Supporting Mathematics Teachers' Development through Higher Education

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Abstract

Mathematics education, both nationally and internationally, is facing a number of challenges with significant on-going shifts in the structure, content, and core principles of mathematics curricula in countries around the world. For example, in Ireland there was an ambitious reform of the post-primary mathematics curricula in 2010 with further changes proposed in 2018. In light of these changes and concerns regarding ineffective teaching and a lack of continuous professional development, the National Council for Curriculum and Assessment (NCCA) has recommended that structures be put in place to facilitate practicing mathematics teachers to achieve postgraduate qualifications, ideally at Masters Level. To facilitate this recommendation, a new Mathematics Education strand of the Master in Education programme in Trinity College Dublin has been developed. This paper outlines the rationale for the new strand, as well as detailing its structure and content.

Keywords: Teacher development, Higher education, Rationale and course design

1. Introduction

Teaching is a multifaceted occupation that must be learned and constantly improved (Ball, 2001), starting with initial teacher education and continuing until retirement. Twenty five years ago, Dean (1991) made the point that teaching is a dynamic process and development does not happen simply as a result of years in the classroom. This is particularly true in today's society as educators bear the responsibility for preparing young people to realise their potential amidst rapid social and economic change. Teachers are charged with having to "prepare students for jobs that have not yet been created, technologies that have not yet been invented and problems that we don't yet know will arise" (Schleicher, 2011, p.42). Such challenges are even more pronounced in STEM (Science, Technology, Engineering and Mathematics) education in Ireland due to the additional charge placed on the post-primary education system to prepare young people to succeed in a 'knowledge-based economy' still reeling from the global financial crisis and subsequent recession (Quinn, 2012).

As the foremost agents of educational change and challenge, teachers must be supported to lead this charge. They cannot influence the educational lives of their students unless they have the knowledge, expertise and backing to do so (Borko, 2004). This is where the importance of continuous professional development (CPD) and alternative forms of support come to the fore. Higher education institutes in Ireland and internationally have a responsibility to develop initiatives to help educators upgrade and enhance their teaching. Trinity College Dublin's (TCD) development of a new strand in Mathematics Education to its existing Master in Education (M.Ed.) programme is one such initiative. Its development follows recommendations made by the National Council for Curriculum and Assessment (NCCA) (2014) for structures to be put in place to facilitate practicing mathematics teachers to achieve postgraduate qualifications, ideally at Masters Level.

The context of the NCCA's recommendation and the subsequent rationale for the development of the new Mathematics Education strand will be detailed in the following section. In the second part of the paper, a more detailed overview of the Mathematics Education strand will be provided. The aims of the programme along with its structure, module development and modes of teaching, learning and assessment will be outlined. It is anticipated that this paper will be of use to other higher education institutes in Ireland and further afield as they initiate programmes designed to support high quality educators through a reseach based programme.

2. Rationale for a Masters Strand in Mathematics Education

2.1 On-Going Curricula Reform

Since the middle of the last century, there have been significant changes in the structure, content, and core principles of mathematics curricula in countries such as the U.S., China, Japan, and the Netherlands (Schoenfeld, 2014). In the U.S., the 'New Math' movement, which focussed on structure, proof and abstraction, had dominated mathematics education in the 1950's and 1960's. This was followed by 'An Agenda for Action' report published by the National Council of Teachers of Mathematics (NCTM) in 1980 which placed problem solving at the centre of school mathematics (Schoenfeld, 2014; Klein, 2007). The 1989 'Curriculum and Evaluation Standards for School Mathematics' built on 'An Agenda for Action' by endorsing student-centred, discovery learning through real world problems (Klein, 2007). However calls for increased levels of accountability and changes such as the No Child Left Behind Act in 2001, prompted a greater focus on standardised testing in U.S. mathematics education with a de-emphasis on reasoning and problem solving. More recently, the widespread adoption of the Common Core State Standards in Mathematics in 2010 indicates that there may be a return to the focus on problem solving and placing mathematics in context (Schoenfeld, 2014). Such changes are only an example of recent curricula shifts in one country. Similar changes have been taking place in countries such as Japan and China, where the influence of the West, has led to greater emphasis on problem solving within their respective curricula (Koyama, 2010; Liu & Li, 2010).

