

Mathematics curriculum *waves* within vocational education

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Links between mathematical attainment and economic performance, coupled with England's poor showing in international comparisons of skills, have focused attention on post-16 mathematics education, for example in the UK Government's 2017 Industrial Strategy. Whilst high-stakes academic qualifications at 16 (GCSE) and 18 (A-level) have stood the test of time, the 'forgotten third' of students in England's Further Education colleges have fared less well. Over the last 30 years a series of mathematics qualifications for vocational students have been established and then discarded. This paper utilises a theory of change approach to understand this repeating pattern for three successive curricula: core, key and functional mathematics. Waves of rise and decline include critical moments of reinforcement, or synergy with wider reforms, but trajectories are also affected by shifting policy visions for Further Education and entrenched knowledge hierarchies that value academic mathematics qualifications over vocational ones. Whether 'alternative' mathematics curricula for FE students can achieve longevity and widespread recognition remains to be seen. The implications from this analysis of historical trajectories are that changes to established attitudes and educational values are needed to halt this repeated cycle of short-lived alternatives to GCSE mathematics.

Keywords: policy; mathematics; vocational education; Further Education.

Introduction

The importance of mathematical skills to economic and thereby life outcomes is well established (Dolton and Vignoles 2002; Ananiadou, Jenkins, and Wolf 2004) but international comparisons have highlighted England's relatively poor numeracy skills (Kankaraš et al. 2016; Wheater et al. 2013) and lower levels of engagement with advanced mathematics (Hodgen et al. 2010) and. Such reports have generated much policy energy, aimed at improving participation and outcomes in post-16 mathematics learning at all levels, evidenced by the prominence of mathematics education in the 2017 Industrial Strategy (BEIS 2017) and the level of government investment in post-16

mathematics following Sir Adrian Smith's report (2017). This paper focuses on mathematics within vocational education, the part of England's education system that broadly caters for what has been called 'the forgotten third' (ASCL 2019) of those considered to have low attainment in mathematics at age 16 years.

In England, students complete high-stakes national examinations in the form of the General Certificate of Secondary Education (GCSE) at age 16 years. Thereafter, post-16 education is characterised by a clear division between vocational and academic pathways with over one third of 16-18-year olds studying in Further Education (FE) colleges (Association of Colleges 2020), the majority on vocational programmes. Since August 2014, students without a 'good pass' (grade 4) in GCSE Mathematics at age 16 have been required to continue studying mathematics with the aim of retaking the GCSE examination until they achieve this grade. Although the lowest-attaining students (GCSE grade 2 and below) may take Functional Skills mathematics qualifications as stepping-stones towards GCSE, there has been an increasing preference for GCSE entry, despite low pass rates (i.e. achieving at least grade 4) for post-16 students retaking GCSE Mathematics, with, for example, only 18.7% of those entered making the grade in 2018 (DfE 2019). This decline in popularity of functional mathematics may be partly attributed to policy drivers that prioritise GCSE but the higher value of GCSE in the labour market and its 'gatekeeping' role for progression are also reasons why GCSE is preferred, adding to some dissatisfaction with the qualification itself (Noyes and Dalby 2020).

This 'GCSE retake' policy is the latest in a series of approaches to post-16 mathematics. In earlier policies, GCSE mathematics has been available as an option but there has been greater emphasis on a succession of other accredited mathematics curricula ('core', 'key' and 'functional') which have followed, one after the other, since

the late 1980s. These mathematics curricula have typically each lasted only a few years, whilst the higher-status, academic-track GCSE qualification has remained as a stable 'brand' throughout. This difference suggests limitations or failings in the conceptualisation, design and/or implementation of these post-16 mathematics curricula, as suggested by Hayward and Fernandez (2004) in their earlier study of core and key skills.

As a result, successive cohorts of students considered as low-attaining at age 16 have been poorly served by undertaking mathematics qualifications that have been too short-lived to achieve recognition and value. The GCSE qualification is well established as a high value qualification but, as the current situation demonstrates, this is not always a realistic goal. Unless an alternative mathematics qualification for post-16 students becomes established long-term and achieves wide recognition, it seems likely that future post-16 students will continue to achieve either low-value qualifications or further low GCSE grades.

By examining three 'alternative' qualifications (core, key and functional skills) over time, we aim to identify patterns in their trajectories and examine how sustainable alternatives might be developed. Through this approach we sought to answer the following questions:

- What patterns can be identified in the trajectories of mathematics curricula for post-16 vocational students?
- What are the possible explanations for these patterns?
- How might more sustainable, high-value qualifications be developed?

The development of mathematics curricula for vocational students cannot be easily disentangled from wider educational systems, policy and practice (Hayward and

Fernandez 2004), particularly in a divided system. The post-16 academic-vocational divide highlights contrasting and contested educational priorities that are evident in recent debates around the relative value of academic-track mathematics qualifications (i.e. GCSE) and ‘alternative’ qualifications (e.g. Functional Skills mathematics). Even in the current climate, where the reform of vocational education is prominent in policy discourse, the claim from Kennedy (1997) that academic success is privileged in this divided system still rings true.

