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How do ITE programmes support pre-service primary teachers to become competent and confident teachers of mathematics? A systematic review of interventions trialled in Scotland and the Republic of Ireland.

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ABSTRACT

Supporting pre-service primary teachers to develop the required specialist knowledge for teaching mathematics is a complex task. The knowledge required for mathematics teaching at primary level is multi-faceted and the efficacy of mathematics teaching is inextricably intertwined with a teacher's own beliefs and attitudes about mathematics and mathematical ability; the challenge for teacher educators, then, is to deliver a comprehensive programme covering mathematics content, pedagogy and curriculum within time-limited programmes of Initial Teacher Education (ITE). This paper presents a systematic review of the recent interventions to pre-service mathematics programmes that have been trialled in ITE institutions across Scotland and the Rep. of Ireland over the last 10 years. The findings and key issues addressed in this paper will have both national and international significance, as educators in ITE establishments strive to provide a comprehensive programme of study and practice, to prepare the very best new teachers for primary education.

KEYWORDS: *primary mathematics, teachers' knowledge and beliefs, pre-service interventions, initial teacher education, maths anxiety, maths avoidance.*

INTRODUCTION

"Scotland has a maths problem" (Scottish Govt. 2016a: 3). In response to this widely held perception, a government-funded group was convened in order to ascertain the means by which greater enthusiasm for maths could be encouraged. The initial report from the Making Maths Count group establishes a purpose and motivation for developing and improving mathematics education, a quest that is not unique to Scotland.

It has been recorded that as many as one in five 16-19 year olds in England are functionally innumerate (Rashid & Brooks 2010), prompting a recent nationwide analysis of the shortcomings in teaching and learning in English schools (Vorderman et al. 2011). Recent statistics presented by the Programme for

International Student Assessment (PISA) indicate that many of the previously top-performing European countries, such as Finland, Netherlands and Belgium, saw a significant drop in their mean scores for mathematics (OECD 2019). A similar rate of decline can be observed in the results returned from Australia and New Zealand, while the United States has consistently returned a significantly lower mean result throughout the same period (OECD 2019). It is perhaps unsurprising, then, that global interest in mathematics teaching and teacher preparation has recently heightened, with particular emphasis on improving attitudes toward maths and the mathematical knowledge of the student population and the teachers themselves (Boaler 2016; Fisher et al. 2018).

The Making Maths Count report sets out ten recommendations to help transform Scotland into a "maths positive nation" (p. 3). Among these recommendations, the group has called for research to be undertaken on how well students in Initial Teacher Education (ITE) are being prepared to teach mathematics. As suggested in the Making Maths Count report (p. 4), this should involve a review of the:

- minimum entry requirements to ITE for maths
- coverage of maths in primary ITE programmes
- means by which ITE institutions "update and improve" their programmes.

Developing teacher confidence in delivering mathematics is given particular gravitas in the Making Maths Count report, with the somewhat paltry suggestion that, if ITE institutions were to "provide a practical focus on teaching and learning styles", that should suffice to replenish the current deficit (Scottish Govt. 2016a: 20). In Scotland, initial teacher education operates within a national partnership model, whereby student teachers undertake a programme of on-campus learning which is supplemented and supported by intermittent professional practice placements in schools. A similar model operates in the Rep. of Ireland, where student teachers spend approximately 20 weeks on school placement during their initial teacher education course (The Teaching Council, 2019). Given this shared partnership approach to initial teacher education, it is pertinent to highlight that the responsibility for ensuring quality teachers of mathematics lies not only with ITE establishments but also with local authorities and schools (GTCS 2006).

Shortcomings in mathematics teaching in Scotland were further explored in the additional research information that was published alongside the main Making Maths Count report (Scottish Govt. 2016b: 11), where "more enthusiastic teachers" and "teachers who enjoy maths" were listed among the suggestions for improvement from children and young people. The prevalence of comments relating to teacher quality in this report provides testimony to the Organisation for Economic Co-operation and Development (OECD) assertions that "quality teaching is vital for improving student learning" (OECD 2011: 7).

In an OECD (2011) publication, titled "Teachers Matter", strong content knowledge is emphasised as a vital component of ITE programmes. This recommendation has been reiterated many times and across a great many nations, with a particular emphasis given to the knowledge required to teach mathematics and the so-called STEM (Science, Technology, Engineering & Mathematics) subjects (Ball, Thames & Phelps 2008; Benken & Brown 2008; Henderson & Rodrigues 2008; Rowland et al. 2009; Thames & Ball 2010; Hourigan & Leavy 2017; Tatto et al. 2018). In a similar vein, it has been shown that teacher

confidence has a direct correlation with subject matter knowledge and, perhaps unsurprisingly, has a high potential for affecting pupil confidence and attitudes towards maths in schools (MacNab & Payne 2003; Henderson & Rodrigues 2008; Swars, Smith, Smith & Hart 2009; Hourigan, Leavy & Carroll 2016).

Framing the question

In my role as teacher educator at Scotland's largest provider of ITE, I have experienced many anecdotal accounts of pre-service teachers displaying insufficient knowledge for delivering primary mathematics lessons. I have also observed, first-hand, concerning evidence of maths anxiety and even maths avoidance amongst pre-service primary teachers. Considering relevant research, together with the evidence seen within my role as a primary education mathematics tutor, it has become apparent that mathematics is an area of the curriculum that requires significant time and attention within the ITE programme in order to adequately prepare primary teachers to be confident and competent teachers in the discipline (McNab & Payne 2003; Henderson 2012).

