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Do advanced qualifications equate to better mathematical knowledge for primary teaching?

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ABSTRACT

This study tests the hypothesis that raising the entry requirement to programmes of Initial Teacher Education in Scotland to Higher Mathematics, would enhance students' subject content knowledge as required for primary teaching. A sample of 149 students entering initial teacher education was investigated using an assessment that measured competence in aspects of numeracy. Students holding Higher Mathematics scored better (Median [interquartile range]) (69.6% [58.7 – 78.3]) than those holding an Intermediate Two scoring (54.3% [41.3 – 63.0]) and a Standard Grade Credit (64.1% [50.0 – 73.9]). However, further analysis shows no statistical difference in the marks of students holding a Higher compared to those holding a Credit Standard Grade (p=0.079), but that those holding an Intermediate two performed significantly poorly compared to those holding a Higher (p<0.0001). Therefore these findings affirm concerns raised by Donaldson (2010) that current requirements relating to qualifications in mathematics do not seem to provide a sufficient guarantee of competence required for teaching.

INTRODUCTION

This paper presents a case study conducted within one Scottish teacher education institution to compare student primary teachers' existing mathematics qualifications to their knowledge of fractions, decimal fractions and percentages required for primary teaching. Mathematical subject knowledge 'plays a significant role in shaping the quality of teaching' (Hansen, 2008, 3) as more knowledgeable mathematics teachers may be better at providing mathematical explanations; representing concepts clearly; interpreting pupil responses to direct them in their learning; and understanding connections within different branches of mathematics (Hill, Rowan and Ball, 2005). Insecure subject knowledge has been linked to poor planning and teaching of mathematics in primary schools (Goulding, Rowland and Barber, 2002). 'Yet subject content knowledge may be insufficient in many entrants to teacher education courses' (Henderson and Rodrigues, 2008: 95).

In 2013, following a period of consultation, the General Teaching Council for Scotland (GTCS) updated the Memorandum on Entry Requirements to Programmes of Initial Teacher Education (ITE) in Scotland. The outcome of this consultation process was maintenance of the status quo for mathematics, with primary candidates requiring a minimum mathematics qualification at Scottish Credit Qualification Framework (SCQF) level 5 or equivalent (GTCS, 2013a). The minimum requirement of English language qualification continues to be SCQF level 6 or equivalent and the update introduces a requirement for primary teachers to have an additional language qualification at SCQF level 6, either on entering the programme of initial teacher education or equivalent upon its completion. This update, may be seen to prioritise languages over mathematics and, predictably, has been the cause of national conversation, most particularly concerning those involved in science, technology, engineering and mathematics (STEM) disciplines. The revised memorandum however does state that 'Consideration will also be given in the future to raising the required level of Maths qualification to SCQF level 6 at a later date' (GTCS, 2013a, 3) and it is essential that any such a raising of entry requirements be progressed in relation to research evidence.

The debate over the mathematics requirement for entry to initial teacher education in Scotland is also influenced by the introduction of the new Curriculum for Excellence (CfE) based SCQF National Five Mathematics qualifications. The suite of National Five qualifications contains two discrete National Five mathematics awards: Mathematics and Mathematics life skills. Both National Five qualifications are deemed to meet the Memorandum on Entry Requirements to Programmes of Initial Teacher Education in Scotland (GTCS, 2013b).

In a reflection on effective teachers of numeracy, Askew *et al.* (1997: 98) propose that 'What would appear to matter … is not formal qualifications or the amount of formal subject knowledge, but the nature of the knowledge about the subject that teachers have.' With the national debate on entry qualifications in mind, the findings of this research will compare aspects of student teachers' subject knowledge of fractions, decimal fractions and percentages required for primary teaching to qualifications held.

Scotland did not participate in the most recent Trends in International Mathematics and Science Study (TIMSS) 2011 (Mullis *et al,.* 2012). The results of the previous survey (TIMSS, 2007) identify Scottish mathematical achievement at both 4th and 8th grade to be significantly lower than the TIMSS scale international average (Mullis, Martin and Foy, 2008). In the Programme for International Student Assessment (PISA) (2009) the capacity of Scottish fifteen year old learners to analyse, reason and communicate effectively as they pose, solve and interpret mathematical problems had deteriorated from a position of: nine countries exceeding Scottish scores, seven with similar results and sixteen with lower results in 2006, to eleven exceeding, eleven similar and ten lower in 2009, when comparing only those countries who were in both the 2006 and 2009 assessments (The Scottish Government, 2010). In the recent Scottish Survey of Literacy and Numeracy (SSLN) 2013 (The Scottish Government, 2014), a comparison with numeracy results of the previous SSLN 2011 (The Scottish Government, 2012) concludes that at both primary stages assessed 'there were statistically

significantly lower levels of attainment in 2013 compared to 2011' (The Scottish Government, 2014).

Presented with such statistics few would disagree with the warning asserted by Bloomer (2013) that Scotland can and must do better at mathematics or face seeing developing countries surge ahead of us. Bloomer continues to propose that in order to achieve such progress primary school teachers should be expected to have passed Higher [SCQF level 6] mathematics. This proposal is similarly reiterated by the Science and Engineering Education Advisory Group (SEEAG) (2012) in their suggestion that the initial teacher education recruitment and entry criteria should set targets for selection of a larger proportion of trainee teachers with mathematics qualifications to at least SCQF level 6. However, research investigating the value of raising the mathematics qualification is found to be lacking. The SEEAG report (2012) cites the findings of Barber and Mourshed (as McKinsey, 2007) to imply a positive correlation between high-performing educational systems and the level of teacher qualification. The 'top-performing' systems of South Korea, Finland, Singapore and Hong Kong are cited because they recruit their teachers from the top third of each graduate cohort from their school system. This positive correlation, between performance and advanced level of teacher qualifications is not discipline specific and therefore, only implies a general consensus that highly qualified teachers best contribute to educational performance. It does not explicitly support the argument as presented by SEEAG (2012) that mathematics requirements should be elevated to a higher status, and prioritised above other curricular areas. Indeed, in Finland despite a rigorous, competitive initial teacher education (ITE) selection process, having completed the mathematics element of the matriculation examination is not compulsory. Malaty (2004) informs that 20% of those embarking upon class teacher education in Finland do not attend any external matriculation mathematics examination.