Positioning any ‘alternative’ to GCSE mathematics, with its well-established academic identity, in this divided system is challenging (Dalby and Noyes 2016) and mirrors, in some ways, repeated unsuccessful attempts to develop ‘middle track’ qualifications that sit between the academic and vocational. These qualifications have often been short-lived, suffering from a lack of identity and status without having the time and appropriate conditions for growth (Raffe, 2015). Alternative qualifications to the widely recognised and established GCSE mathematics have attracted some similar criticisms to ‘middle track’ qualifications concerning their design and also their value in the labour market, highlighting how the context is equally as important as the qualification itself (Keep 2012).

Views of what constitutes an appropriate mathematics curriculum for post-16 vocational education in England have ranged between various descriptions of a specific set of skills for each vocational or technical area, and a generic common core of mathematical knowledge that underpins all applications in life and work. Different qualifications and modes of assessment have been developed, which stand apart from academic-track qualifications and mostly focus on attainment at Level 2¹ and below.

¹ Level 2 qualifications are equivalent to GCSE grade 4.

Fundamental to these alternative curricula is a conceptualisation of *mathematics for life and work* as a set of generic skills that have been successively modified since the term was introduced in the landmark report by Cockcroft (1982). The development of these different conceptualisations and their subsequent demise lies at the heart of the following analysis.

Multiple stakeholders with different perspectives on mathematics in vocational education add considerable complexity to policy discourses. Business and industry reports have typically foregrounded specific skills shortages or basic skills needs (e.g. British Academy 2015; Confederation of British Industry 1989, 2015). Employers' perceptions about the mathematics required for the workplace are joined in this contested space by representations from the Further Education sector (e.g. Education and Training Foundation; Association of Colleges) and those with an academic perspective on post-16 mathematics. The form and content of a post-16 mathematics curriculum is not easily agreed when fundamental views of the purpose and need for mathematics vary.

- This lack of agreement has resulted in contestation about different conceptualisations of an 'alternative' mathematics and the subsequent demise of successive qualifications. The reasons for the failure of these successive curricula are examined in this paper by tracing their trajectories over the last 30 years, identifying common patterns and theorising causal influences.

In the following section we set out key aspects of our *theory of change* approach (Funnell and Rogers 2011) before proceeding to describe the methodology and present our analysis of the trajectories of three specific curricula (core skills, key skills, functional skills). Following a summary of each curriculum *wave*, we present a more

specific theory of change before discussing the patterns that emerged from our analysis and the implications. This builds towards some general conclusions about curriculum cycles and the implications for those aiming for high quality, sustainable post-16 mathematics qualifications for vocational students in England.

Theory of change

The analysis derives from careful examination of how the ideas, influences and ideologies evidenced in a range of official documents have coalesced to shape policy and curriculum development over recent decades. It is an analysis of both the *product* and the *process* of continuous development (Bowe, Ball, and Gold 2017), involving complex relationships of power in a contested space where policy development does not necessarily follow a rational progression (Bell and Stevenson 2006). Our aim is not to explore the full detail of these interactions within policy discourse, or the complex process of mediation and moderation from various actors (Ball 1993), but to summarise key influences and their effects on the broad shape of mathematics policy over time.

The *theory of change* approach aims to examine mathematics policy development over time and seeks to explain how various historical ‘interventions’ have worked as a causal chain with a series of *inputs*, *outputs*, *outcomes* and *impact* (Funnell and Rogers 2011). In our case, we are considering complex historical policy implementation processes within a reflexive system in an unstable field (Lucas and Crowther 2016). Within the range of practical and theoretical uses of theories of change this presents a case of organised complexity (Rogers 2008) in which multiple parts and actions interact in unpredictable and non-random patterned ways. Our approach involves a comparative analysis of particular initiatives in different contextual conditions (Rogers 2008; Sanderson 2000), so the effects of any changes in context also need to be considered.

Within such a system of organised complexity, the analysis enables exploration of patterns in the growth and decline of successive mathematics qualifications. Whilst mindful of the limitations of oversimplifying the complexity and variability of maths policy and curriculum change, useful patterns can emerge with proper consideration of inputs and outputs under changing conditions over time.

The following ideas from the theory of change literature are pertinent to our approach.

- (1) Rogers (2008) and Vogel (2012) highlight the need to consider the effects of *contextual factors* as part of a logic model.
- (2) Contextual factors also influence how any initiative fits within the existing climate and the extent of any *resonance*.
- (3) The *combination and balance* of factors is important since this affects how policy is shaped and how it resonates with national agendas.
- (4) *Opportunities for synergy* with contextual factors that can be leveraged, such as integration with other initiatives, are key (Rogers 2008; Vogel 2012). Strong connections with other systems are important (Clark and Taplin 2012) and serendipity can catalyse action (Sanderson 2000).
- (5) *Reinforcement* is important and can take different forms. Systems also have inbuilt reflexivity whereby social actors reflect and adapt, thereby changing the effects of the intervention.
- (6) There may be *critical moments* or *tipping points* that accelerate or slow activity or change processes (Rogers 2008; Glouberman and Zimmerman 2002), for example a major report.