Following extensive early scoping searches, it was found that research interest in primary mathematics has recently increased, largely due to the international variation in mathematics results, as reported by PISA and Trends in International Mathematics and Science Study (TIMSS). Studies carried out by TIMSS in the late 1990's, identified teacher quality as a common latent factor across each of the three main practices that impacted most significantly on children's learning (Hsieh et al. 2011).

The Mathematics Teacher Education and Development Study (TEDS-M) is a large-scale cross-national funded study that has been carried out to determine the most effective content and approaches for ITE mathematics (Tatto et al. 2012); this is the first and only study of its kind, which drew on evidence from 17 countries to explore future mathematics teachers' characteristics and beliefs, as well as their mathematical and pedagogical knowledge. While the TEDS-M study is undoubtedly a significant resource for educators and policy reviewers, the study took a very broad view of ITE maths provision across 17 nations, with a particular focus on the existing policy framework of each of the participant countries, relating to mathematical knowledge on entry to the ITE programmes and the rigour applied to the accreditation of their courses (Tatto 2014). The study concluded that the design of ITE programmes can have a significant impact on the knowledge that student teachers acquire prior to joining the profession, though specific information on the most appropriate content or approaches within these programmes has not been forthcoming as a result of the study. Despite the broad reach of the TEDS-M study and the relevance of their findings, ambiguity remains, particularly when educators are cognisant of the contextual factors that influence ITE in different nations (Henderson 2012b; Hourigan & Leavy 2017). Stating a case for further research to be carried out on mathematics within ITE, Hourigan & Leavy (2017) profess that "it is important that each country undertakes their own inquiry at a local level in order to address the specific needs of the student teachers in that national context" (p. 824).

In contrast to the extensive studies carried out elsewhere, during early scoping searches, a significant dearth of research was noticed within the Scottish context

of mathematics education for ITE. This may, in part, be attributed to the bygone view that teacher educators in Scotland held of their role; as McCall (2017) records in his historical overview of teacher education in Scotland, "The vast majority of the staff (at ITE institutions) considered their main, or only role, as a teaching one" and staff often "claimed that they were too busy teaching" to engage in research (p. 605). Notwithstanding the lack of research activity around primary mathematics ITE in Scotland, it is of international interest to consider approaches to provision of ITE mathematics programmes so that each country can determine the most appropriate methods and means by which they might prepare their new teachers. This is no more evident than in the TIMSS and PISA reports, which "enable different nations to understand one another's educational situations" (Hsieh et al. 2011).

In order to closely examine the forms of provision for primary mathematics ITE, it was decided that a small scale geographically limited systematic review of literature, with a particular focus on the interventions used to overcome the deficit in pre-service teacher knowledge and confidence for teaching maths, would be worthwhile. The merits of a systematic approach to literature review are many, not least of which being the opportunity to flag up gaps in the research literature (Petticrew & Roberts 2006).

Given the limited scope of Scottish research relating to ITE primary maths provision, an eye has been cast across the sea to the Republic of Ireland, where a more substantial recent body of research has been undertaken by a number of teacher educators working in the field. Not discounting the comparative population size and the commonalities in socio-political perspectives, both Scotland and the Rep. of Ireland are currently undergoing significant curricular reform which seeks to revolutionise the way in which mathematics is taught in the primary classroom (Dept. of Education and Skills (DES) 2011; Scottish Govt. 2011). Explicably, these reforms have had significant ramifications for the preparatory work that is undertaken in ITE programmes. In addition, it is noteworthy that primary teachers in Scotland and in the Rep. of Ireland must undertake a tailored programme of ITE, for which the minimum requirements for maths qualification on entry to the programme are currently being reviewed (Dept. of Education and Skills 2017; Scottish Govt. 2018)

To facilitate this study, different types of review questions (i.e. descriptive, normative, causal, theoretical and relational) were considered (Boland, Cherry & Dickson 2017). A normative approach was decided to be most fitting as it would allow the researcher to explore preferences about what *should* happen during ITE to ensure that new teachers are adequately prepared to teach mathematics after qualification. While the actual findings of this systematic review are presented descriptively and without judgement, it is expected that a normative perspective will allow the reader to consider the merits of the interventions that are identified. The relative successes that were reportedly achieved as a result of the various interventions are duly noted in this paper, so that a normative view of the efficacy of those interventions might be achieved.

Aims and Limitations

Taking account of all that is known about the impact of teacher knowledge and teacher confidence on children's learning (OECD 2011), the intention of this paper is to explore the associated developments in mathematics programmes for ITE. This review aims to provide a summary of the themes that have been addressed through recent research on ITE mathematics provision in Scotland and the Rep. of Ireland, with a view to informing potential changes and improvements to the mathematics programmes currently provided by ITE institutions. In particular, interventions which have been trialled within ITE programmes to address the deficiencies in the subject matter knowledge and confidence of pre-service teachers, will be examined. Areas for further investigation will be highlighted, with particular reference to gaps in current research, most noticeably within the Scottish context for primary mathematics ITE.