Askew *et al.* (1997) concluded from their study of primary teachers that it was not essential to hold advanced qualifications in mathematics to be effective. Furthermore, in an assessment of student primary teachers' mathematical knowledge Morris (2001) found that previous qualifications gave no indication of test performance. Henderson and Rodrigues (2008) and Henderson (2012b) investigated Scottish student primary teachers' mathematical competence and mathematics qualifications. These studies in part, relate the mathematics qualifications held by student primary teachers to their performance in an online mathematics assessment. The results conclude that students who hold a Higher [SCQF level 6] Mathematics were no more competent in the mathematics assessment than their counterparts with SCQF level 5 qualifications. Indeed Henderson (2012b: 384) questions 'The wisdom of policymakers' regular insistence that primary teachers should possess a higher mathematics qualification as a cure-all for current levels of mathematics attainment.' There are similarities between our study and that of Henderson and Rodrigues (2008) and Henderson (2012b), but there are also significant differences in scale and methodology.

For more than two decades policy-makers in the United Kingdom have promoted teachers' subject knowledge and the application of this subject

knowledge in the classroom as fundamental to raising standards of teaching (Aubrey, 1997). There have been calls, from politicians and educators alike, for improvement of the knowledge base of teachers in order to enhance the teaching of mathematics. In England, the Department for Education and Ofsted (2013: n.p.) are encouraging 'more new primary teachers to specialise in maths by prioritising funding for graduates with a 2:1 or first class degree in the subject.' Where consensus varies, is in identification of the most relevant content knowledge for primary teaching. In 1998 the UK government specified a mathematical curriculum for ITE in England and Wales by identifying what mathematics knowledge and understanding student teachers need in order to underpin effective mathematics teaching at primary level (DfEE, 1998). However, Poulson (2001, 51) warned that:

> The emphasis on formal knowledge, and top-down policies prescribing in detail the knowledge bases and competencies to be acquired by teachers in primary schools has resulted in tacit knowledge, and its relationship to formal knowledge, being largely ignored.

In England prospective candidates are required to pass the professional skills test before they start an initial teacher education course: 'Initial teacher training (ITT) providers will use the skills tests results to help them decide the suitability of an applicant' (Department for Education, 2013, n.p.). Mathematical subject knowledge is also assessed, via entrance exams as part the primary ITE selection process in Japan, China, Czech Republic and Finland (Burghes, 2008). No such equivalent online graduate teacher assessment or national curriculum for ITE exists in Scotland. Measures have been taken to respond to the statement that a small, but significant, number of initial teacher education students lack some of the fundamental attributes to become good teachers, including basic weaknesses in numeracy (Donaldson, 2010). Education Scotland has developed an Aspiring Teachers web resource where interested parties are encouraged to explore their 'own knowledge and understanding of number and reasoning skills with a view to teaching others' (Education Scotland, 2013, n.p.) and ITE institutions are employing formative diagnostic numeracy assessments during teacher education courses.

Internationally a range of measures and processes are being applied in recognition of a need to determine ITE students' competence to teach mathematics for understanding in the primary classroom. In states across America teacher licensing exams are administered, yet the focus of such assessments is inconsistent. Some exams assess individuals' ability to solve problems, other exams the ability to construct mathematical questions and tasks for students and still other exams the ability to understand and apply mathematics content to teaching (Hill, Schillin and Ball, 2004).

In order to teach, mathematics subject knowledge with depth of understanding is vital. This essential knowledge comprises: an ability to think mathematically, subject related pedagogical knowledge and subject content knowledge at an appropriate level (French, 2005). Perhaps unsurprisingly, this secure subject content knowledge does not develop as a result of the process of teaching others (McNamara *et al.,* 2002) and 'It is axiomatic that teachers' [subject content] knowledge of mathematics alone is insufficient to support their attempts to teach

for understanding' (Silverman and Thompson, 2008: 499). Indeed, Tatto *et al.* (2012) concluded five fundamental sources as most relevant to the education and performance of future teachers of mathematics to be: student achievement in mathematics; the mathematics curriculum studied; the quality of mathematics lessons; the nature of teacher education programs and the content of teacher education programs. The latter two sources then entirely dependent upon the teacher education experience and certainly, the development of pedagogical content knowledge has to be a focus for initial teacher education courses, however consideration of the quality and content of prior subject content learning is particularly relevant as the extent of mathematics input in Scottish initial teacher education courses is increasingly divergent and emphasis on support for further development of mathematical subject content knowledge is variant. The prospective teacher's mathematical knowledge base needs to include a sound understanding of the preceding material to be used as the foundation stone for future teaching (Bell, 2006). 'How well teachers know mathematics is central to their capacity to use instructional materials wisely, to assess students' progress, and to make sound judgements' (Ball, Hill and Bass, 2005: 14).

Such subject content knowledge can be further conceptualised to consider: substantive knowledge (the facts, concepts and processes of mathematics and the links between them) and syntactic knowledge (the process of deducting mathematical truths) (Rowland *et al.,* 2009). Substantive knowledge can be acquired with instrumental or relational understanding. The latter comprises both knowing what to do and why. In contrast, instumental understanding has been described as applying 'rules without reasons' (Skemp, 1978, 2). Mathematics teaching requires relational understanding to promote thinking about how familiar concepts and procedures can help in new situations (Leikin and Levav-Waynberg, 2007). In a reflection on ITE entrants holding a grade C in GCSE mathematics Bell (2006) suggests that 'the difficulty arises if their mathematical knowledge is that of rules and algorithms and not of understanding of their school mathematics.' Subject content knowledge impacts a teacher's sense of self-efficacy (Swackhamer *et al.,* 2009). This study informs the debate specifically by investigating primary education students' substantive knowledge; relating the links between topics, procedures and concepts of fractions, decimals and percentages.

Depth of understanding of mathematics is required to progress the teaching of mathematics (Silverman and Thompson, 2008). The definition of 'deep learning' as transferrable to effective primary teaching requires exploration. The call for a higher level of entry qualification in mathematics suggests that deep learning is learning at an advanced, complex level. However student teachers and indeed policymakers must realise that with depth of learning comes an appreciation that:

> Many concepts in mathematics are inter-related, so knowing one helps you understand others. Learners need to be given opportunities to experiment with the concepts that they learn, to apply them to other areas, to reformulate them and describe them to someone else (Maths Excellence Group, 2011: 8).