Despite the significant reforms that were taking place internationally, Ireland had remained relatively removed from such developments. A study carried out by Oldham (2001) found that the 'New Math' curricular culture had dominated Irish mathematics teaching for the previous forty years. This culture resulted in a highly didactic and procedural approach to mathematics teaching in Ireland (NCCA, 2005). The first snippet of change evident was a reform of the Irish primary school mathematics curriculum in 1999, which is still in use today. The primary school curriculum plays a key role in preparing children to meet the demands of the 21st century and prepares them to think and communicate quantitatively and to use mathematics to solve problems (Irish National Teachers Organisation (INTO) 2013).

However these changes at primary level were not reflected at post-primary level until September 2010, when the Irish government initiated a major reform of the mathematics curriculum, entitled Project Maths. The implementation of Project Maths involved changes to the content students learn in mathematics, the way in which they learn it and how they are assessed (Prendergast & O'Meara, 2016). The initiative is designed to ensure an appropriate balance between mathematical theory and concepts and developing practical applications skills (Project Maths Development Team, 2010). The assessment also reflects the importance assigned to problem solving and applications in the teaching and learning of the subject. The five strands of mathematics at primary level (Number, Algebra, Shape and Space, Measure, Data) are linked to the five strands at post-primary level (Number, Algebra, Geometry and Trigonometry, Functions, Statistics and Probability) in order to ensure better continuity not just in pedagogical approaches but also in content.

2.2 Promoting Effective Teaching of Mathematics

One of the main reasons for the reform of the Irish post-primary mathematics curriculum was the poor performance of students in state examinations and their subsequent under preparedness for third level (Faulkner et al., 2010). This has typically been attributed to ineffective teaching of the subject at post-primary level (Gill et al., 2010; Prendergast & O'Donoghue, 2014a). Research carried out by Morgan and Morris (2009) described post-primary mathematics teaching in Ireland as consisting of whole class teaching and the replication of skills as demonstrated by the teacher. This resulted in students learning the 'how' rather than the 'why' of mathematics (Prendergast & O'Donoghue, 2014b). The recent curriculum reforms brought about by Project Maths are a direct attempt to combat these problems and to place greater emphasis on student understanding of mathematical concepts, through effective teaching of the subject. Many of the activities are student centred and new concepts are constructed by linking to previous knowledge (Prendergast et al., 2014a). However, such a pedagogical approach requires teachers to have a more in-depth knowledge of their subject areas. They may have to step away from their previously rehearsed methods and consider a variety of different approasches (Smith, 2004). Such knowledge in its entirety has been typically phrased as mathematical knowledge for teaching (MKT) and it includes both content and pedagogical considerations (Hill et al., 2005). Many studies have found that teachers' MKT is essential to the improvement of mathematics education (National Mathematics Advisory Panel, 2008; Kulm, 2008) and has been linked with improvements in students' achievement (Hill et al., 2005, Baumert et al., 2010).

However despite such obvious importance, research studies have found signs of poor MKT amongst teachers (Ma

1999). Many teachers exhibit a procedural level of understanding of mathematics and this is mirrored in their classrooms (Kulm, 2008). There are various reasons are cited for this in the literature. Thanheiser et al. (2013) suggest that there are inadequacies in teachers' knowledge of mathematics when they graduate from their teacher education programmes. There is also a high number of teachers teaching the subject who are not qualified to do so. These teachers generally possess a teaching qualification, but not specifically for the subject of mathematics. An Irish study carried out by Ni Riordain and Hannigan (2011) found that 48 per cent of teachers who were teaching mathematics at post-primary level did not have a subject specific teaching qualification. Additionally, the absence of effective continuous professional development (CPD) programmes in Ireland mean that practising teachers do not continue to update their MKT (Finucane, 2004).

2.3 Supporting the Development of Mathematics Teachers

The curricula changes discussed previously cannot impact on the educational lives of students unless teachers have the knowledge and expertise to do so (Borko, 2004). It is important that they are given the chance to renew their skills and keep up-to-date with new pedagogical and syllabi changes such as those brought about by Project Maths.