Within the parameters of time and resource available, this review has been limited by geographical area and by dates of publication. The date of publication criterion was influenced by the relatively recent trends in curriculum development, which Priestley & Biesta (2013) summarise as "a return to constructivist and child-centred approaches, an emphasis on the teacher as a central agent in curriculum development, and the formulation of curricula in terms of competences and capacities" (Walsh 2016: 2). This shift can be clearly observed in recent curricular reforms in both Scotland and the Rep. of Ireland, and for this reason, only papers published after the introduction of the Scottish CfE and the Irish Reform Curriculum (circa 2007-8) will be considered for review. In keeping with an aggregate review, every attempt has been made to collate all of the relevant research in order to give weight to the extent of the different findings (Gough, Oliver & Thomas 2012). However, a configurative review approach should not be de-merited for this study, as the range and nature of interventions uncovered in the research will provide 'food for thought' with regard to the overall aim of this review.

Prior to exploring the research publications, it is important to consider both the Irish and Scottish context for mathematics provision in schools and in ITE institutions, in order to understand the similarities, differences and recent developments. Some consideration will be given to policy statements and the international context for developing mathematics education.

SETTING THE CONTEXT

Scotland

As evidenced by both international and national survey reports, Scotland's attainment levels in maths have been noticeably falling over the last two decades. The results from the Programme for International Student Assessment (PISA), carried out every three years by the Organisation for Economic and Co-operative Development (OECD), show that Scotland's maths attainment has fallen, study after study, and at a faster rate than the OECD average reduction (Pritchard 2014).

TABLE 1: SCOTTISH MEAN PERFORMANCE IN MATHS, AS COMPARED TO THE OECD AVERAGE.

	2003	2006	2009	2012	2015
Scotland	524	506	499	498	491
OECD	500	498	496	494	490

Since 2003, Scotland's place in the international ranking amongst PISA participating countries has shifted significantly, whereby 14 of the participating administrations showed significantly higher results than Scotland in 2015, compared to only 5 in 2003 (Scottish Government 2016c). The PISA findings have been corroborated by the results of the Scottish Survey of Literacy and Numeracy which were published in 2016 (Scottish Government 2016d). The numeracy results from this survey demonstrated that there has been a significant percentage decrease in numeracy attainment among P4 pupils between 2011 and 2015, with only 66% of pupils performing well or very well in 2015, compared to 76% in 2011. The recent results for P7 and S2 pupils are more stable, though declines in numeracy attainment have been recorded at all levels between 2011 and 2015.
Scotland's Curriculum for Excellence (CfE), which was first published in 2004 and implemented nationally in 2010-11, has received much of the blame for the falling levels of attainment in mathematics. In particular, the emphasis on skills development, in place of knowledge acquisition, has received criticism, primarily due to the absence of detailed content which is expected should guide and inform teachers in the planning and delivery of lessons (Priestley 2010; Henderson 2012; Farmer 2013). Contrary to the pedagogical guidance of the CfE, which was largely based on constructivist principles of learning, many children in Scotland still experienced teacher-led learning and textbook based tasks during lessons, as reported by a number of national surveys (Scottish Govt. 2009; Scottish Govt. 2012; Hudson, Henderson & Hudson 2015). It can also be assumed that many experienced teachers, who had taught under the previous curriculum guidance, will have retained their knowledge of content and would have carried out the planning of lessons accordingly. For this reason, amongst others, it is difficult to obtain a clear picture of exactly how CfE has impacted on pupils' attainment levels in maths. A more certain assumption can be made about the impact of the CfE on newly-qualified teachers, who will not have the same trove of knowledge to call upon in the absence of guidance within the curriculum.

Just as the validity, reliability and relevance of national and international survey results cannot be debated within the scope of this paper, neither is it the purpose of this review to critique the CfE or its enactment in schools. However, it is important to note these points and to consider the implications of the reported figures in PISA and the *Scottish Survey of Literacy and Numeracy* (Scottish Govt. 2017a), as they set the stage for developments in mathematics ITE programmes yet to be explored.

Recent developments in Scotland

An update on the progress of the recommended actions from the original Making Maths Count report (Scottish Govt. 2016a) was detailed in "Making Maths Count – One Year Review Report" (2018). This update explains that an analysis of the numeracy and maths component of ITE programmes had been carried out in Scotland and that a second phase of the exercise "looking at the qualitative aspect of ITE was underway" (p. 5). The information provided in the report is limited and many questions around the specific aims and actions of the work remain. However, the updated report notes that concerns have been identified around the variation of the results found through the quantitative analysis of maths in ITE, particularly due to the "relative proportion of numeracy content in comparison to the other subjects" (p.5). Further action has been requested on these tasks, with some responsibility assigned to the General Teaching Council for Scotland to embed these questions into their future plans. It is expected that the Making Maths Count group will also contribute to the accreditation review of the ITE framework for Scotland.

Republic of Ireland

Recent PISA results for Ireland show a marked improvement in the mean maths scores compared to the OECD average (OECD 2018).

TABLE 2: IRELAND'S MEAN PERFORMANCE IN MATHS AS COMPARED TO THE OECD AVERAGE

	2003	2006	2009	2012	2015
Ireland	503	501	487	501	504
Scotland	524	506	499	498	491
OECD	500	498	496	494	490

