 2004 and 2010. In particular, major curriculum reform projects need to take better account of the temporal interlockings and interference of their constituent processes as well as the likely impact of parallel policy changes. The adiabatic principle is a particularly useful metaphor for the loss of policy impetus in a project like this and explaining why so little change can result in classrooms from such curriculum design policy projects. In contrast, changes in classrooms seem most likely to result from (heterochronic) processes whereby apparently small actions result in an 'avalanche of consequences' that cut across time-scales in unpredictable ways.

Notes

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[i] Young people in England 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 subjects. Obtaining five or more higher grades (A*-C) in these 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 awards (A levels). These are the standard university-entrance qualifications and most students choose to study three or four subjects over the following two years, up to the age of 18 (Year 13).

[ii] Trends in International Mathematics and Science Survey

[iii] Programme for International Student Assessment

[iv] PISA tests were first conducted in 2000 and then every 3 years after. In 2000 and 2003 England did not meet the strict statistical criteria for inclusion. However, Gove claims that England 'plummeted' in the PISA league table over the last 10 years. In response, Andreas Schleicher, Head of the Indicators and Analysis Division (Directorate for Education) at the

OECD, when interviewed on BBC Radio 4's More or Less (24/4/11, bbc.co.uk/programmes/b010fd86) explained that "there is little doubt that the performance of the UK has at best been flat" and that claims of plummeting cannot be made from the data. 32 countries participated in 2000 and this had doubled by 2009 so league tables are not comparing like with like.

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

[vi] ACME is a committee of the Royal Society. It represents the mathematics education community, advising ministers and other interested parties on all aspects of mathematics education

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