These key ideas were used in the analysis, in conjunction with an initial conceptual framework based on a theory of change approach, including inputs, outputs, outcomes

and contextual factors. The analytic process is explained further in the following section.

Methodology

In order to examine the trajectories of the three ‘alternative’ mathematics qualifications (core skills, key skills and functional skills) a large database of documents was assembled, validated and mapped to a timeline. This documentary evidence includes reports published over a 20-year period between 1998 and 2018 by a range of stakeholders. The inclusion criteria used were the relevance and impact of a document to *either* mathematics in post-16 vocational education, *or* relevant wider reforms, so that the context was also considered. The documents fell into four broad categories:

- legislation and government consultation;
- published reports led or commissioned by government;
- published reports from other national organisations and stakeholder groups;
- published documents on curriculum developments from a range of sources.

Carefully chosen sector experts, each with specific knowledge and long experience in a relevant area (e.g. mathematics education, vocational education, government policy), reviewed the database and validated a core set of documents. This resulted in a final dataset of over 100 documents. The documents were assembled into a timeline and the key messages were summarised for each report. Other contextual changes (e.g. political, funding mechanisms) were also incorporated into the timeline.

The analysis was carried out in three stages. Firstly, the document summaries were examined and coded to the conceptual framework derived from a theory of change approach: inputs, outputs, outcomes and contextual factors. Secondly, an iterative process of emergent coding was used to identify themes within each of these categories

and add a second level of coding to the documents in the database. This was informed by the secondary concepts identified earlier from the theory of change literature (resonance, combination and balance, opportunities for synergy, reinforcement, critical moments). A more detailed logic model was developed as a heuristic tool during the coding process to represent the key themes that emerged. Finally, the coded documents were assembled into three shorter timelines, one for each of the qualifications being considered, so narratives could be developed to summarise the three trajectories and the influences that shaped them.

The policy trajectories of the three successive 'alternative' curricula considered (core skills, key skills and functional skills) are summarised in the following section. This is followed by the more detailed theory of change and logic model derived from the analysis, which informs a discussion of the implications for future policy development in this area.

Policy timeline and analysis

Core skills

A common mathematics curriculum for vocational students first emerged in the 1980s when Youth Training Schemes (YTS) specified particular 'transferable' skills (e.g. numeracy) as essential for the workplace. This echoed earlier claims that three core skills - communication, numeracy and personal skills - were important for employability and should be an entitlement in FE (Further Education Unit 1979). Similar core skills were included in new Business and Technology Educational Council (BTEC) specifications in 1983. The *combination* of interest from different influential stakeholders provided extended *reinforcement* of the fundamental idea of an alternative

mathematics curriculum for vocational and technical pathways, albeit with varied conceptualisations of what form this should take.

The evolution of core skills involved an extended period of conceptual development as understandings and definitions by different bodies were proposed and adapted. This was contextualised in an education system that focussed on mathematics as an academic discipline and paid little attention to the use of mathematics within vocational and technical areas. Further development of the concept followed with the National Curriculum Council (NCC) proposing eight core skills (National Curriculum Council 1990) and the Department for Education and Skills narrowing this to three core generic skills considered essential for the future economy, which now included mathematics rather than numeracy. Although debates over the use, comparability and appropriateness of these two terms (mathematics and numeracy) continue, this was an important point where the notion of a mathematics curriculum for life and work was *reinforced* and there was some agreement about the existence of some important generic skills.

A new term surfaced when ‘application of number’ became a core skill in the new General National Vocational Qualifications (GNVQ) in 1992. The *synergy* with wider vocational reform through inclusion within GNVQs helped to establish an applied form of mathematics as a ‘core’ skill underpinning vocational learning (Green 1998), even though core skills was arguably a product of the divided system rather than a solution (Hodgson and Spours 2002). This *critical moment* saw an alternative to academic mathematics integrated into vocational education (GNVQs), thereby providing an ideal opportunity for a mathematics skills-based curriculum to flourish.

The core skills approach was however primarily a deficit model which prioritised addressing gaps in knowledge of basic mathematical techniques over skills in

using and applying them. Although central to vocational qualifications, the core skills units lacked vocational relevance and by the mid-1990s, after 17 years of development (1979-1996), they were ready for change.