While it is difficult to determine the precise reasons for these improved scores, they may, in part, be attributed to Ireland's focussed development and implementation of a reformed curriculum for mathematics education at both primary and secondary level. The secondary level 'Project Maths' curriculum was rolled out nationally in Ireland in 2010 and was intended to have a greater focus on conceptual understanding while promoting problem-solving within a realistic context (Leavy, Hourigan & Carroll 2017; Prendergast & Roche 2017). This development followed a primary national curriculum of 'reform' mathematics, introduced in 2005 to lead Irish primary teachers away from "traditional", "tell and drill" teaching towards a more constructivist approach to teaching and learning (Hourigan & Leavy 2017). The reformed primary curriculum emphasised the development of strategies and the importance of language for deep learning in mathematics. Ireland's recent stable figures in the maths PISA scores may also have been influenced by the *National Strategy on Literacy and Numeracy for Learning and Life (2011-2020)* (DES 2011), which supported improvements in

maths attainment, as evidenced through the National Assessments of English Reading and Maths (NAERM) (Dept. of Education & Skills 2017). The *Strategy* (DES 2011) placed a strong emphasis on the quality and content of ITE and a complete overhaul of ITE provision in Ireland proceeded, with many of the 19 pre-existing ITE institutions being amalgamated into new centres for teacher education, which were closely associated with or situated within universities. The suggested reforms advocate the development of research-informed programme provision and it has been reported that the institutions concerned have taken a "positive and constructive approach to the implementation of the reforms" (Dept. for Education & Skills 2017: 29). However, Ireland's education professionals will not rest on their laurels, as the Minister for Education, Richard Bruton, noted in a recent press release that, "while it is good to see Irish students performing above the OECD average in maths and science, we still need to make improvements" (Dept. for Education & Skills 2016). "Review and reform has been a constant feature of the Irish mathematics education landscape for the last 15 years" (Leavy, Hourigan & Carroll 2017: 509). This exigency for educational enhancement is reflected by the output of research-informed reports that are emerging from Irish ITE institutions in recent years.

METHOD

Following initial scoping searches conducted over a number of months, key search terms were identified and collated within one expanded search sequence of terms as shown in Table 3 below. Initially, it was hoped that Singaporean ITE provision could be included within the scope of this review, due to the countries recent esteem as a consistent top ranking country on the PISA results board (OECD 2018). However the body of literature that was returned through this search was immense, with a great deal of research emanating from the TEDS-M study (Tatto et al. 2012). Consideration was also given to countries within the United Kingdom. Reasons for limiting the review to Scotland and the Rep. of Ireland were numerous, perhaps the most noteworthy being the difference in qualification at postgraduate level, i.e. PGDE in Scotland and Ireland, as opposed to PGCE in England, Wales and Northern Ireland. The range and variation of routes into teaching that are currently operational in England were also deemed to be incongruous with the scope of this review. Ultimately, the decision was taken to limit the review to Scotland and Rep. of Ireland, in order to achieve a comprehensive review within these two countries. The initial search was conducted on 28th February 2018 across a range of databases, the most fruitful of which was 'Education Abstracts (H. Wilson)', which was searched through Ebsco*host*.

TABLE 3: SEARCH TERMS USED TO CARRY OUT SYSTEMATIC REVIEW OF PRIMARY MATHS IN ITE

(math* OR numeracy) AND
(teacher education OR teacher development OR student teacher* OR pre*service teacher* OR teacher*training OR ITE OR ITT OR Initial Teacher Education OR newly qualified teacher OR NQT) AND
(primary OR elementary NOT secondary NOT high school) AND
(Scotland OR Scottish OR Singapor* OR Ireland OR Irish)

A full list of the searched databases can be seen in Table 4. Limiters applied to the search included: dates (Jan 2006 – Feb 2018), language group (English) and population (human). Hand searching of relevant journal and online publication lists, such as *Scottish Educational Review*, *Scottish Mathematical Council*, *GTCS* publications, NCCA and Educational Research Centre for Ireland, was also undertaken between 28th February and 6th April 2018. A Zetoc alert for 'math* and teacher education' was created and new publications were acknowledged throughout this time.

TABLE 4: DATABASES SEARCHED.

Ebsco*host*	**Other providers**
American Doctoral Dissertations, Audiobook Collection (EBSCOhost), British Education Index Child Development & Adolescent Studies, Communication & Mass Media Complete, Education Abstracts (H.W. Wilson), Educational Administration Abstracts, ERIC, Humanities International Complete, MathSciNet via EBSCOhost, OmniFile Full Text Select (H.W. Wilson), PsycARTICLES, PsycBOOKS, PsycINFO	Web of Science Open Grey MathEduc Google & Google Scholar

The number of records returned and excluded at each stage of the review can be seen in Appendix 1 (PRISMA flow diagram 2009). After the initial de-duplication through EndNote, 152 records were screened by title and/or abstract with the inclusion criteria of maths, primary, ITE, Scotland/Ireland applied. As recommended by Dunbar & Fleeman (2014), where doubt remained about whether the record fully met the inclusion criteria, the record was included through the screening stage. Following this initial screening process, full-text papers of all 30 potentially eligible studies were obtained and 21 of these were excluded as they did not fully meet the inclusion criteria for this review.

The reasons for exclusion were many; some papers were omitted because they didn't take a specific focus on ITE maths and others took too particular a focus on one aspect of ITE maths, such as statistics or geometry. As might be expected, there is also a body of research investigating ITE for secondary maths; these papers were also excluded due to the primary education focus of this review. A number of papers did not relate to ITE in either Ireland or Scotland and other studies concentrated on teacher education as continued professional learning beyond ITE. As stated in the review question, this paper is interested in research that has been carried out on primary maths ITE programmes in Scotland and the Rep. of Ireland.

EXAMINING THE ARTICLES

Of the nine papers reviewed, four relate specifically to the Scottish context for primary maths ITE (Henderson & Rodrigues 2008; Henderson 2012a; Henderson 2012b; McKechan & Day 2015). Two of these studies examine pre-service primary teachers' mathematical knowledge and attitudes towards maths (Henderson & Rodrigues 2008; Henderson 2012b) and one has a main focus on the math knowledge base that pre-service primary teachers possess on entry to ITE (McKechan & Day 2015).