Despite such obvious importance, many problems remain regarding the provision of CPD (Hill, 2009). Twenty years agao in the U.S., Sykes (1996, p.465) characterises the failure of professional development as "the most serious unsolved problem for policy and practice in American education". More recently, respondents to the Smith Inquiry (2004) have noted with concern that in contrast to other professions, there is not a strong tradition of CPD among teachers in the UK. Research from an Irish perspective is sparse but a study carried out by Finucane (2004) paints a similarly bleak picture. The majority of teachers attend in–school developments or short once-off courses. Such courses have been the subject of much disapproval, particularly because of their short duration and the lack of any appropriate follow up. Finucane (2004) determines that the average amount of time spent on CPD by respondents in her study is 2.5 days a year.

Over the course of the Project Maths implementation period, mathematics teachers in Ireland received ten national day-long workshops to inform them and develop their knowledge of the curricula changes. These workshops explored the different pedagogical approaches and content changes over the five strands of the reformed curricula. However, a study carried out by Prendergast and Treacy (2015) has since found that further and on-going professional development around the new teaching approaches need to be provided for mathematics teachers in order for their learning to be continued and sustained. This is supported by Cosgrove et al.'s (2012) report which found that Irish mathematics teachers want more professional development. In light of such findings, and the concerns regarding ineffective teaching of the subject, the NCCA (2014) have recommended that practicing mathematics teachers be developed further and facilitated to achieve postgraduate qualifications, ideally at Masters Level. The newly designed Mathematics Education strand of TCD's School of Education M.Ed. programme will specifically address the NCCA recommendations.

3. The Master in Education Programme

The M.Ed. programme is run by the School of Education in Trinity College Dublin. The School which was established in 1905 has grown in size and reputation over the past 100 years and provides a substantial range of postgraduate courses in education, as well as undertaking research on many different areas of educational life. It is one of the major professional schools of the University with a current enrolment of over 600 postgraduate students. It has seventeen full-time and over thirty part-time academic staff. The School is committed to engaging with educational issues through teaching and research at a number of levels including initial teacher education, postgraduate teacher education and continuing professional development.

The M.Ed. is one of the School's flagship programmes. The course is open to educators at all levels of the education system, as well as those interested in diversifying their careers and working in the area of education and training. Applicants are normally expected to hold an honours degree and have at least two years' experience in the field of education.

Including the new strand in Mathematics Education, there are thirteen distinct specialisms such as Science Education, Music in Education, Leadership and Management in Education and Early Childhood Studies, to name but a few.

4. Overview of the Mathematics Education Strand

The Mathematics Education strand of the M.Ed. aims to act as an enhancement course for developing high quality mathematics educators. It intends to address mathematical content knowledge along with exploring mathematical practices for teachers and highlighting current national and international issues in mathematics education. The course is rooted in practical experience while emphasising the theoretical study of education. It is suited to mathematics

educators at all levels of the education system, but particularly post-primary teachers.

Overall the strand aims to integrate theory with practice and is intended for practitioners who wish to gain a comprehensive and contemporary understanding of mathematics education through a research-based programme. There are seven main learning outcomes:

1. critically identify and reflect on current issues and new developments in mathematics and Science, Technology, Engineering and Mathematics (STEM) education including: gender equality opportunities for developing community science; and emerging pedagogical advances; and
2. apply theories of mathematics and education in the process of school-based curriculum development in mathematics including: development and evaluation of short-courses promoting mathematical content (e.g. upper post-primary education internationally) and leading on national numeracy initiatives; and
3. articulate and apply arguments, concepts and theories of mathematics education, with specific reference to best practice from a national and international perspective, both orally and in writing; and
4. engage critically with a wide variety of literature in mathematics and STEM education, and
5. research topical issues in mathematics education and identify how these can be related to current developments in the domain from a national and international context; and
6. analyse, discuss and communicate frontier research and its implications for developing best practices in the mathematics classroom and build support for mathematizing amongst society more generally; and
7. appraise key topics in mathematics and mathematics education modelled through pedagogical processes of independent study, peer/group-engagement in class and collaborative use of virtual learning environments.

4.1 Programme Structure

The Mathematics Education strand mirrors the structure of the existing M.Ed. 'parent' programme. Hence the total credit rating for the strand is 90 ECTS. ECTS stands for European Credit Transfer and Accumulation System. It is a way of comparing and accrediting undergraduate and postgraduate modules and programmes across the European Union and other collaborating countries. The ECTS weighting for a module is an estimate of the student workload required for that module, based on factors such as the number of contact hours, the number and length of assessment exercises, class preparation and private study time, examinations, school placements, and so on as appropriate.