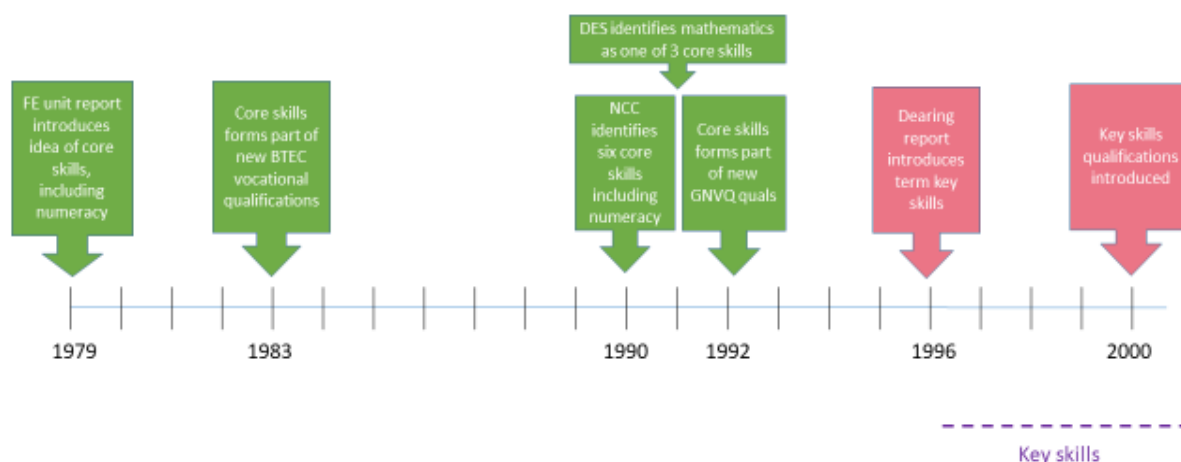


Figure 1. The core skills curriculum wave (and formation of the key skills wave)

During this period, government had committed to putting employers at the heart of skills policy so their influence was understandably strong. The perception that young people needed some core mathematics or numeracy skills for the workplace was supported in turn by industry and FE stakeholders (Confederation of British Industry 1989; Further Education Unit 1979). This sustained *reinforcement* of the need for generic mathematical skills, combined with government interest in skills for the workplace, provided fertile ground for an extended period of conceptual development in which there was widespread acceptance of the notion of developing generic skills in the application of mathematics.

Strong calls for better adult skills (Moser 1999) provided another *critical moment* in the core skills trajectory since this landmark report highlighted the need for improved numeracy skills in the adult population and stimulated new thinking about how this unacceptable situation could be addressed. Although providing *reinforcement*

of the need for better skills, it also inferred that the policies and curriculum of the day were not producing the required outcomes, suggesting that it was time for a different approach.

Key Skills

The foundations for a new mathematics curriculum suitable for vocational students had already been established with the re-branding and re-definition of ‘core skills’ as ‘key skills’ in the Dearing report (1996). The transition took place in the *context* of a new Labour government intent upon improving life choices through education and a minister with genuine insights into, and enthusiasm for, Further Education. This *resonance* with a national agenda created favourable conditions for change. Despite doubts about the conceptual validity of such transferable skills (Hyland and Johnson 1998) and the sustainability of any form of generic skills without wider-scale changes in the policy environment (Hayward and Fernandez 2004), key skills received increasing attention and could claim to be a major influence on post-16 education (Bolton and Hyland 2003). The key skills approach assumed the existence of foundational skills but placed an emphasis on applying these in a vocational context. The dual concepts of vocationally-relevant mathematics and a common core of procedural skills were both present but the early summative assessment privileged evidence that students could use and apply mathematical skills in familiar vocational contexts.

Key Skills Application of Number was subsequently invigorated through new Key Skills Standards (QCA 2000) and qualifications with a clearer curriculum structure, linked to the Adult Numeracy Core Curriculum (DfES 2001). The assessment decoupled basic procedural knowledge from application by using both an external test and a student portfolio. This dual approach offered the promise of bridging the

academic knowledge-based view of mathematics classrooms and the skills-based approach characteristic of vocational education.

Linking the new Key Skills to the adult numeracy curriculum helped frame the concept more securely but links to the Skills for Life Initiative also provided valuable opportunities for *synergy*. Although the focus of Skills for Life was adult skills, this major initiative afforded Key Skills both credibility and support. This included a boost to participation prompted by the inclusion of Key Skills qualifications in the demanding Skills for Life participation and achievement targets.

Although the need for mathematics skills for life (Moser 1999) and the workplace (Hoyles et al. 2002) was *reinforced*, the emergence of an alternative vocational curriculum in a more unified 14-19 system (DfES 2005; Tomlinson 2004) ultimately led to the end of key skills. Influential criticism of the effectiveness of post-14 maths (Smith, 2004) and the dual importance of the subject to both academic and vocational disciplines (ACME 2006) led to a *critical moment* where essential mathematics skills within the new 14-19 vocational diplomas would be termed 'functional', as suggested by Tomlinson (2004), rather than 'key'. The stated intention was that functional skills would be a part of every post-14 pathway including academic, vocational and Foundation Learning (Department for Children Schools and Families 2008).

The rejection of key skills by schools and higher education also contributed to its demise. Less than 10 years from the introduction of the term key skills (Dearing 1996), the post-16 mathematics landscape again lacked a credible alternative to GCSE. Despite attempts to revise the Key Skills Standards (QCA 2004) and revive the qualifications, with the name of a successor established within a wider proposed reform,

there was more interest in a new qualification than in sustaining one that had promised to span the academic-vocational divide and failed.

