Higher Applications of Mathematics - developing a new qualification in Scotland to increase participation and achievement

Martin Brown, Kevin Gibson and Sue Pope

Scottish Qualifications Authority

At almost 50%, Scotland's participation in post-compulsory school mathematics is in sharp contrast to participation rates in the rest of the UK. The current Higher in Mathematics is valued as a highly effective component in preparation for STEM-related further study and employment. However, there is an increasing need for mathematical and statistical literacy across an increasingly wide range of academic disciplines, in life and in work. The Scottish Qualifications Authority (SQA) is developing a new distinctive Higher in Applications of Mathematics to meet this need. This draws on the work in England on Free Standing Mathematics Qualifications, AS and A level Use of Mathematics, and Core Maths, international developments, and work by the Organisation for Economic Co-operation and Development (OECD) on mathematical literacy in the Programme for International Student Assessment (PISA).

Key words: post-compulsory participation; qualification development; applications of mathematics; mathematical literacy; statistical literacy

Introduction and background

Post-compulsory participation in STEM is considerably higher in Scotland than across the rest of the United Kingdom (UK) (Bennett, Braund & Sharpe, 2013). However, the participation rate in Scotland is slowly declining whilst the need for STEM literacy is increasing. The Scottish economy is growing fastest in STEM-related businesses and industries. In 2017, 37% of all employment was in STEM and this is projected to rise to over 40% in the next few years (Scottish Government, 2017).

Hodgen, Pepper, Sturman & Ruddock, (2010) found that post-compulsory mathematics participation in the UK was substantially lower than in other countries. However, there was variation across the UK; it was roughly 10% in England, Wales and Northern Ireland, whereas Scotland was exceptional in that many (40 to 50%) young people studied Higher Mathematics. In England in 2018, mathematics was one of the most popular A levels, with 90000 entries (this represents just over 10% of all entries and approximately 25% of all A level candidates, who are about half of the entire cohort (DfE, 2019)). This is a modest increase from 2010.

In modern society, the need for mathematical literacy is increasing. Many employers report struggling to recruit suitably qualified and skilled staff (CBI & Pearson Education, 2016). Most university courses need mathematics, albeit at a relatively basic level, for example proportional and statistical reasoning (Hodgen, McAlinden &Tomei, 2014). While Higher Mathematics is well respected in Scotland as preparation for STEM-related university courses and employment, it will not meet the increasing demand. More young people need to study mathematics that develops their ability to use and apply mathematics in a wide range of everyday situations.

Following the Making Mathematics Count report (Smith, 2004), there have been a number of initiatives in England aimed at increasing post-16 participation in mathematics. The Mathematics Pathways Project culminated in trialling a number of new qualifications, including A level Use of Mathematics. Despite evidence of increased participation from a hitherto untapped cohort, the Use of Mathematics development was shelved (Noyes, Drake, Wake & Murphy, 2010). In 2012, the Department for Education (DfE) asked the Advisory Committee on Mathematics Education (ACME) to convene an expert panel to design an alternative qualification that would increase participation in post-16 mathematics. The report was published in 2013 and informed the development of a new suite of Core Maths qualifications, equivalent to an AS level, with the first awards given in 2016. Uptake has risen year on year, to 9000 entries in 2019 (Mathematics in Education & Industry (MEI), 2019).