The 90 ECTS includes a taught component comprising four modules, each carrying 15 ECTS. In TCD, 1 ECTS unit is defined as 20 hours of student input, so a 15-credit module is designed to require 300 hours of student input. The is broken down into 25 hours of direct class contact time, 150 hours of private study time including research and reading and 125 hours for assessment and assignments. The remaining 30 ECTS are designated for a dissertation module which involves carrying out a research project in a relevant area of mathematics education and writing a dissertation under the guidance of a supervisor. The programme can be taken on a one year full-time basis or on a two or three year part-time basis as denoted by Table 1. The new strand will have the same level of EU and non EU fees as the existing M.Ed. programme. €6,756 for full-time (1 year) EU students, €10,876 for full-time (1 year) non-EU students. Part-time fees vary per year depending on the specific option (2 year; 3 year) chosen by students.

Table 1. Programme Structure

Options	Year 1	Year 2	Year 3
One Year Full-Time	Four Modules Dissertation		
Two Year Part-time	Four Modules	Dissertation	
Three Year Part-time	Two Modules	Two Modules	Dissertation

4.2 Module Development

As detailed previously the programme comprises of four main modules and a dissertation module. Much research went into the design and development of these modules for the new Mathematics Education strand. Similar programmes, nationally and internationally, were examined. There is only one other such programme presently being

offered in another higher education institute in Ireland. However closer inspection of this programme indicated that two thirds of the course consisted of mathematics and one third of mathematics education. It was decided that the M.Ed. in Mathematics Education in TCD would primarily be education based and follow the lead of similar programmes offered internationally in universities such as Western University in Canada and Curtin University in Australia. One of the main aims of the TCD M.Ed. programme is to integrate theory and research with practice. Hence it was decided to design one module based primarily on the theoretical aspects of mathematics education (see Module 1) and a subsequent module on how such theory translates into practice (see Module 2) The third module is primarily research based and focuses not just on mathematics education but on other STEM disciplines (see Module 3). Although mathematics will permeate the content of each of the aforementioned modules, it was decided to have one module where there is more of a focus on mathematics, albeit interlinked with how best it is taught. There was much debate regarding the specific focus of this module. It was decided to base it on one of the five strands of the revised post-primary syllabus. Many aspects of each of these strands will permeate the other three modules. However it was decided to base a full module on the teaching and learning of Geometry and Trigonometry. Unlike the preceding curriculum, one fifth of the reformed post-primary curriculum in Ireland is now focused on Geometry and Trigonometry. Therefore it is desirable that those teaching mathematics in Ireland should study this very distinctive element of the subject in-depth. A key component of the Geometry and Trigonometry module on the new strand is its delivery by the School of Mathematics in TCD, a world-leading School that will bring expertise and practical experience to the course for all participants. Each of the four modules will now be described in further detail and their learning outcomes outlined.

Module 1. Studies in mathematics education. This module will delineate the main assumptions behind a range of studies for conceptualising and analysing mathematics education and their implications for policy and classroom practice. In particular, participants will engage with core readings in learning theories, the teaching methodologies they often imply, and the mathematical knowledge for teaching they may require. The course will also equip participants with a knowledge of mathematics education development from a national and international perspective that will serve as a platform to examine the current position of Irish mathematics education. Through their encounters with influential scholarly texts, participants will develop a critical perspective on studies currently impacting on mathematics education and shaping alternatives for the future.

Module 2. Best practices in mathematics education. This module explores new ideas and developments in mathematics education which are of major importance to practitioners working in the field. The theoretical perspectives associated with teaching and learning in mathematics will be investigated in the face of emerging methodologies, societal changes and new technologies. Through situating the module within a practitioner – scholar approach, students will develop competencies in effectively using research and applying knowledge and techniques to solve authentic problems of practice related to mathematics education.

Module 3. Geometry and trigonometry. Synthetic geometry developed from stated axioms and definitions in a formal sequence of theorems now forms the basis of a significant component of the current post-primary mathematics curriculum in Ireland. A theory of this nature did not form part of the preceding post-primary curriculum. Also no other part of that curriculum is explicitly based on a formal axiomatic theory, comprising axioms and theorems in an ordered sequence. Therefore it is desirable that those teaching mathematics at post-primary level should study this very distinctive part of the curriculum in depth.