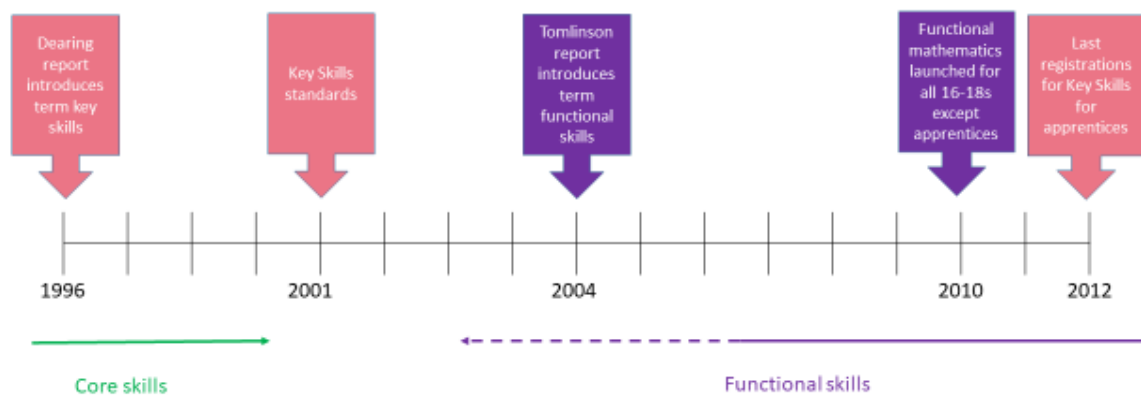


Figure 2. The key skills curriculum wave (and formation of the functional skills wave)

Functional skills

The concept of functional skills introduced by Tomlinson (2004) addressed the same issue of developing mathematical skills that would enable students to become active and responsible citizens in life, education and work (QCA 2007). There was a shift in emphasis towards application across a range of contexts, rather than only familiar settings. An element of developing problem-solving skills also appeared in the functional mathematics specifications. These changes moved the curriculum towards a position in which knowledge of basic mathematics was essential and vocational relevance was possible, but skills in application and problem solving in a range of contexts were encouraged. This curriculum emphasis more closely matched the identified needs of the workplace, described by Hoyles (2002) as mathematical literacy but the conceptual development took place during the decade-long Skills for Life Initiative when ‘basic skills’ was high on the Labour government. The *cultural context* provided fertile ground for the development of ideas in line with the agenda of improving skills for life and the workplace.

Given the previous challenges of designing a qualification with an emphasis on using and applying mathematics, the development of a sustainable functional mathematics qualification, acceptable as an alternative to GCSE, would not prove easy. Policymakers have the advantage of being able to learn from history but whether this meant that this latest ‘alternative’ post-16 mathematics qualification could avoid a trajectory similar to its forerunners was debatable.

An important *opportunity for synergy* to strengthen the case for functional skills was its inclusion within the new 14-19 Diploma. This provided functional skills with a secure space within vocational education and encouraged wider participation. However, a *critical moment* soon followed when the proposed diploma failed to gain political traction and consequently functional skills was uncoupled from vocational pathways. Similarly, although the original intention was for functional skills mathematics to be an essential part of GCSE Mathematics assessment, the later decoupling of functional skills from GCSE Mathematics left it as stand-alone qualification.

Despite this unfulfilled opportunity for *synergy*, the need for functional skills was *reinforced* through a series of reports about the skills needs in industry (Confederation of British Industry 2015; BIS 2010) the mathematics needed in the workplace (Hodgen and Marks 2013) and the link between poor skills and the economy (OECD 2010). The Skills for Life survey results (BIS 2011) showed little change in adult numeracy levels and international comparisons highlighted the need for improvement (Kankaraš et al. 2016; Wheeler et al. 2013). The need for better mathematics skills was reiterated by other stakeholders (Vorderman 2011; ACME 2011) resulting in great interest in credible attempts to address the problem. Links between mathematics and economic performance were becoming more influential again under the new Conservative-led coalition government and political interest in

developing an effective national skills strategy (BIS 2010) provided a favourable environment for change.

A second, more serious *critical moment* for functional skills was the Wolf review (2011) of vocational education commissioned by the new government. This not only proposed wide-scale changes in the vocational qualification landscape but also was critical of both the value and the conceptualisation of key skills and functional skills. The effects of this report introduced doubts about the credibility and efficacy of functional skills, which lingered through the following years.

A series of reports offered insight into the problems of improving post-16 mathematics outcomes for students with low attainment (Higton et al. 2017; Robey and Jones 2015) but proposed few solutions and a review of functional skills qualifications was undertaken. The first reform in 2012 led to increased difficulty in order to create better parity with GCSE mathematics but this made Level 2 functional skills mathematics more inaccessible for some students and the attempt at reinforcement did little to restore confidence in the qualification. Further revisions in 2019 have had a similar effect of increasing difficulty but this does not necessarily widen usage.