McNamara *et al.* (2002) and Silver *et al.* (2005) reiterate the requirement for teachers' subject content knowledge to contain a rich network of connections between different mathematical ideas as limitations in teachers' mathematical

knowledge may obstruct the use of multiple solutions in the classroom. 'Trainees who have several representations for mathematical ideas and whose knowledge is already richly linked will be able to draw upon these both in planning and in spontaneous teaching interactions' (Goulding, 2003: 75). In considering the minimum level of mathematics qualification for entry to ITE it is essential to investigate whether having studied more complex matter within a subject discipline is likely to result in the development of the relational, connected mathematical principles required for effective teaching at primary school level. In providing Scottish teachers with prompts to support Curriculum for Excellence (CfE) mathematics the Mathematics Excellence Group (2011) emphasise connectionism: between different aspects of mathematics, such as connections between operations and, connections between topics such as shape, number and algebra; between different representations of mathematics, including moving between symbols, words, diagrams, objects and graphs, and with learners' methods, including valuing their methods, being interested in their thinking and sharing their methods. Brown *et al.* (1999) also highlight features of connectionism by suggesting that teachers should draw links between alternative perspectives as offered by children and discuss how these 'connect' with the curriculum topics being addressed and that the teacher and children collaborate, sharing personal insights and phenomena. This collaborative connectivity presents scope for mathematical meanings to be socially constructed at the level of classroom activity through attempts at achieving shared understanding of ideas derived from curriculum topics (Cobb and Yackel, 1998). However, Brown et al (1999: 318) suggest that 'such an approach might be beyond the current intellect and performance capacity of many non-specialist students.'

The question then is, what specialist subject content knowledge is most relevant to effective primary teaching? Studies have been found to demonstrate that teachers' mathematical knowledge helps support student achievement (Ball, Hill and Bass, 2005; French, 2005; Ball, Thames and Phelps, 2008). What is largely unknown is the impact of the nature and extent of that knowledge (Ball, Hill and Bass, 2005). This research explores whether the additional content knowledge studied at Higher level, in relation to aspects such as calculus, is likely to facilitate the development of connected thinking at the level of concepts developed in the primary classroom. Rowland *et al.* (2000: 16) caution against the dangers of weak (and average) student teachers rote learning mathematics in order to pass subject knowledge assessments; 'If the rationality and semantic unity of mathematics has eluded them despite their best endeavours, they will hardly be well placed to communicate it to their pupils'. Askew *et al.* (1997) conclude that highly effective mathematics teaching is 'not associated with having an A-level or degree in mathematics', but is dependent upon the knowledge and awareness of inter-relations between the areas of the primary mathematics curriculum. Potentially the ITE student 'whose knowledge is already richly linked will be able to draw upon these in planning and spontaneous teaching interactions' (Goulding, 2003) and for these students insights gained in pedagogical content knowledge will further enrich subject content knowledge, thus blurring the boundaries between the content domains. It should be recognised that 'the knowledge required to meet any public qualification standard, even if it is judged to be very

good by that standard, may need to be transformed and enriched in order to support the act of teaching' (Goulding, 2003, 73) and here lies the role of mathematics in ITE. Nonetheless, initial teacher education institutions wish to set standards for entry that attract individuals with well-established, connected subject content knowledge.

Mathematics, as a discipline within primary schools, requires to assert its identify amid the broader agenda and busy schedule of ITE and the report Teaching Scotland's Future - Report of a Review of Teacher Education in Scotland (Donaldson, 2010) has gone some way to raising the profile of student teacher subject knowledge for primary mathematics teaching via a recommendation that difficulties with numeracy displayed by some newly qualified teachers need to be addressed at entry and during the course. Proposals from the Report have resulted in the long-standing undergraduate Bachelor of Education (BEd) Primary teaching programme being phased out across Scotland, to be replaced by a range of flexible alternative routes designed to present student teachers with a degree of autonomy to follow their interests and develop expertise within their chosen disciplines. It must be recognised that all primary teachers require to be successful teachers of mathematics therefore student teachers' relational mathematical subject knowledge for primary teaching requires to be developed if mathematics is to be generated and connected rather than merely administered in the classroom.

The Scottish Executive Education Department launched CfE in 2004 and an evolutionary period invariably follows the introduction of any new curriculum. Nonetheless Henderson (2012a) questions whether Scotland's CfE will result in the desired transformational change with a focus on mathematics. Henderson (2012a) continues to suggests that for change to be enacted successfully, and constructivist models of teaching mathematics employed, addressing the subject knowledge of some primary teachers must be a key consideration. In the Scottish Survey of Literacy and Numeracy (SSLN) (2011; 2013) Primary four learners, assessed across aspects of the numeracy curriculum, found tasks relating to fractions, decimal fractions and percentages to be most challenging. Fewer Primary four learners considered themselves to be good at these aspects than any other aspect of the numeracy curriculum. Similarly, Primary seven learners found fractions, decimal fractions and percentages difficult scoring second lowest of all aspects of numeracy in relation to performance and perceived competence (The Scottish Government 2012; 2014). It is perhaps too early to conclude that transformational change will not transpire in these pivotal areas of numeracy as part of CfE. However given the continued lack of attainment, it is particularly relevant to consider the areas of fractions, decimal fractions and percentages to be key in exploring student teachers' subject content knowledge for teaching mathematics to primary learners.

METHODOLOGY

This case study aims to test the hypothesis that raising the entry requirement for primary teaching to SCQF level 6, Higher Mathematics, would enhance students' subject content knowledge as required for primary teaching. It directly compares student primary teachers' existing mathematics qualifications to their performance

in an assessment of knowledge relating to fractions, decimal fractions and percentages required for primary teaching.

Participants

In this paper we draw upon data gathered via an assessment exercise involving undergraduate primary ITE students studying at One Scottish University. The sample relates to two cohorts of undergraduate primary teaching students (n=149) at the beginning of a mathematics module in the first year of a four-year BA programme. This equates to two annual cycles of results from the entire undergraduate year one student population at the institution. A sample of two cohorts is utilised because 'the bigger the sample size, the smaller the numerical value of the statistic required in order to reach significance' (Punch and Oancea, 2014: 331). A census sample is utilised whereby there has been no selection process applied to determine the optimum sample in relation to sample representativeness (Menter *et al.,* 2011). The sample represents the census population as is inescapably limited to data from two cohorts. These being the only two cohorts to have embarked on the new BA (Honours) degree since programme initiation. The sample is therefore the entire population.