Scotland is committed to becoming a 'maths positive nation' (Making Maths Count, 2016) and is in a position to learn from England and other countries around the world to develop a world-class qualification that increases participation, meets the needs of employers and universities, and equips learners with skills and dispositions that will last a lifetime. New Zealand has increased participation in mathematics by developing more inclusive and attractive qualifications that include statistics and applications of mathematics (Hodgen, Marks & Pepper 2013). Japan is considering how it can develop and recognise transferable mathematical skills, working with those responsible for the development of Core Maths in England. OECD's PISA programme assesses the mathematical literacy of 15 year-olds and the recently published 2021 framework (OECD, 2019) has mathematical reasoning and problem solving at its heart (Figure 1).
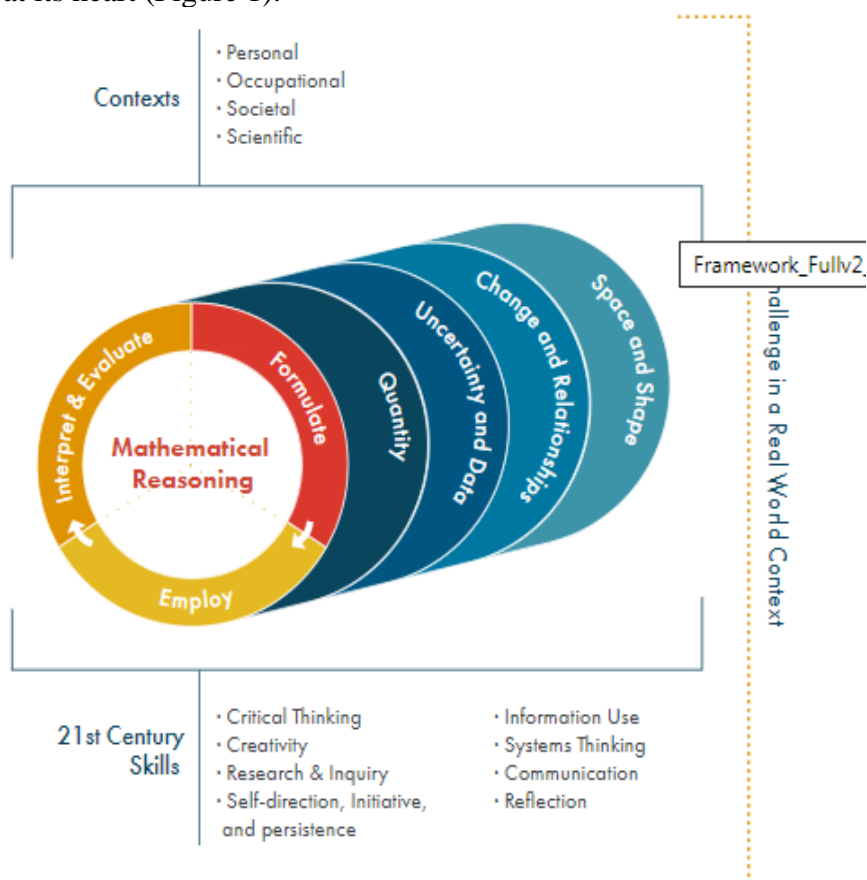

Figure 1. The PISA 2021 mathematics framework

Education Scotland's 2019 report on mathematics education, *Multiplying skills, adding value,* highlights the 'importance of numeracy and mathematics skills in the labour market, such as the influence of digital technologies on the world of work.' (p.9), and that 'The curriculum needs constant review to ensure it is relevant, for example capturing real-world numeracy and mathematics contexts' (p.9).

In Scotland, SQA is responsible for developing national qualifications and ensuring standards are maintained. The Scottish Education system includes qualifications and awards at different levels on the Scottish Credit and Qualifications Framework (SCQF, n.d.). National Courses are assessed internally at levels 1 to 4 and externally at levels 5 to 7 (National 5, Higher and Advanced Higher respectively). Currently, there are two National 5 qualifications: Mathematics and Applications of Mathematics, and the ratio of entries in 2019 was 10:1 respectively. At Higher, there is a single Mathematics qualification and an internally assessed Statistics award. While there is relatively good progression from National 5 Mathematics to Higher Mathematics, those who achieve a grade C at National 5 are far less likely to be successful. At Advanced Higher, Mathematics is the most popular subject. There are also Advanced Higher courses in Statistics and the Mathematics of Mechanics, both with relatively few candidates (SQA, n.d.).

Externally assessed national qualifications are compiled by teams of practicing teachers led by a Principal Assessor. They are graded A to D and are designed so the threshold for grade C is 50% and the threshold for grade A is 70%. This is known as 'notional difficulty'. Once the assessments have been marked, the Principal Assessor receives qualitative feedback from markers on how the assessment performed and is provided with quantitative data including item analysis. This information is used in determining the grade boundaries to ensure fairness to candidates and comparability year on year.

Developing the new Higher

Given the context set out in the introduction, Scotland needs a new qualification that will engage a wider cohort of leaners and enable them to develop the mathematical and statistical literacy necessary for modern life, work and further study. A team of teachers, academics and employers is working with SQA officers to develop the new Higher in Applications of Mathematics. This new qualification is designed to provide suitable progression pathways for both National 5 courses. Figure 2 illustrates how the new qualification will fit with existing qualifications.