In the current policy situation, GCSE Mathematics has become established as the preferred post-16 mathematics qualification but vocational reforms are also underway. With previous changes to the vocational curriculum, a new conceptualisation of mathematics and new qualifications have been introduced, providing valuable *opportunities for synergy*. The most recent reforms in vocational education may constitute a final *critical moment* for functional skills. The embedding of general mathematical competences into the new technical level qualifications (T-levels) provides opportunities for higher-attaining students to improve their skills but debates

about the suitability of existing mathematics qualifications for those with lower mathematics attainment at age 16 continues.

The theory of change

The above accounts of these three curriculum waves suggest three main inputs into a logic model:

- (1) Reports presenting *evidence of need* for better mathematic skills occur frequently and tend to trigger or renew interest in post-16 mathematics. Skills deficits are repeatedly identified in two main categories: general adult numeracy skills and the mathematical skills required by employers for the benefit of the economy.
- (2) Developments in the *conceptualisation* of the form of mathematics that is appropriate as a preparation for life and work for post-16 students on vocational or technical pathways. This conceptualisation helps define the type of curriculum and assessment that is deemed desirable.
- (3) *Evidence of the outcomes* of current policy and curriculum shape views on the effectiveness of existing policy and curriculum. The outcomes affect public confidence in the policy and negative outcomes result in pressure for change.

These inputs take place in a space where contextual factors affect the growth of ideas and therefore these are included in the logic model. The main contextual influences can be summarised as:

- *Vocational reforms*. These provide synergy when a mathematics curriculum is developed in conjunction with new vocational qualifications, providing potential for the curriculum to serve a genuine vocational purpose.

- *The established curriculum.* The wider curriculum, extending longitudinally into school and adult mathematics, and laterally across parallel post-16 pathways, tends to privilege academic-track mathematics. A vocational mathematics curriculum that does not align well with this faces considerable threats to its legitimacy.
- *Political conditions.* These conditions include the dominant political ideologies and priorities of the day. The harmonisation of mathematics policy ideas with broader political intentions can support a new intervention, whilst dissonance has the opposite effect.
- *Timely inputs from other sources.* Multiple reports and voices can be focused and timed in ways that amplify or diminish their combined impact.

The combination of these *inputs* and *contextual factors* results in periods of either growth or decline of new ideas in policy discourse. These ideas are in turn consolidated into policy positions, with accompanying levers that support implementation. Related artefacts include the curriculum, qualifications and assessment specifications. The process of policy genesis, design, implementation and enactment is complex and involves a myriad of actors, texts and processes at different scales and in various places.

The *outcomes* in our theory of change logic model are of three broad types:

- Student achievement, e.g. qualifications and grades
- Student progress, e.g. measures of value added
- Wider scale evaluations of national skills

In the extended time periods under consideration, these outcomes also feed back into the cycle as inputs showing evidence of the effectiveness of current policy.

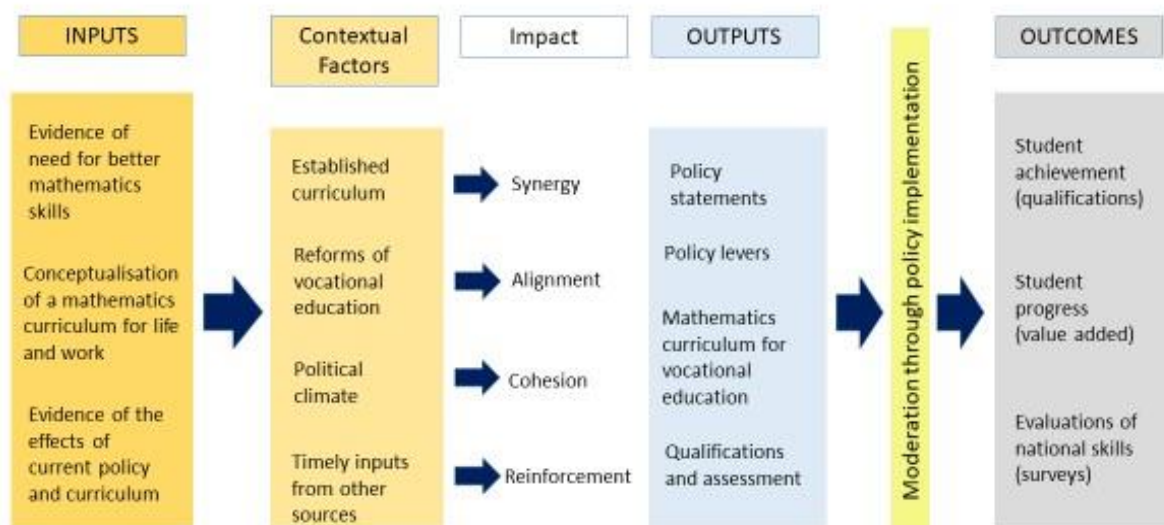


Figure 3: A logic model for the development of ‘alternative’ mathematics curricula in vocational education.