One Scottish discussion paper (Henderson 2012a) was also included because of the relevant and noteworthy recommendations that it contains. It is worth highlighting here that this systemic review of literature found only four peer-reviewed journal articles, published within the last 12 years, which go any way towards illuminating developments in Scottish primary mathematics in ITE.

The remaining five papers represent data obtained from studies conducted in Irish ITE institutions (Hourigan & O' Donoghue 2015; Leavy, Hourigan & Carroll 2016; Hourigan & Leavy 2017; Leavy, Hourigan & Carroll 2017; Leavy & Hourigan 2018). Two of these Irish papers (Hourigan, Leavy & Carroll 2016; Leavy, Hourigan & Carroll 2017) were side-line studies from one larger study and they prioritised pre-service teacher attitudes towards maths. The remaining three papers are primarily interested in examining pre-service teachers' mathematical knowledge acquisition during ITE. While every possible effort was made to ensure that this systematic review identifies all relevant papers, it is worth remembering that some restrictive exclusion criteria have been applied.

Competence in Primary Maths Teaching

During the last two decades, mathematical knowledge for teaching has become a subject of interest, and even concern (Hill, Schilling, & Ball 2004; Hourigan & Leavy 2017). Each of the studies considered in this review makes particular reference to the importance of primary teacher mathematical competence and the impact this will have on children's learning. A better understanding of the specific knowledge that pre-service teachers require at qualification has been the holy grail of many research studies around the globe in recent years (Delaney et al. 2008; Hourigan & Leavy 2017). It is no longer acceptable to assume that teachers should only be able to 'do' maths in order to be able to teach maths. The teaching of primary maths, it would seem, is a complex and rich phenomenon which requires significant depth of understanding of mathematical content and its associated pedagogy, the

mathematics curricula, as well as an appreciation of students and their potential misunderstandings.

Many researchers have been guided by Shulman (1986) when deconstructing the knowledge required for maths teaching, to identify three components of Mathematical Content Knowledge (MCK): subject matter content knowledge (SMCK), pedagogical content knowledge (PCK) and curriculum knowledge (Henderson 2012a; Henderson & Rodrigues 2015; Hourigan & O' Donoghue 2015; Leavy, Hourigan & Carroll 2016; Hourigan & Leavy 2017; Leavy & Hourigan 2018). SMCK has been further sub-divided by Ball, Hill & Bass (2005) to include common content knowledge (CCK) and specialised content knowledge (SCK) (Henderson 2012a; Hourigan & Leavy 2017), with a further category, that is Horizon Knowledge, being more recently added to the mix by Thames and Ball (2010). Horizon knowledge describes the necessity for teachers to have an awareness of related concepts or connections in order to best support their pupils in learning about mathematics (Hourigan & Leavy 2017). An examination of the levels of SMCK held by pre-service teachers, at either entry to ITE or as a result of the ITE intervention, has been the focus of many of the papers under review here (Henderson & Rodrigues 2008; Henderson 2012b; Hourigan & O' Donoghue 2015; McKechan & Day 2015; Leavy & Hourigan 2018).

In addition to having well-developed SMCK, teachers need to be able to transform the subject knowledge into a form that is accessible to the learners. This ability has been classified as Pedagogical Content Knowledge (PCK) and involves complex connections such as 'knowledge of content and students', 'knowledge of content and teaching', 'knowledge of content and curriculum' and 'knowledge of typical errors and misconceptions' (Ball, Thames & Phelps, 2008). These components of PCK have recently been explored by Hourigan & Leavy (2017) and Leavy & Hourigan (2018), who have presented them as an important consideration of effective teacher preparation, alongside MCK.

Confidence, Attitudes and Beliefs

Questions have also been raised about whether the mathematical knowledge that teachers hold has any bearing on their confidence, attitudes and beliefs for teaching mathematics (Henderson & Rodrigues 2008; Hourigan, Leavy & Carroll 2016; Leavy, Hourigan & Carroll 2017). Accepting Walker & Avant's theory (1995) that attitudes are borne from three basic characteristics: consistency, predispositions and learning; it is important to consider how insufficient mathematical knowledge might impact on teacher development and ultimately teacher efficacy (Hourigan, Leavy & Carroll 2016). "The importance of teachers possessing a positive attitude towards mathematics has long been established" (Hourigan, Leavy & Carroll 2016: 320, citing Charalambous et al. 2009 and Isenberg & Altizer-Tuning 1984). It has been suggested that teachers with low self-efficacy for maths are more likely to use teacher-centred strategies, text-book work and lecturing (Wilkins 2008). These approaches are now largely deemed unacceptable due to the curricular reforms that promote learner-centred, constructivist and social constructivist approaches to teaching and learning (Henderson 2012b; Leavy, Hourigan & Carroll 2017). Coupled with the understanding that teacher attitudes can have a positive or detrimental effect on

children's attitudes towards learning (Phillips 1973; Aiken 1974; Philippou and Christou 1998), research into pre-service teacher attitudes towards maths is highly warranted.

