The A-level assessment reform agenda – Where is the mathematics for the sciences?

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Abstract
Rapid policy reform, revamped curricula, the removal of practical assessment and revisions to the role, scope and approach to mathematical assessment within the sciences, have all characterised the post-16 A-level science landscape in England in recent years. In an unprecedented policy move, recent Government A-level reforms stipulated statutory requirements for the mathematical content within the A-level sciences physics, chemistry, and biology for the first time. Parallel policy developments have simultaneously advocated the study of mathematics as a subject to the age of 18 for all young people. The authors refer to these two policies as an 'embedding' policy and an 'adding' policy, respectively. Collectively, they symbolise a policy shift in the approach to mathematics within the study of the sciences at pre-university level in England. This paper presents a concise summary review of the key milestones in the 2010-2017 parliamentary sessions leading to these changes. It also considers the scope of the changes and the implications for implementation. Throughout there will be a strong emphasis on the role of mathematical development within the sciences for the transition to higher education.

1. Introduction
Government, policy makers, employers and learned societies within the UK, and more widely, recognise the economic need for a ready supply of graduates in the Science, Technology, Engineering and Mathematics (STEM) disciplines (Royal Society, 2011; CBI, 2009). While the need for graduates specialising in mathematics as a discipline is unquestionable, the facilitative role of the subject within other scientific and social science domains provides a further incentive for its study (Deloitte, 2012). Within Government international comparisons are influential in driving change. Performances in global tests such as the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA) provide international rankings of achievement. Also research has drawn attention to the low participation in post-16 mathematics in England (Hodgen *et al*., 2010). Inevitably this results in young people arriving at university who have lost mathematical fluency (ACME, 2011), some of whom also harbour misplaced expectations about the mathematical demands of their degree programmes. The latter is due, at least in part, to the reluctance of universities to provide adequate signalling of the mathematical demands of their degree offerings (Hodgen, McAlinden & Tomei, 2014).

In recent years the post-16 qualifications landscape in England has undergone major reforms resulting in a new suite of qualifications being introduced across the disciplines. In this paper some of these changes are considered with a primary focus on mathematics for the sciences. The timeframe of interest spans the last two parliamentary sessions (2010-2017) for which a necessarily concise overview summary of changes in the policy approach to mathematics for science A-levels in England is presented. The period in question has been one of substantial and rapid change. It has seen an unprecedented shift to a dual policy approach to mathematics in the A-level sciences, which the authors refer to collectively as the *adding policy* and the *embedding policy* (McAlinden & Noyes, 2017). While the principal focus here is on the historical development and early-stage implementation of these policy changes, some consideration will also be given to their implications for further study in the sciences within the context of transitions into higher education.

2. Reforms to qualifications

2.1 Background on qualifications in England

For the benefit of the reader unfamiliar with the English qualifications framework a brief résumé of the qualifications that will feature in the ensuing narrative follows. In England the General Certificate of Secondary Education (GCSE) qualifications are taken at the age of 16, with Advanced Level (A-level) qualifications being taken usually two years later. Advanced Subsidiary (AS) qualifications, equivalent to about half of an A-level, are also on offer. For GCSE, young people study a range of subjects (about 10) and if they perform sufficiently well can progress to further study at A-level. Here the selection of subjects taken is much narrower (most commonly 3 or 4) and the content of the qualifications is more specialised. AS and A-levels are categorised as Level 3 qualifications while a pass at grade C or above in GCSE is taken to equate to achievement at Level 2. Very recently, Core Maths, a new Level 3 qualification about the same size as an AS qualification, has been introduced, with the first assessment taking place in 2016. While other post-16 qualifications do exist, they will not feature here.

2.2 Mathematics for all to 18

In England the study of mathematics post-16 is not compulsory and large numbers of young people who have successfully passed GCSE Mathematics choose not to continue with their study of mathematics. This can have negative consequences for their preparedness for the mathematical demands of the workplace and higher education. Many students arriving at university at age 18, have not studied mathematics since their GCSEs, by which time their mathematical skills will have deteriorated (ACME, 2011). To support these students in coping with the mathematical and quantitative demands of their degree studies, universities have to invest heavily in mathematical interventions at curriculum, programme and institutional level (Hodgen, McAlinden & Tomei, 2014). Employers too have raised concerns with the Confederation of British Industry (CBI) in 2009 calling for a major policy change to mathematical education. ‘Government needs to ensure that all young people, regardless of what route they choose, study some form of maths or numeracy education after 16’ (CBI, 2009, Recommendation 22, p.46).

Following the election of a new Conservative-led Coalition Government in 2010 came the announcement of an increase in the minimum school-leaving age and a commitment to major qualification reforms across the disciplines (DfE, 2010). The publication of the Nuffield Foundation report *Is the UK an outlier*? provided evidence of levels of uptake of post-16 mathematics in England that were substantially lower than those in other international jurisdictions (Hodgen *et al*., 2010). The work of the Advisory Committee on Mathematics (ACME) drew further attention to the low levels of mathematics participation post-16 and highlighted the issue as a national cause for concern (ACME, 2011). Citing this evidence, in 2011 the Secretary of State for Education took the step of announcing the Government’s goal that ‘within a decade the vast majority of pupils are studying maths right through to the age of 18’ (Gove, 2011).