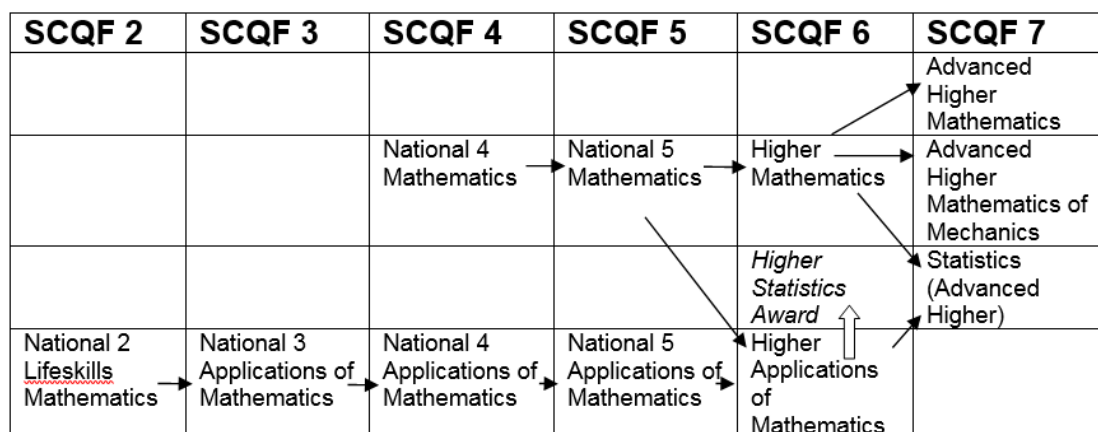| SCQF 2	SCQF 3	SCQF 4	SCQF 5	SCQF 6	SCQF 7
					Advanced Higher Mathematics
		National 4 Mathematics	National 5 Mathematics	Higher Mathematics	Advanced Higher Mathematics of Mechanics
				Higher Statistics Award	Statistics (Advanced Higher)
National 2 Lifeskills Mathematics	National 3 Applications of Mathematics	National 4 Applications of Mathematics	National 5 Applications of Mathematics	Higher Applications of Mathematics	

Figure 2. Scottish Mathematics Qualifications Pathways

The team has been working since the start of 2019 and the course specification and sample assessment materials will be available by the end of June 2020 for first teaching in August 2021, with first awards in 2022. This timeline allows centres a full year to prepare for teaching the course. In addition to developing the qualification, SQA is working with universities, Education Scotland and other organisations who provide teacher continuing professional development (CPD) to ensure teachers are well prepared for teaching the new course. SQA is also working with Scottish Government, universities and other key stakeholders to raise awareness of the new course and build demand.

In the new Higher course, consistent with the PISA 2021 Mathematics Framework, learners will be expected to select suitable mathematics and/or statistics to use in a situation/problem. The course specification is likely to include the following elements, but these are subject to review and validation prior to publication in June 2020:.

Course rationale

The application of mathematics considers a problem from a real-life context, identifies the relevant information, formulates the problem in appropriate mathematical or statistical terms, applies tools correctly, finds a solution and interprets the solution in the context of the problem.

The Higher Applications of Mathematics course focuses on the development of the mathematical and analytical skills required in a modern day society and for the future workforce. This enables learners to further develop quantitative and mathematical literacy, problem solving and reasoning skills, and to apply mathematics in a variety of real-life contexts, some of which may be complex and unfamiliar.

The skills, knowledge and understanding in the course support learning and further study, and build confidence in a wide range of curricular areas, including humanities, social sciences, health care, and business. As such, it is distinctive from Higher Mathematics, which prepares learners for progression to further study and careers in mathematics and STEM-related disciplines.

Purpose

Higher Applications of Mathematics equips learners with the skills needed to interpret, analyse, and critically appraise statistical and mathematical information; simplify and solve problems; assess risk and make informed decisions by enhancing critical and logical thinking. It is distinctive to Higher Mathematics and is suitable for all learners who have successfully completed mathematics courses at SCQF level 5 or equivalent.

Aims

- Select, apply, combine and adapt mathematical and statistical literacy skills needed for life, work and further study in a wide range of curricular areas.
- Further develop financial literacy in real-life contexts.
- Use mathematical reasoning skills to generalise, build arguments, draw logical conclusions, assess risk, and make informed decisions in familiar and unfamiliar situations.
- Use a range of mathematical skills to analyse, interpret and present data and numerical information.

- Appraise quantitative information critically in the light of modelling or statistical assumptions.
- Use appropriate digital technology to manipulate and model mathematical, statistical and financial information.

Knowledge, Skills and Understanding

- Mathematical modelling
- Statistics and probability
- Finance
- Planning techniques

Possible assessment model

- Statistics project
- Question paper with access to digital technology (spreadsheets, R)

Conclusion

This exciting development is an opportunity to substantially increase participation in SCQF level 6 mathematics in Scotland. Current qualifications emphasise accurate use of techniques, whilst this new qualification will focus on the use and application of mathematics and statistics. The ability to use technology for modelling and solving problems is integral to the course. Being able to select some suitable mathematics to explore a situation/problem (formulate) and then interpret the outcomes of the mathematical analysis, and evaluate the chosen approach, is similar to the PISA 2021 Mathematics Framework. This will help ensure learners who successfully complete the new Higher course will have the skills to navigate modern society and be successful in the fourth industrial revolution.

However, there are many challenges:
- Preparing teachers to teach the new course.
- Ensuring employers, universities and training providers look for the course.
- Attracting young people to choose to study the course.

SQA is working closely with partners to optimise the successful implementation of the new Higher in Applications of Mathematics.

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