Study Demographics

All studies were carried out within each of the respective author's own ITE institutions and were limited to prospective teachers within that same institution. The Scottish studies were exclusive to two ITE institutions (University of Dundee and University of the West of Scotland) and research was conducted at only one ITE institution (University of Limerick) in Ireland. There was significant variation in participant group sizes; two of the studies involved entire cohorts of teachers (as many as 40% of the nation's trainees) (Hourigan, Leavy & Carroll 2016), while others were subject to voluntary participation, with participant numbers varying from 25 (Leavy & Hourigan 2018) to approx. 400 (Leavy, Hourigan & Carroll 2017).

All of these research studies pertain to the knowledge and/or attitudes of students on undergraduate ITE courses, which highlights a concerning lack of attention to the student experience of PGDE mathematics provision within primary ITE programmes. The exact numbers of teachers who qualify through the PGDE route have not been identified at the time of writing but it is understood through personal experience of teaching on the programmes at Scotland's largest ITE provider that the numbers are significant. It is likely that more than 50% of all newly qualified teachers have taken the graduate route to qualification in both Scotland and Ireland.

Research Instruments

All but one (McKechan & Day 2015) of the eight research studies took a mixed method approach to achieve triangulation of the data, whereby quantitative data gathered from online/paper assessments and questionnaires was cross-checked with qualitative data gathered from open-ended surveys (Leavy, Hourigan & Carroll 2017), semi-structured interviews, as well as documentary and observational data (Hourigan & O' Donoghue 2015; Leavy & Hourigan 2018).

To gather information relating to student attitudes and confidence towards maths, an online survey was the primary source of data collection for each related study. The Scottish studies (Henderson & Rodrigues 2008; Henderson 2012b) asked a mixture of open-ended questions and statements based on those from the ASDQII instrument (Marsh 1993), the Marat (2005) scale-based questionnaire, the Claiborne & Ellett (2005) student data collection questionnaire and the Modified Fennema-Sherman Mathematics Attitude Scale (PEAR 2018). Using open ended questions, prompted students "to expand further on their experiences when involved in mathematical activities and also their levels of confidence" (Henderson, 2012b: 379).

Two of the Irish studies (Hourigan & O' Donoghue 2015; Leavy, Hourigan & Carroll 2017) used Aiken's Revised Mathematics Attitude Scale (Aiken 1974) to record and evaluate student responses to a set of statements about their ITE maths programme. When describing the research instrument, the third Irish study on pre-service teacher attitudes towards their maths programme (Hourigan & Leavy 2017) refers only to a post-programme qualitative survey that was created to allow

students to respond openly with qualitative statements about their experience of the programme. As noted in their paper, through open ended survey questions, Hourigan & Leavy (2017) sought "to gain insight into students' experiences, the perceived effects, causal relationships and miscellaneous or unanticipated information" (p. 813).

To assess student teacher mathematical knowledge and competence for teaching primary maths, an online assessment was used by Henderson & Rodrigues (2008), where McKechan & Day (2015) preferred a paper alternative. Hourigan & Leavy (2015) administered both a pre and post-programme test to determine the knowledge gained as a result of the maths programme at their ITE institution, with a "paired sample measure" comparison between the two tests (p. 65).

INTERVENTIONS TO ITE MATHS PROGRAMMES

"In the past, ITE mathematics education programmes have been described as 'weak interventions' in affecting student teachers' knowledge, beliefs and attitudes" (Ball 1990; Nesbitt Vacc & Bright 1994; Feiman-Nemser 2001; Benken & Brown 2008, cited by Hourigan & Leavy 2017: 186). In order to determine the most appropriate content and/or the most effective approaches to ITE maths education, a number of studies evaluated interventions which had been introduced to their programmes. These interventions were intended to support the student teachers to develop the necessary attitudes and/or knowledge for teaching. Some of the interventions targeted deficiencies in the ITE maths programmes and one involved a complete overhaul of the programme to fit with national guidelines for ITE provision.

Formative Assessment Tool

Henderson & Rodrigues (2008) used an online assessment tool that required student teachers, in the first year of their Bachelor of Education (BEd) programme, to achieve 80% accuracy on 28 randomly generated questions. Students were given 10 weeks to prepare for the assessment and were encouraged to complete the test a number of times in order to raise their score to 80%, if they had scored below the threshold. 65% of student teachers did not evidence appropriate mathematical SMCK for teaching in this test. Interestingly no comparison was found between the level of qualification on entry to the course and the student teachers' level of achievement on the test, i.e. students with a higher level qualification in maths did not always achieve a grade above 80% on the test. As suggested by Askew, Brown, Rhodes, Johnson et al. (1997); this study found that "teachers did not have to hold advanced qualifications in mathematics to be effective"; it is not formal subject knowledge that is required, but specialist knowledge for teaching that needs to be developed (Henderson & Rodrigues 2008). In order to improve student teachers' mathematical SMCK during ITE, Henderson & Rodrigues (2008) suggest that an online mathematics assessment should be introduced as a gatekeeper to the primary teaching qualification. Also worthy of note is the finding that confidence and qualification were not inextricably linked, whereby 50% of the participants who had a higher level mathematics qualification were not confident in their mathematical ability.

In her 2012 study, Henderson reiterates the claim that an online assessment is a useful intervention to support primary teachers in their ITE maths programme. The study carried out in 2012 tested the impact of an online assessment on the mathematical SMCK across all four year groups of the BEd programme at the same ITE institution (Henderson 2012b). The results of this study found that a formative assessment tool can go some way to improving SMK for primary maths teaching. The results also reinforced the findings from 2008 that higher qualifications do not necessarily lead to improved knowledge or confidence in maths. Interestingly, this study was motivated by a concern that had been expressed by Rowland, Martyn, Barber and Heal (2000), indicating that an audit of knowledge may have a detrimental effect on students because of the tendency to rote-learn procedures in order to pass the test. Pertinent to the question set out in this systematic review, Henderson (2012b: 377) asks "how else are teacher education institutions to address the lack of mathematics content knowledge possessed by many pre-service teachers?"