The achievement of the Government's policy aim of mathematics for all to 18, the *adding policy* (McAlinden & Noyes, 2017), required a mathematics qualification suitable for those young people who had passed GCSE Mathematics but were not continuing on to A-level study in the subject. The Core Maths qualification, which subsequently emerged to fill this gap, was designed to have a strong focus on practical applications of mathematics and problem solving. It sought to consolidate the mathematics learnt at GCSE but also included some new material (Browne *et al*., 2013). Deliberately, the content did not include calculus but did contain statistics, which was considered to be useful across disciplines such as those employing quantitative methods (e.g. biology, geography etc.). The qualification was duly introduced and reached its first final assessment point in the summer of 2016. While Core Maths is still in its infancy, a notable feature of its launch was the accompanying poor communication strategy. In particular, at the time of its introduction six new qualifications were categorised under the umbrella term of Core Maths, none of which explicitly contained the name Core Maths in its title.

2.3 Embedding mathematics within the sciences

In parallel with the development of Core Maths, major reforms of A-level qualifications across the disciplines were taking place and the mathematics within disciplines was also under scrutiny. The Science Community Representing Education (SCORE) analysis of the 2010 A-level science qualifications identified weakness in the mathematics within A-level science assessments and highlighted differences between the mathematical experiences offered by qualifications from different awarding organisations in the same science discipline (SCORE, 2012). Similar findings were obtained in a parallel study of a range of other disciplines (economics, geography, psychology, sociology, business studies and computing) (Nuffield, 2012). These two reports sent out strong messages about mathematics within the disciplines, which resonated loudly during the process of A-level science reform. The resulting reformed A-level science qualifications were required, for the first time, to comply with statutory minimum requirements for the percentages of mathematical content within assessments. The actual requirements were 10% for biology, 20% for chemistry and 40% for physics respectively (DfE, 2014). This policy, which the authors refer to as the *embedding policy*, when combined with the policy goal of mathematics for all to 18, the *adding policy*, represents a new policy approach to tackling the need for mathematics for the sciences (McAlinden & Noyes, 2017).

3. New Science A-levels

The newly reformed science A-levels were introduced for first teaching in September 2015, with the associated first assessment point being in the summer of 2017. Prior to the availability of actual previous examination papers the sample assessment materials (SAMs), published by awarding organisations, will have provided the first and best indicators of the likely assessments of these new qualifications. They will have also been influential drivers of classroom teaching.

In preparation for the first assessment point of the new science A-levels, the authors undertook a systematic analysis of the mathematical assessment requirements of the biology, chemistry and physics A-levels, as exemplified by the SAMs published by three awarding organisations in England (McAlinden & Noyes, 2017). Using the GCSE Mathematics qualification as a fundamental reference point, they mapped the mathematics in the A-level SAMs to carefully selected categories. These included mathematical content, mathematical demand and mathematical process skills. The analysis also looked at the mathematical complexity, levels of embedding and the theoretical or practical nature of each question. Syntheses of these findings led to three summary 'mathematical portraits' for the sciences, based on the published SAMs. These provide concise summaries of the mathematics within the qualifications and highlight the very different nature of the mathematics required across the sciences. All show a heavy, but not exclusive, reliance on GCSE Mathematics, which could be expected from its role as an implicit prerequisite. However, particularly in the cases of chemistry and physics, the overall challenge of the mathematical work goes well beyond that which might realistically be expected at GCSE. This opens up many questions about the best choice of accompanying mathematics qualification to support young people while they are actively engaged in the study of A-level sciences and to ensure that they are well prepared for the mathematical demands of further study (McAlinden & Noyes, 2017; Hodgen, McAlinden & Tomei, 2014).

For the purposes of completeness it is worth noting that in addition to changes to mathematical requirements in the reformed science A-levels, there have also been major changes to the assessment of experimental work. In particular, formal laboratory-based practical assessment no longer contributes to the overall marks for the qualifications, although awarding organisations are offering their own practical endorsements. As a consequence, the assessment of the mathematics which arises in experimental work is now only being formally assessed via the written examination papers.

4. Discussion

The opportunities afforded by successful attainment in biology, chemistry and physics A-levels are vast. Collectively these A-levels provide a formative education in science upon which higher level undergraduate study or career development can build. Young people need to be well prepared for the mathematical demands of these pathways (ACME, 2011; Hodgen, McAlinden & Tomei, 2014). The new policy approach in England of *adding* and *embedding* mathematics in the sciences has many merits, but also presents considerable challenges if it is to accomplish its long-term aim.

Achieving the underpinning aspirations of the *adding policy* requires cultural changes in attitudes to mathematics and an informed understanding of its value in society, the workplace and in higher education. Realising the goal of mathematics for all to 18, without compulsion, comes with challenges, not least of which is the recent evidence that such a move does not have the support of the majority of young people (Noyes & Adkins, 2016). Much still remains to be done to improve awareness and understanding of mathematics pathways, in particular regarding the new Core Maths route. Ultimately, whether or not the qualification will be successful will depend on a multitude of factors, including the value placed upon it by universities and employers (Hodgen, McAlinden & Tomei, 2014). Furthermore, the authors' examination of the *embedding policy* draws attention to the role of post-16 mathematics qualifications in supporting young people with the mathematics now currently embedded in the reformed A-level sciences (McAlinden & Noyes, 2017).

Of necessity, the achievement of progress through both the *adding* and *embedding* of mathematics relies heavily on the effective delivery of mathematics teaching, irrespective of its context, whether within science or mathematics qualifications. To this end, much work remains to be done. In particular, there is a need to substantially increase the capacity of the teaching workforce and to provide timely opportunities for professional development and upskilling of those entering and working within the profession.

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