Module 4. Frontier research and current debates in STEM. The purpose of this module is to ensure that the students on the course gain experience interacting with frontier research being carried out in the university. It also engages the students with the most pressing topics and concerns that STEM education faces nationally and internationally. Thanks to support from a number of Schools within the Faculty of Engineering Maths and Science, current active research in diverse fields will be shared with students who in turn will have to explicate the ideas in order to share them with varied audiences. This course will facilitate students as they examine and shape scientific knowledge as it passes from research data into the public realm. They will also be challenged to argue their opinion on current debates within STEM education.

Dissertation module. The dissertation is designed to enable students to undertake a more in-depth study of some aspect of their professional life than is possible through their modular studies.

4.3 Modes of Teaching, Learning and Assessment

The integration of theory, practice and research is stressed in the content of each of the modules and active teaching and learning strategies will be used in their presentation. There will be a mixture of lectures, problem-solving and practical workshops that incorporate teamwork, collaborative learning and whole class input and discussion. This

will offer learners a flexible approach to learning with a special emphasis on peer teaching. As many of the participants may be practising teachers, the teaching activities are organised outside of normal school hours, such as during the evenings and at weekends

In terms of assessment, each participant will complete written (or equivalent) assignment(s) of between 4,000-5,000 words per strand module, which will be graded as distinction, pass, or fail. The type of assessment may vary according to the requirements of the module, and a variety of methods including projects, case studies, portfolios, reports and essays will be used. The dissertation module entails two components: a 2,000 word dissertation proposal assessed on a pass/fail basis and a 20,000 word dissertation graded on the basis of distinction, pass, or fail. A participant who achieves a distinction in the dissertation and a distinction in two or more modules may be awarded the M.Ed. with Distinction.

5. Discussions and Conclusions

The on-going changes in the structure, content, and core principles of mathematics curricula in Ireland and internationally, the evidence of ineffective teaching, and the lack of continuous professional development all provide a rationale for the NCCA's (2014) recommendation that practising teachers should be facilitated to achieve postgraduate qualifications. Such qualifications would go a long way in the pursuit of effective teaching which is the backbone of any successful education system. As mentioned previously, teaching is a multifaceted occupation and is one that needs to be learned and continually improved (Ball, 2001). Teachers must have a deep and comprehensive understanding of the content they teach. They must understand the main concepts of the subject and how these can be built upon to construct new knowledge. Changes in curricula, such as Project Maths, and the influx of digital technologies into the classroom have impacted both on the subject matter and on possible modes of teaching and learning. Such shifts in perspective on what constitutes mathematical competence require a different style of teaching, in which students' own participation in the learning process is to the fore (Göransson, Hellblom-Thibblin & Axdorph, 2016). Thus the provision of high quality CPD is essential so that teachers are supported in keeping abreast of the on-going changes to their profession. The situation whereby Irish teachers spend a mere 2.5 days a year on their development (Finucane, 2014) is no longer sutainable. Ireland must follow the lead of countries such as the Netherlands, Japan and China where developing professional knowledge and skills is part of a teachers work (Ball, 2001). However teachers must be facilitated in this effort and professional devolvement opportunities must be made available to them. The newly designed strand of the M.Ed. in Mathematics Education described in this paper is one such opportunity.

The authors believe that a course like the M.Ed. in Mathematics Education is vitally important to improving the teaching and learning of mathematics in Ireland and further afield. The four modules are designed to specifically address the main issues in teacher education and development, both nationally and internationally. They provide the opportunity for mathematics educators at all levels to address their mathematical content knowledge along with exploring mathematical practices for teachers and highlighting current national and international issues in mathematics education. The integration of theory and practice gives practitioners a comprehensive and contemporary understanding of mathematics education through a research-based programme. The course is currently open for applications and seeks to not only attract Irish mathematics educators but also to reach out to the international mathematics education community. Further research is planned to provide evidence to support the benefit of a course of this nature and it is hoped that this evidence will help to convince mathematics educators worldwide, of its value. While there are many challenges ahead for mathematics education and researchers working in this field, innovative new courses like the Mathematics Education strand of the M.Ed. can help ensure that we are prepared to face such challenges.

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