Another assessment tool was used by McKechan and Day (2015) in their study of primary ITE entrants' mathematics SMCK, though not as a formative means of improving that knowledge. Unlike the previous two Scottish studies, the purpose of McKechan and Day's (2015) study was not to measure the success of the assessment tool as an intervention, but to take an exclusive focus on the examination of whether SMCK in maths matched the participants' qualification on entry to the course. The findings of this study also support Henderson (2012b) and Henderson & Rodriques (2008) in their suggestion that a higher qualification does not guarantee that entrants will have the desired knowledge for teaching. It was found that as many as one third of students who had a Higher grade pass in Maths scored below the threshold score (<63%) in the assessment. This study gives some clout to the suggestion made by Donaldson (2010) 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" (McKechan & Day 2015: 81).

Needs-Led Support Sessions

Due to the already over-subscribed timetable of the ITE programme at their institution, it was not possible for Hourigan and O' Donoghue (2015) to extend the existing primary maths programme in order to address deficiencies in pre-service teachers' maths SMCK. As a means of supporting students to develop the necessary knowledge for teaching, weekly support sessions were offered alongside the existing main maths provision of the course. It was hoped that intervention participation would positively affect the students' beliefs, attitudes and confidence regarding the subject of maths and its teaching and that participants "would develop an appreciation of the intellectual richness of elementary mathematics as well as a deep and connected understanding of fundamental mathematics concepts" (Hourigan & O' Donoghue 2015: 62). A pre and post-intervention test was administered to all participants and significant positive improvements were seen in the post intervention test. The results of the test showed an increase in both 'common' and 'specialised' SMCK which has been attributed to the design characteristics of the intervention (see Table 5).

TABLE 5: CHARACTERISTICS OF THE NEED-LED INTERVENTION (HOURIGAN & O' DONOGHUE 2015)

Participants would:	
A	reflect on their pre-tertiary experiences, identifying potential strengths and weaknesses
B	experience the mathematics they will teach
C	build on prior knowledge of concepts/procedures
D	recognize and develop alternative approaches
E	demonstrate an understanding of connections which exist
F	explain procedures/concepts through verbalization and/or the use of structural materials
G	work in various groupings (individual/pairs/groups)
H	select appropriate representations of a concept/procedure
I	examine pupil work and interpret possible sources of pupil error

This study also sought to measure the impact of the intervention on the students' attitudes towards mathematics. To this end, Shapiro's framework (Table 6) was used to evaluate the intervention, which was a common tool applied to the findings in three of the five Irish studies (Hourigan & O' Donoghue 2015; Leavy, Hourigan & Carroll 2016; Hourigan & Leavy 2017). Improved confidence was recorded as well as an increased awareness of the complexity of maths at this level.

TABLE 6: CHARACTERISTICS OF SHAPIRO'S (1987) EVALUATION CRITERIA (HOURIGAN & O' DONOGHUE 2015)

Treatment effectiveness	Insight into the amount of change (in Math SMCK) evident among the participant group, ideally in comparison with the control group who have not experienced the intervention.
Social validity	The 'effectiveness of the programme' as perceived by the participants.
Treatment acceptability	Whether or not the potential participants 'like' the intervention procedure implemented.
Treatment integrity	The extent to which the intervention is implemented as intended across all presentations.

Five Module Maths Programme

The characteristics (Table 5) identified and trialled by Hourigan and O' Donoghue (2015) in their needs-led intervention, were further developed and extended to influence the revised programme for primary maths ITE at the same institution. This new programme consisted of five modules, spanning five semesters of an eight semester long undergraduate ITE programme. As described by Leavy, Hourigan & Carroll (2016) and Hourigan & Leavy (2017), the mathematics

education modules were intended to support students to develop both subject matter knowledge and pedagogical content knowledge and to positively affect student teacher beliefs about the nature of mathematics and its importance, as well as to impact on attitudes and confidence regarding mathematics and its teaching. Leavy, Hourigan & Carroll (2016) examine the views that student teachers held of their maths ITE programme, while Hourigan & Leavy (2017) focus on the perceived effects of participation in the mathematics education programme and aim to identify which components of the programme were perceived to be most valuable.

The Aiken Mathematics Attitude Scale (1974), which assessed students' enjoyment of the maths programme and their view of the value of maths, was utilised to create a pre and post-programme survey. The survey was completed by almost 400 of the participants and demonstrated a significant difference in the mean scores, indicating a marked improvement in attitudes towards maths by the end of the five module intervention. In particular, the students shared their enjoyment of the 'small group' tutorial structure (25 participants) which was associated with opportunities to "engage, explore, interact and reflect" on their learning (Leavy, Hourigan & Carroll 2016: 339). Both studies rely on self-report methods of data collection, therefore, as acknowledged by Hourigan & Leavy (2017), they cannot make any claim that the findings reflect actual improvements in participant knowledge or attitudes as a result of the intervention. However, the reported results indicate a very positive outcome in both domains (Hourigan & Leavy 2017).