Discussion

Our earlier analysis of the process of policy development for functional mathematics (Dalby and Noyes 2020) shows four sequential phases:

- Conception – the developmental process from introduction of the concept to pilot-ready qualifications
- Inception – the start of a limited pilot to the evaluation of the qualification
- Implementation – scaled-up national delivery of new qualifications
- Decline – shift in policy, decline in use and emergence of successor

The extended analysis of three ‘alternative’ mathematics curricula in vocational education (core skills, key skills and functional mathematics) presented in this paper shows evidence of similar patterns of rise and decline in each case. Their trajectories resemble overlapping waves, in which a conceptualisation is introduced and then developed into a more formal curriculum with some form of accreditation. The policy

waves considered here suggest that after a new conceptualisation is introduced it takes several years, under favourable conditions, before a curriculum is ready for widespread use. The curriculum then thrives for some time as it becomes central to government policy and reaches a mid-cycle peak. At some point in this trajectory, a new conceptualisation is introduced and gains attention. Confidence in the current curriculum declines and a new successor is developed to take its place. This repeated pattern is not dissimilar to that of ‘middle track’ qualifications (e.g. GNVQ, 14-19 diploma) that are short-lived but later reinvented with a new branding, only to follow a now predictable path (Hodgson and Spours 2007).

Within each of these wave-like trajectories we can identify critical moments where a conceptualisation is either significantly reinforced by a key report or where doubts are introduced that undermine confidence. In particular, the review of a qualification can become a critical moment since this is usually triggered by identification of some weakness. Whilst changes may be intended to redress weaknesses and extend the life of the qualification, they can have the opposite effect and hasten its demise. In this sense, the review is a potential ‘rescue operation’ that may or may not be successful but acts as a critical point in the trajectory. Revisions in the decline period may extend the life of the qualification for a while longer but unlike changes to GCSE and A-level qualifications, reviews of Key Skills and Functional Skills mathematics have failed to restore confidence in the long term.

Our analysis indicates four key types of phenomena that are instrumental in shaping these policy trajectories:

- opportunities for synergy with wider reforms
- reinforcement from other reports
- a sympathetic political climate

- alignment to the established academic mathematics curriculum.

For example, integration into government-backed vocational (or quasi-vocational) qualifications, such as GNVQ or the 14-19 diploma, helped position key skills and functional skills and defined their purpose within a wider reform. However, the failure of the diploma to gain wide usage led to some unsatisfactory repositioning of functional skills as a ‘stepping stone’ to GCSE, a purpose for which it was never intended and which contributed to its decline. Mathematics curricula, such as key skills and functional skills, may have benefit in the short term from being embedded into vocational or ‘middle track’ qualification reforms but have needed adaptation and resilience to survive as ‘stand-alone’ qualifications beyond the lifespan of their vocational partners.

Reinforcement of the need for better skills in mathematics from stakeholders and supportive government priorities and ideologies have, at times, provided favourable conditions for the growth of new mathematics qualifications for life and work. Alignment to an established curriculum, such as the connection between Key Skills qualifications, the adult numeracy core curriculum and the national curriculum in schools have provided links to help position the qualification. In contrast, the decoupling of functional skills from GCSE removed an important connection that left functional skills with a purely vocational purpose until later devalued and repositioned as just a ‘stepping stone’ to GCSE. The strength of these links has however been in connections to an academic school-based curriculum or qualification rather than to vocational mathematics. The influence of academic values has been consistently strong and resulted in several examples where ‘academic drift’ (Hodgson and Spours 2008) has shaped the trajectory of a qualification primarily intended for vocational learners.

Successive curriculum waves also highlight an interesting progression in modes of assessment. Even if a conceptualisation is theoretically sound, the means of assessment may not be widely accepted and criticisms can hasten decline (Green 1998; Wolf 2011; Hyland and Johnson 1998). Over the decades, there is a trend towards national standardised tests of these qualifications. Recognition of core skills involved a tick list of competencies and early assessment of Key Skills required a record of evidence within vocational learning. Later Key Skills was assessed through a combination of national test and portfolio evidence and functional skills by national test alone, except at the lowest levels. This drift towards standardised timed-written assessment reflects the adoption of academic rather than vocational assessment models.

Other key inputs that support the growth and sustainability of an alternative mathematics curriculum involve a synergy with vocational reform, or alignment to the established academic curriculum. Vocational reforms are, however, relatively short-lived and can leave a qualification such as functional skills inappropriately positioned if the vocational initiative (i.e. 14-19 Diplomas) is curtailed. In contrast, alignment to the academic curriculum can offer a more secure position in the long-term but brings risks of the vocational purpose being diluted and the qualification being adapted for a different use, as evidenced in recent reforms of functional skills mathematics that have resulted in additional GCSE content in order to improve credibility as a stepping-stone. Alignment to the established mathematics curriculum may have a positive effect on the acceptance and sustainability of an 'alternative' qualification but threatens its suitability for vocational purposes.