Instrument

This case study utilises the percentage test scores achieved in a subject content knowledge assessment of mathematics. The SSLN, 2011 and 2013 (The Scottish Government, 2012; 2014) highlight that the fraction context (including fractions, decimal fractions and percentages) remains a particular challenge for learners. Primary education students' subject content knowledge of fractions is therefore pertinent. We measured subject content knowledge for teaching fractions, decimal fractions and percentages, including aspects of relational understanding and computational facility. Performance, as percentage test scores, will be directly compared to qualifications held, including consideration of grade bandings, to determine if a relationship exists between personal mathematical subject content knowledge and level of existing SCQF mathematics qualifications.

The relational elements of the assessment tool were designed with consideration of Mousley's (2004) identification of the three types of mathematical connection: new and existing knowledge; various mathematical ideas and representations; and mathematics learned in school and everyday life. Thus, the assessment consists of content related to: identification of mathematical facts, application and illustration of mental methods of calculation by relating the fraction context to number operations, and application of the concept of equivalence in fractions across visual and linear structures.

The following section provides a breakdown of the detail of the assessment tool. One numerical example of each question type asked is presented (excluding diagrammatic examples). The assessment tool consisted of multiple examples of each type of question.

Initially, non-contextual questions were asked to assess:

- knowledge of place value structure (Identify the value of the shaded digit: 43254.4583).
- calculation of vulgar fractions, decimal fractions and percentages as factors of positive integers (all examples were divisible without remainder) (Calculate ¼ of 256).
- ordering of decimal fractions and vulgar fractions (Write in order of size starting with the smallest 0.012, 0.02, 0.1, 0.102, 0.12).
- conversion between representations of fractions (Convert ⅝ into a decimal fraction).

Secondly, questions connected application of fraction concepts to contextual examples involving money and information handling structures:

- calculation of percentage price increase / reduction (A shop is offering a 16% discount from the marked ticket price of all items. Calculate the reduced prices).
- interpretation of Venn diagram to determine fraction representations.
- interpretation of Carroll diagram to determine fraction representations.

Finally, questions assessed comprehension of diagrammatic and linear structures in relation to fraction concepts:

- identification of fraction calculations illustration to represent given fractions (Sketch a diagram to represent 2/6).
- illustration to represent given fractions as factors of positive integers (Sketch a diagram to illustrate how you would find ⅜ of 32).
- conversion between representations of fractions, decimal fractions and percentages and placement on equivalence number line expanding zero to one
- sketched on number lines.
- illustration to represent breakdown of number operation calculations on number lines (an example sketch for each operation was provided) (Complete the following calculations and illustrate your thinking on a number line: 3.233 + 1.64).

Analysis

All subject content knowledge assessment of mathematics tests were marked by the first author and moderated by the second author with each paper being check for marker consistency and accuracy. The scores for each question in the test was then manually entered into a score matrix on Microsoft Excel© to facilitate further detailed analysis of how the students' performed in each question (data not presented here). This process was double entered by a research assistant into the Excel spreadsheet to ensure accuracy.

The data was imported into SPSS© version 20, where downstream statistical analysis was performed. Firstly, the distribution of the data was checked for normality using a Kolmogorov–Smirnov test, which confirmed that the data was normally distributed. Descriptive statistical analysis was performed on the data which was then stratified and categorized according to students' highest entry level Mathematics qualification. The mean, standard deviation, standard error of mean, median and interquartile range were then calculated for each entry level qualification category.

Secondly, statistical analysis was performed where the data was analysed using a Friedman two-way analysis of variance (ANOVA). Post hoc analysis was then conducted using a Wilcoxon signed-rank test with a Bonferroni correction applied to establish whether there was a statistically significant difference between the students' percentage test scores and their entry level Mathematics qualification. Statistics are presented as medians (interquartile range) unless otherwise stated.

FINDINGS

The findings of the case study are presented from the perspective of students' overall performance in the subject content knowledge assessment of mathematics test in comparison to existing SCQF mathematics qualifications held on the Unified Points Score Scale that relates to the Universities and Colleges Admissions Service (UCAS) points tariff system (The Scottish Government, 2009). The statistical analysis of students' entry-level mathematics qualification in relation to each students' percentage test score in order to determine whether there was a statistically significant difference in student performance based on entry-level Mathematics qualifications within our sample is presented. The sample was not stratified to compare students' performance by gender as the sample was predominantly female (93%) any such comparison judged to be invalid.

Students' Entry Level Mathematics Qualification

The percentage distribution of students within the sample by entry-level Mathematics qualification is shown in Figure 1. It is interesting to note that 49.7% of the sample hold a Higher qualification with 30.5% holding an Intermediate two and 15.4% holding a Standard Grade Credit. There were 4.4% of students in the sample who did not disclose their highest mathematics qualification (see Figure 1 for more detail). This data was excluded from the statistical analysis.

FIGURE 1:

DISTRIBUTION OF STUDENTS' ENTRY LEVEL MATHEMATICS QUALIFICATIONS
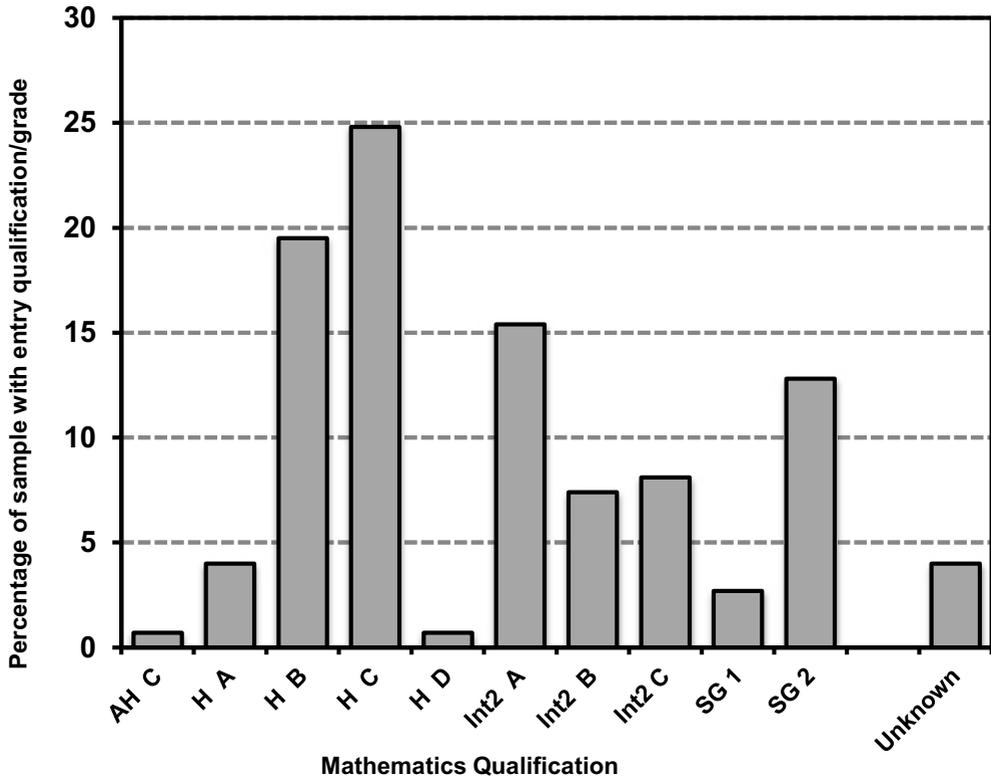

Students' Performance in the Subject Content Knowledge Assessment

The distribution of students' scores for the subject content knowledge assessment of mathematics test indicates that the combined test results are normally distributed (See figure 2) and indicates that the overall mean % score ± standard deviation for the subject content knowledge assessment was 62.2% ± 15.7, with a median score of 63%. The mean score for those holding a Higher on entry to ITE was 68.2% ± 13.7% and for those holding an Intermediate two, 52.1% ± 14.2% and a Standard Grade Credit, 61.7% ± 14.9%.

FIGURE 2:

PERCENTAGE DISTRIBUTION OF STUDENTS' SCORES FOR THE SUBJECTS CONTENT KNOWLEDGE ASSESSMENT.
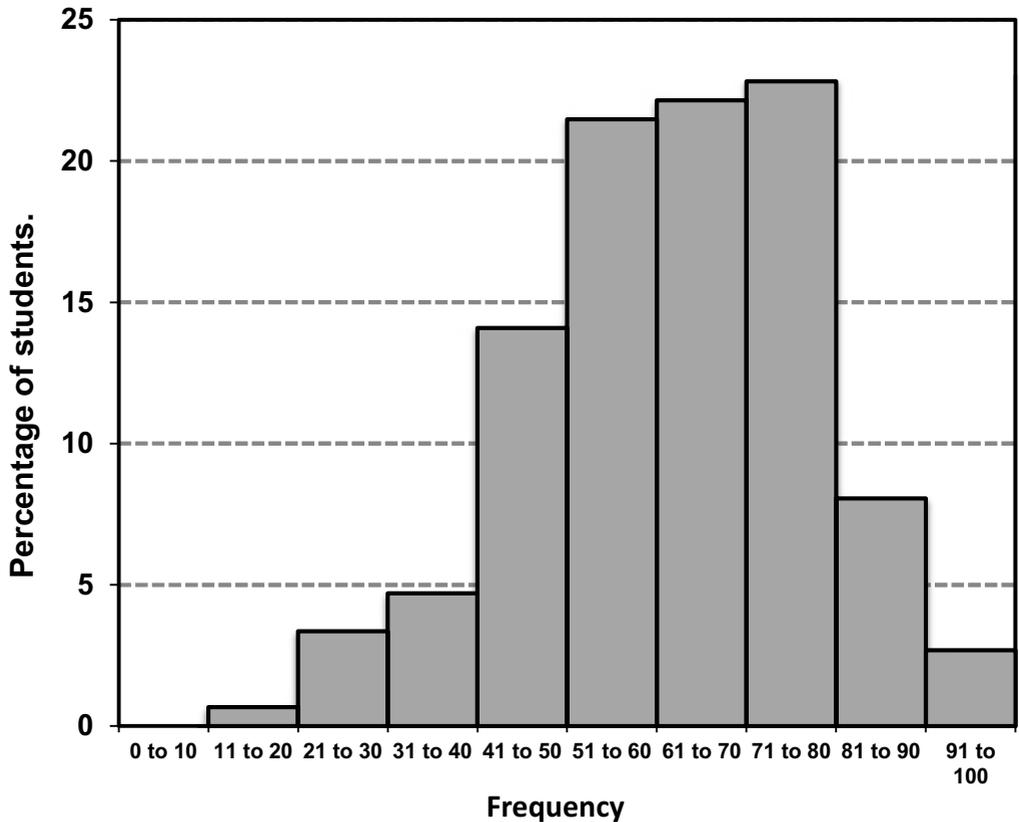
The research tool assesses subject content knowledge at a level required for primary teaching and as such an arbitrary threshold of 63% has been adopted. This threshold was selected, in the absence of a benchmark in the Scottish system, to reflect the score required in the numeracy element of the Professional Skills test (PST) in England, although no comparison is drawn between the content assessed in this exercise and the PST. Figure 3 shows students' percentage score for the subject content knowledge assessment plotted against their entry level Mathematics qualification.

FIGURE 3:

PLOT OF STUDENTS' NUMERACY TEST SCORES AGAINST THEIR ENTRY LEVEL MATHEMATICS QUALIFICATION

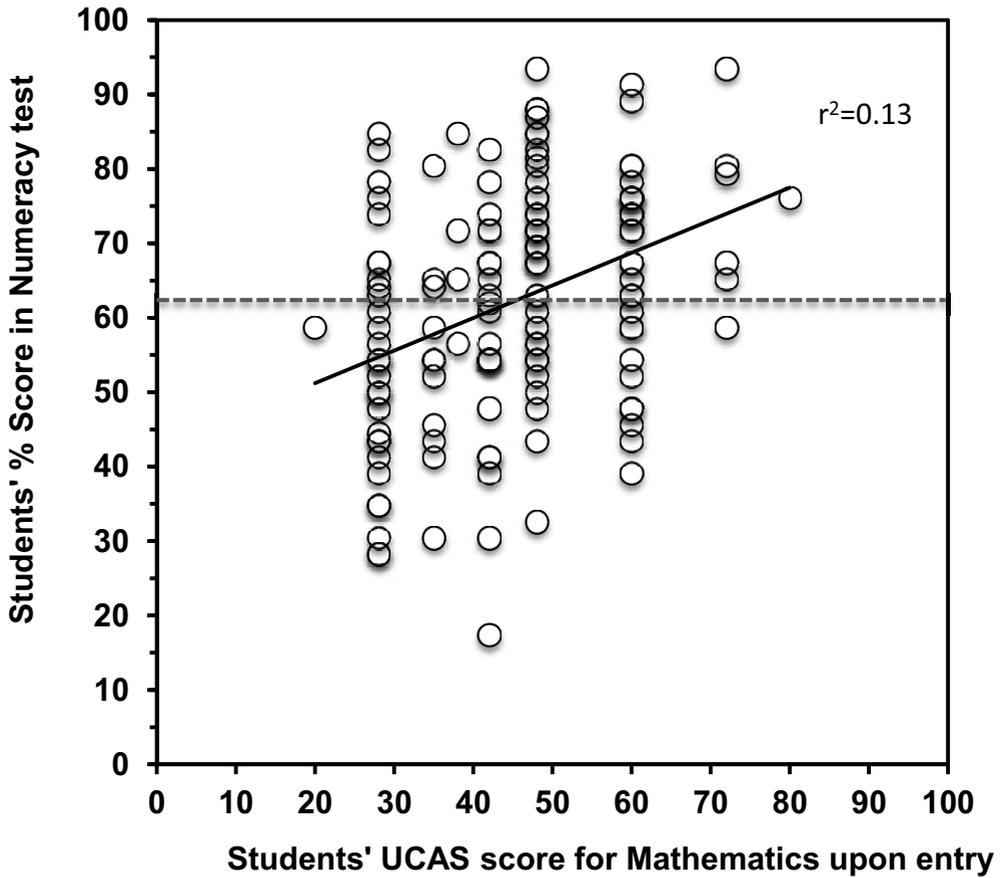
Figure 3 shows that there is a small but statistically insignificant positive correlation ($r^2=0.13$) between Students' scores in the subject content knowledge assessment and their Unified Points Score for Mathematics on entry to ITE. The distribution of students for each Mathematics entry qualification who scored <63% and >63% in the subject content knowledge assessment are shown in Table 1.

TABLE 1:

DISTRIBUTION OF STUDENTS FOR EACH MATHEMATICS ENTRY QUALIFICATION ABOVE AND BELOW THE 63% THRESHOLD FOR THE NUMERACY TEST.

Mathematics Entry Qualification, Grade (UCAS Score)	< 63%		>63%	
	n	%	n	%
Advanced Higher C (80)	*	*	1	100
Total Higher	**23**	**31.5**	**50**	**68.5**
Higher A (72)	1	4.3	5	10.0
Higher B (60)	10	43.5	19	38.0
Higher C (48)	12	52.2	25	50.0
Higher D (38)	*	*	1	100
Total Int2	**34**	**73.9**	**12**	**26.1**
Int2 A (42)	15	44.1	8	66.7
Int2 B (35)	8	23.5	3	25.0
Int2 C (28)	11	32.4	1	8.3
Total SG	**11**	**47.8**	**12**	**52.2**
SG 1 (38)	1	9.1	3	25
SG 2 (28)	10	90.9	9	75
Total Unknown	**4**	**66.7**	**2**	**33.3**

Data from table 1 indicates that approximately one third of students who had a Higher grade pass in Mathematics scored below the threshold score (<63%) in the subject content knowledge assessment of mathematics test. Of the 50 students who held a Higher pass and achieved a percentage score equal to or greater than the threshold mark in the subject content knowledge assessment, 25 Students held a C grade pass on entry to ITE (68% of Higher C ≥ threshold mark), 19 students held a B (66% of Higher B ≥ threshold mark) and five students held an A grade pass at Higher (83% of Higher A ≥ threshold mark). By comparison, just over half of the students holding a Standard Grade (SG) Credit pass achieved the threshold mark. Of the 12 students holding a SG Credit pass who scored equal to or greater than the threshold mark nine students held a grade 2 Credit pass (47% of SG2 ≥ threshold mark) with three students holding a grade 1 Credit pass (75% of SG1 ≥ threshold mark). Therefore, with recognition of the limitations of the small SG sample size, it is noteworthy that, proportionally, a higher percentage of

students with a SG1 pass scored equal to or greater than the threshold (75%) than either the Higher B (63%) or Higher C pass (66%).

In contrast, 34 students holding an Intermediate two pass on entry to ITE fell below the 63% cut-off score. Of those who scored <63%, 15 students held an A pass at Intermediate two, 8 students held a B grade pass and 11 students held a C grade pass. By comparison, of the 12 students holding a pass at Intermediate two and scoring >63%, eight students held an A grade pass at intermediate two, three students held a B grade pass and one student held a C grade pass.

Statistical analysis of entry level qualifications and students' performance.

Figure 4 shows a boxplot of the students' test scores for each group of Mathematics qualification. What is important to note is that the distribution of marks for the Intermediate two group (54.3% [41.3 - 63.0]) is lower than that of the Higher group (69.6% [58.7 – 78.3]). However, the Standard Grade scores (64.1% [50.0 – 73.9]) were broadly in line with those of the Higher group.