Lesson Study

The most recent study identified within the scope of this review (Leavy & Hourigan 2018), takes another approach to supporting pre-service teachers in developing their mathematical knowledge; that of Japanese Lesson Study (Lewis and Tsuchida 1998). It was expected that engaging prospective teachers in Lesson Study would support a focus on both SMCK and PCK and "provide insights into how these knowledge domains interact with and inform instructional practices, teaching strategies, the construction of learning objectives and goals" (Leavy & Hourigan 2018: 50).

This study involved 25 pre-service teachers in the third year of a four-year ITE programme. The participants voluntarily undertook an additional module which ran alongside the main maths ITE provision and involved a 10 week lesson study cycle, whereby participants worked in small groups of 5 to plan, implement, evaluate and amend a lesson on early number for an infant class. Refinements were made to the lesson after each of the three teaching sessions and the final lesson plan was then discussed and shared with the larger group. Documentary and observational data was kept by the researchers throughout the duration of the module and during each cycle of the lesson study analysis. Findings from this data, together with data collected from the 'concept assignment' that was completed at the end of the module, were summarised under two main knowledge statements. Through analysis of the data, it was revealed that the intervention supported student teachers to "develop understanding of the importance of a particular concept within a topic of study" and to become more aware of "the knowledge needed to identify the source of children's mathematical errors" (Leavy & Hourigan 2018: 58).

While the organisational complexity of this approach might detract from its appeal as a widespread intervention to primary maths ITE provision, it is important to note that this study demonstrates success in supporting students to develop the "highly integrated and robust content and pedagogical understandings" that are necessary for good teaching (Leavy & Hourigan 2018: 58). Perhaps, a scaled-down version of Lesson Study would be a feasible alternative for widespread usage in ITE programmes.

SUMMARY OF FINDINGS

The research studies identified in this review have been carried out by teacher educators within the realms of their own ITE institutions. These are case studies that have used action research to shed light on the practices that are ongoing in Scottish and Irish ITE programmes. It is evident from the literature that mathematical knowledge for teaching has long been an area of interest and one which continues to confound researchers due to its complex categorisations and the problematic time constraints of ITE provision (Ball et al. 2008). While the findings of this review indicate that there are still no conclusive means by which ITE programmes can ensure that prospective teachers acquire the levels of MCK and PCK that are necessary to support learning in the primary classroom, the studies explored here make sensible suggestions for supporting the knowledge development of pre-service teachers and provide evidence to indicate the efficacy of the intervention. This review provides a helpful overview of worthy interventions or amendments to ITE maths programmes which may be replicated internationally. When considering and comparing ITE provision across the two main current routes into teaching, i.e. the four year undergraduate degree in Primary Education and the one year Postgraduate Diploma in Education, the opportunities to implement such interventions may be limited due to time constraints and competing priorities. ITE programmes can and, as evidence suggests, often do, highlight the gaps in student teacher knowledge so that newly qualified teachers are aware of their responsibilities as they set forth on a journey of professional learning; a journey that will expectedly involve a continual process of self-reflection and reflexive practice (Stingu 2012). Each of the interventions examined in this review has, either explicitly or indirectly, made reference to the self-efficacy and professionalism that is expected of all teachers in the profession. Given the variety of interventions trialled and relative complexity in deducing the impact of each, the principle message that emanates from this review is probably that of the vital role that ITE plays in developing student teachers' attitudes and beliefs about mathematics and mathematical ability, while also promoting the practice of professional reflection for identifying areas for development. Regardless of a student teacher's knowledge and attitudes towards mathematics on entry to ITE, significant development must take place in order that student teachers are adequately prepared for their role in the classroom (Henderson 2012a; Leavy & Hourigan 2018; McKechan & Day 2015). Swars, Smith, Smith, Carothers & Myers (2018) profess that "teacher's beliefs are influential in how and what they learn and should be targets for change during teacher education". The primary role of ITE might then be to foster a growth mind-set belief for mathematics, which applies not

only to the student teachers but to the young mathematical minds that they will nurture in schools.

CONCLUSION

This review has identified a variety of possible and plausible interventions that have the potential to improve the mathematical knowledge and confidence with maths for new primary teachers entering the profession. This summary of the interventions trialled in ITE is worthy of consideration by an international audience due to both the usability of the interventions and the often analogous nature of mathematics curricula across the globe. It has been noted that high levels of resourcing in terms of time, staffing and finance will be required in order to make the necessary improvements to mathematics education in Scotland (Pritchard 2014). The Making Maths Count group is one of a number of Scottish Government responses to the recent decline in Scotland's maths results. While the recommendations it has made (Scottish Govt. 2016a) are relevant and worthwhile, more will need to be done to raise the status of primary mathematics education in Scotland. Reassuringly, the Scottish Mathematical Council (2017) has recently launched an annual primary publication to sit alongside their stalwart secondary magazine, the first copy of which was delivered to primary schools in March 2018. Perhaps this form of accessible discussion will serve to highlight the ongoing developments in primary mathematics and mathematics within ITE provision.

Despite the recent interest in supporting and developing quality mathematics education, little research has been carried out on ITE primary maths provision in Scotland. A more rigorous examination of the findings of international studies relating to the maths programme provision for ITE, such as those carried out in Ireland and further afield, would be beneficial.

With the stage set for radical change to ITE provision (Scottish Govt. 2017b; Scottish Govt. 2017c), further discussions around entry requirements to ITE programmes will be expected. A robust body of research around mathematics programme provision, to include an examination of the current strengths and potential areas for development, should be considered before policymakers make any final decisions about raising the mathematics entry requirements to ITE.

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Appendix 1: PRISMA 2009 Flow Diagram (Adapted)