The difficulty of positioning a mathematics qualification in the middle ground where it is vocationally relevant but also has academic credibility is a recurring problem for other qualifications termed 'middle track' (Raffe 2015; Hodgson and Spours 2007).

Although some qualifications may have design weaknesses, Keep (2012) identifies that structures in the labour market, for example concerning recruitment and selection, are also responsible for the short lifespan of non-academic qualifications. The position of GCSE as the preferred qualification by employers and the main ‘gatekeeper’ for further studies, constitutes an ongoing challenge to the success of any alternative mathematics qualification. Without addressing both design issues and the conditions for growth, it seems unlikely that any new alternative mathematics qualification will achieve widespread recognition and sustainability.

The instability of the Further Education sector in England (City and Guilds 2016; Norris and Adam 2017) is also a threat to establishing credible alternative qualifications that retain their exchange value.. Changes in government (or minister) create disruption across education but arguably, more so in the Further Education sector than in schools, which makes the chances of establishing a mathematics curriculum for vocational learners doubly difficult. Indeed, it is notable that the three waves considered here broadly align to periods of government. Furthermore, ministerial transitions can shift political ideology even without a change of government so such changes are a key input into our logic model.

Conclusions

Mathematics within post-16 vocational education in England has taken several different forms over the last 30 years but alternative curricula (core skills, key skills, functional skills) have successively failed to achieve the same sustained use and recognition as academic-track mathematics qualifications (i.e. GCSE and A-level). Whilst some mathematics remains naturally embedded within vocational learning in the form of specific technical applications and GCSE has been offered continuously, although not consistently, to post-16 students, the ‘GCSE retake’ policy currently ensures academic

mathematics now holds a secure place in post-16 vocational education.

Conceptualisations of generic skills for life and work have been largely overtaken by the drive for qualifications of an academic nature.

Attempts to define and develop a sustainable alternative mathematics curriculum, that could sit comfortably alongside GCSE, remain unfruitful, as predicted by Hayward and Fernandez (2004). From the current situation, we can project three possible directions for future policy and practice:

- (1) GCSE mathematics becomes established as the new wave in this progression, with any 'alternative' qualification becoming either redundant or constrained to very limited usage.
- (2) A new conceptualisation of mathematics for life and work is developed, supported and replaces Functional Skills Mathematics.
- (3) The decline phase of Functional Skills Mathematics is halted by a major intervention and the qualification survives for an extended period beyond this critical point.

Our analysis suggests that the third scenario is unlikely, since this would require an unprecedented break in the wave cycle. The second follows historic patterns and is therefore likely to occur, but a new conceptualisation would be likely to then follow a path that replicates previous wave patterns and be unsustainable without tackling the underlying problems that have led to the failure of previous attempts. The first option currently has a strong foothold, despite poor GCSE achievement rates for post-16 students who are retaking the qualification.

Whether a qualification is 'fit for purpose' depends on its intended primary function and this is very much a contested space. Some have questioned the credibility of the fundamental concepts of key skills and functional skills, as well as the value of

the qualifications (Green 1998; Wolf 2011; Hyland and Johnson 1998). The logic from a government perspective may be the need for better mathematics skills in order to develop a strong economy but employers, but mathematics education and vocational education would visualise different sets of skills. Greater stability in the school mathematics curriculum makes alignment to the academic curriculum post-16 an attractive option but this is arguably suboptimal from a vocational and employer perspective.

Unintended outcomes of policy are a familiar occurrence in Further Education (Steer et al. 2007; Dalby and Noyes 2018) and are a concern for a sector that is expected to provide skilled individuals for industry and business. A lack of impact on national skills levels (Moser 1999; BIS 2011; Wheeler et al. 2013; Kankaraš et al. 2016) and the short lifespan of any alternative post-16 mathematics curriculum, reflects a long-standing structural problem. This surfaces in contestation over, and weaknesses in the design of:

- the original qualification concept
- the development of curriculum and assessment
- the policy levers that support implementation.

The theory of change developed through this examination of policy trajectories indicates some important inputs and conditions for growth, which should be taken into account in future policy development in this space. Learning from the past is not a commonplace or effectual practice in education (Raffe and Spours 2007) but a consideration of the factors that influence growth as identified from this study, within a scenario-planning approach, would be a first step towards avoiding a replication of these predictable patterns in policy trajectories.

The analysis also highlights the challenges of designing mathematics qualifications and related policies in an unstable environment where academic values tend to take priority and mathematics qualifications associated with vocational education do not have parity of esteem. The relatively short lifetime of these alternative qualifications also constrains attempts to establish wide recognition and value. Wider recognition of the value and purpose of post-16 mathematics for vocational education may facilitate the development of a more distinctive alternative but this is unlikely to be sustained without a more collaborative approach to policy development (Raffe 2015), including a stronger vocational voice in policy discourse and qualification design. Meanwhile, students who do not achieve the required standard in GCSE Mathematics by age 16 years, many of whom are socially disadvantaged, seem destined to short-term policies and variability in the qualifications they are offered unless they persist with the academic mathematics they have already failed and are highly likely to fail again.

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