FIGURE 4: BOXPLOT OF STUDENTS' TEST SCORE COMPARED TO THE STUDENTS ENTRY LEVEL MATHEMATICS QUALIFICATION.
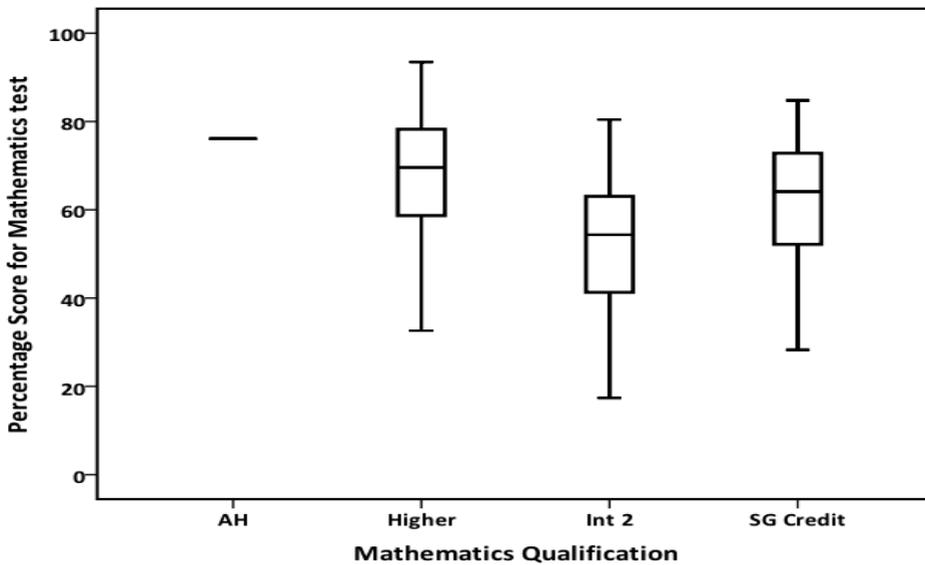
There was a statistically significant difference between students' performance in the subject content knowledge assessment and their highest level of Mathematics qualification on entry to initial teacher education (χ^2 = 6.69 p=0.035). Post hoc analysis conducted using Wilcoxon signed-rank tests with a Bonferroni correction applied, resulted in a significance level set at p<0.017. This analysis indicated that there was no significant difference between the test scores for those students who held Higher Mathematics as their ITE entry-level qualification and those holding only a Standard Grade Credit pass in Mathematics (z=-1.755 p=0.079). In addition, there was no significant difference between those students

holding a Standard grade when compared to those students holding an Intermediate two mathematics pass on entry to ITE ($z=-1.252$, $p=0.211$). However, there was a significant difference between those students holding a Higher compared to those holding an Intermediate two ($z=-5.019$, $p<0.0001$).

CONCLUSION

The data presented in this case study confirms that primary education students who held a SCQF level 6 Higher Grade qualification did not perform significantly better in a subject content knowledge assessment of Mathematics test when compared to students who held a SCQF level 5 Standard Grade Credit pass only ($z=-1.755$, $p=0.079$). Students who held an SCQF level 5 intermediate two mathematics qualification performed significantly worse than those who held a Higher Grade in the subject content knowledge assessment of mathematics test ($z=-5.019$, $p<0.0001$). Students who held an Intermediate two pass did not perform better than Students holding Standard Grade Credit pass on entry to ITE.

DISCUSSION

The findings gained from this case study reflect usefully upon the hypothesis posed at the start of this article; raising the entry requirement for primary teaching to SCQF level 6, Higher Mathematics, would enhance students' subject content knowledge as required for primary teaching. In this final section we reflect on the limitations of the study, the hypothesis posed, and the potential implications for policy and further research while relating our remarks to current literature on the mathematical content knowledge of in-service and pre-service teachers.

Limitation of the case study.

The findings described within this case study come with some limitations. We recognise that measuring aspects of primary education student teachers' mathematical content knowledge at the start of their programme does not imply that a relationship inevitably exists between such content knowledge, as measured by the assessment, and the kinds of teaching performance that will directly lead to improved pupil achievement. Primary educators' professional development in the mathematical domain is a life long process and it is expected that ITE courses will support the further development of mathematical knowledge domains and that individuals will take responsibility for continuing professional development. Therefore, we do not claim that a student teacher's prospective potential to expand and deepen subject content knowledge, pedagogical content knowledge or curriculum knowledge is indicated by examination of ITE entry-level student teachers' knowledge.

As this study is small scale and relies on a convenience sampling technique, we recognise that the number of students holding an Intermediate two or a Standard Grade award is relatively low compared to those holding a Higher Grade. We also acknowledge that a larger number of students holding an Intermediate two or Standard Grade Credit award might affect the outcome of the hypothesis tested in this research. However, we would suggest that since our sample is representative of the population of students recruited onto the BA (Hons)

Education programme within this University, the data gathered in this research provides tutors with a useful baseline measure of students' mathematical content knowledge upon entry to ITE. It provides information that could be used to target differentiated support and modified teaching in mathematics modules to better support specific weaknesses in students' mathematical content knowledge.

Implications for policy and practice

Clearly 'effectiveness in teaching resides not simply in the knowledge a teacher has accrued but how this knowledge is used in classrooms' (Hill, Rowan and Ball, 2005, 376). Nonetheless, this study takes cognisance of the importance of primary teachers' substantive mathematical subject content knowledge, and relational, connected understanding as a key factor: in spontaneous teaching interactions (Goulding, 2003); in the use of multiple solutions in the classroom (McNamara *et al.*, 2002; Silver *et al.*, 2005); in the use of instructional materials, assessment of students' progress, and judgements (Ball, Thames and Phelps, 2008) and in promoting thinking about how familiar concepts and procedures can help in new situations (Leikin and Levav-Waynberg, 2007). The disappointingly low results reported in this study indicate that, on entry to their ITE programme, many student teachers' mathematical content knowledge in the areas of fractions, decimals and percentages is lacking and affirms the concern raised by Donaldson (2010) that 'Current requirements relating to Scottish Qualifications Authority qualifications in … mathematics do not seem to provide a sufficient guarantee of the levels of competence which are required for teaching.'

It must be emphasised that this research was implemented with students upon entry to a four-year BA degree and *before* any Mathematics instruction had taken place. This presents scope for ITE to address subject content knowledge competence levels as students progress through their programme. Potentially the opportunity to develop subject content knowledge, pedagogical knowledge and curriculum knowledge simultaneously may create a more meaningful experience for some student teachers. This experience developed through practical application on teaching placement may support progression where previous attempts at relational content knowledge development have proven unsuccessful. It must be recognised that primary school teachers are generalists, not simply teachers of mathematics and as such they have to grasp a level of content knowledge to teach across all of the knowledge domains of Curriculum for Excellence, some of which they may not have *any* prior knowledge of at all and if teaching competence depended on the level of knowledge on entry to study, teacher education students would need to be highly qualified in a range of subjects. Indeed, there are calls from various lobbies requiring initial teacher education programmes to input information in particular subject areas and this exacerbates the myth that some Scottish educationalists have been trying to expose; that everything a teacher needs to know and be able to do for the length of their career can be transmitted to them in an ITE programme. Nonetheless, many concepts related to number and number processes are hierarchal in nature. Where pivotal building blocks in the conceptual hierarchy exist as gaps or unresolved misconceptions, relational understanding becomes limited. The fundamental prerequisite structure of number process knowledge deems it

inappropriate for teachers to opt to attain aspects on a need to know basis, as may be utilised in other areas. Despite the inevitable additional resource and staffing implications, it is suggested then that mathematics, as a discipline, should assert itself in ITE, in relation to the nature and extent of both core course content and practice-based application, whilst recognising that it is surely desirable to select potential primary education students with an existing level of numeracy competence.

Ultimately, all an ITE programme can do is prepare teachers who are on a career long journey to develop mathematical knowledge for teaching and unless a continuum of teacher learning is envisaged whereby all primary teachers reach acceptable levels of competence in the early phase, with established processes to identify and support teachers eager to specialise in the promotion of mathematical learning at the primary level for the collegiate benefit of their educational community, it is possible that teachers who feel less secure with numeracy will stop learning after entering into practice and will stop identifying their own learning needs in case they are perceived as incompetent.

The current requirements relating to SCQF mathematics qualifications do not, then, guarantee competence for teaching. Data from this study does not however, support the suggestion that targets should be set for selecting a larger proportion of student teachers with mathematics qualification to at least SCQF level 6 (SEEAG, 2012).

When results were considered in relation to grade bandings, they were found to contradict the general assertion that students with an SCQF level 6 Higher mathematics qualification have an enhanced mathematical content knowledge suitable for primary teaching, since those students holding a SCQF level 6 Higher grade A did indeed perform best, but were closely followed by those holding an SCQF level 5 Standard Grade Credit pass and that the difference in the performance of these two groups of students in the mathematical content knowledge assessment was not statistically significant. There is then no significant evidence base, from this research, to suggest that studying the Higher, as opposed to Standard Grade will enhance students' subject content knowledge as required for primary teaching and there would be practical implications in progressing such a policy. The percentage of those with SCQF level 6 Mathematics on entry in the two cohorts studied is higher than it has been at the institution in previous years and is higher than some other Scottish teacher education institutions and indeed a requirement for Mathematics at SCQF Level 6 is likely to present, at least short term, challenges in initial teacher education recruitment. The SEEAG report (2012, 14) informs that 'The best performing education systems attract the best teachers, recruited from amongst the best university graduates.' However, Scottish teacher education institutions are unlikely to be able to recruit from the most highly attaining university graduates or school leavers until pay and conditions, reward and recognition for teachers is on a par with careers taken by similarly qualified peers.

Results from this study suggest that the current format of study for mathematics at level 6 does not enhance the development of subject content knowledge as relevant to fractions, decimals and percentages for primary teaching. A better indicator of relational understanding of these numeracy elements may be the grade obtained in the more general level 5 qualification. Henderson (2012a)

proposed that a more dedicated qualification, as opposed to a more advanced qualification could provide a way forward. Indeed, with the imminent move to the new National 5 qualifications further longitudinal study should be undertaken to consider the impact of these curricular reforms on ITE students' subject content knowledge on entry to ITE programmes.

The findings presented in this research corroborate the view expressed by Henderson and Rodrigues (2008) that the mathematics qualifications of primary education students does not guarantee their competence with regards to the subject content knowledge required for primary teaching. However, this begs the question as to why this is the case? It could be argued that there is a disconnect between the mathematical content knowledge and conceptual understanding required by primary students to become competent teachers of primary mathematics and the nature of the mathematics content knowledge and conceptual understanding required to be successful within the Higher and Advanced Higher Mathematics Curriculum. For example, it does not necessarily follow that because a student can demonstrate a good conceptual understanding of differential calculus (a component of the Higher Mathematics syllabus), that they will be able to demonstrate a good conceptual understanding of fractions, decimal fraction and percentages as required for primary teaching. Indeed, Swars *et al.* (2007) found that the nature of the knowledge held was key to student teachers' mathematical beliefs: those with more specialised content knowledge for teaching mathematics, not more advanced mathematical knowledge outwith the teaching domain, were more likely to believe that children can construct their own mathematical knowledge and that mathematics skills should be taught with understanding.

Those students within our sample holding an Intermediate two qualification on entry to ITE performed significantly less well than those holding a Higher with 73.9% of those students holding an Intermediate two Mathematics qualification scoring below the 63% cut-off score whereas 68.5% of those holding a Higher Mathematics scoring above the 63% cut-off score. This finding merits further thought since Henderson and Rodrigues (2008) found that students within their sample who held Intermediate Two Mathematics were no less competent compared to those holding a Higher or Standard Grade Mathematics. The difference between our findings and those of Henderson and Rodrigues (2008) might be due to differences in the instruments used and in the sample characteristics. On the face of it, this finding may be seen to suggest that Intermediate two Mathematics (SCQF level 5), which has a higher proportion of numeracy based conceptual components when compared to Higher Mathematics (SCQF level 6), does not provide sufficient support for students understanding of the subject content knowledge of fractions, decimal fractions, percentages and aspects of relational understanding and computational facility. However, another possible explanation could be related to the mathematical background of the students.

Scottish School students wishing to continue mathematical study have most commonly progressed from Standard Grade Mathematics (at the end of fourth year) to Higher Mathematics in fifth year, if they attain a Credit level (Grade 1 or 2) pass at Standard Grade. If a student attains a General level (Grade 3 or 4) pass

at Standard Grade they will most commonly be counselled to take Intermediate 2 Mathematics in fifth year. It is possible that those students holding Intermediate Two Mathematics may have struggled with key mathematical concepts at Standard Grade and whilst they have worked hard to pass Intermediate 2 in fifth year (or for some sixth year) they may still be carrying many conceptual weaknesses which are highlighted by the subject content knowledge test. It is possible that additional data exploring the routes of study pursued by the student sample would further expand and explain findings

Looking to the future, in 2013 the National Qualifications Framework changed as a result of Curriculum for Excellence, with a new National Five Mathematics qualification being introduced to replace the older Standard Grade and Intermediate Two Mathematics qualifications. Further research in this area will be required over the next few years to establish whether the curricular changes to mathematics qualifications have had a positive impact on primary education students' level of mathematical content knowledge. To echo the words of Sheila Henderson, 'previous curriculum reform in mathematics in the shape of *5-14*, which had already advocated many of these reforms [as proffered by CfE] ***did not*** lead to change and, without addressing primary teachers' own subject knowledge, it has to be questioned whether *CfE* will either' (Henderson, 2012a: 54, emphasis added:).

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