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Research paper

An examination of the professional development needs of out-of-field mathematics teachers

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HIGHLIGHTS

- Profiling out-of-field mathematics teachers in the Irish context (n = 202).
- Evidence of inadequate subject content knowledge and knowledge of the mathematics curriculum.
- Teachers described themselves as *somewhat/very confident* in teaching all mathematics content.
- Importance placed on designing appropriate professional development programs.

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ABSTRACT

This paper presents an empirical study examining the professional development needs of out-of-field mathematics teachers in the Irish context (n = 202). An online questionnaire gathered data on cohort demographics and confidence with regard to teaching mathematics. A paper-and-pencil test evaluated teachers' cognitive and conceptual proficiency with curriculum-aligned mathematical content. Low achievement levels and high occurrence of conceptual errors indicate inadequate subject content knowledge and difficulties with the content of the curriculum. Additionally, these teachers described themselves as either *somewhat* or *very confident* in teaching all content. The discrepancies which exist between confidence levels and content proficiency highlight the importance of designing appropriate professional development programs that are situated and practice based.

1. Introduction

Out-of-field mathematics teaching is a significant concern shared by researchers throughout the world (Akiba, LeTendre, & Scribner, 2007). Defined as "teachers assigned by school administrators to teach subjects which do not match their training or education" (Ingersoll, 2002, p. 5), out-of-field mathematics teachers generally possess a teaching qualification but have limited advanced studies of mathematical content and little or no specific training in mathematics education. Numerous studies have been undertaken in various contexts, for example, the USA (Ingersoll, 2003), Australia (McConney & Price, 2009), UK (Crisan & Rodd, 2011) and South Korea (Ee-gyeong, 2011), in relation to the rate of out-of-field mathematics teachers. Other studies have been undertaken in relation to the impact of teacher qualification/certification and effectiveness on student achievement in mathematics (e.g., Darling-Hammond, 2000; Sanders & Rivers, 1996; Wenglinsky, 2000). New research emerging in the out-of-field domain relates to examining teacher identity (e.g., Hobbs, 2012) and their lived experiences (e.g., Du Plessis, Gillies, & Carroll, 2015) in order to understand the complexities surrounding out-of-field teaching (Hobbs, 2013). Similarly, extensive literature exists regarding professional development needs and professional development programmes for in-field mathematics teachers. However, there is growing recognition for the need to develop specific professional development programs for out-of-field teachers which are grounded in research and meeting their specific needs (Du Plessis, Gillies, & Carroll, 2014).

In the Irish context, a part-time, two-year national Professional

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Diploma in Mathematics for Teaching (PDMT) has been established in order to up-skill out-of-field mathematics teachers. This presents a rich opportunity for an examination of the needs of out-of-field teachers and the measures which can be taken to address this urgent and worldwide concern. The research presented in this paper is specifically focused on examining the professional development needs of teachers *commencing* the PDMT. This is conducted from a mathematical knowledge perspective and evaluated in terms of potential impact on the development of professional learning programs given their experiences and confidences in relation to teaching mathematics. Studies on the role of mathematical knowledge in teaching have generally been focused on in-field and pre-service mathematics teacher education (Delaney, 2012). Key research has demonstrated the critical role of a teacher's knowledge base in facilitating teaching and learning in mathematics (Ball, Thames, & Phelps, 2008; Fennema & Franke, 1992; Shulman, 1986). For example, Lampert (2001) exemplified how mathematical knowledge can enhance teaching through lesson preparation, whole-class discussion, facilitating pupils working independently and establishing a classroom culture. Other examples include Hill et al.'s (2008) research which demonstrated the impact of high mathematical knowledge on creating learning opportunities in the classroom and excellent teaching skills such as making connections between representations and utilising mathematically precise and comprehensible definitions.

To perceive that such skills can be obtained without formal preparation undermines and underestimates the complexity of the mathematics teaching profession. To teach mathematics without a formal qualification is challenging and may have a negative effect both on students' mathematical learning, and on the teachers themselves. Research exploring the issue in relation to out-of-field mathematics teachers is new and developing. Providing suitable professional development opportunities for these teachers is of upmost importance (Du Plessis et al., 2014). Although this study was conducted in the Irish context, the curricular content for which teachers' proficiency is considered is closely aligned with that of other countries and the mathematical framework for international assessments such as the Programme for International Student Assessment (PISA). Thus, it is well positioned to inform other international contexts and contribute to a growing international conversation about out-of-field mathematics teaching, mathematical knowledge and professional development.

2. Background to the study

The Irish post-primary (approx. age 12–17/18) education system operates on a centralised education model and contains very prescriptive syllabi, with a state examination after year three and a terminal state examination upon completion of post-primary education. These are the Junior Certificate (JC) (Years 1–3) and Leaving Certificate (LC) Examinations (Years 5 and 6),[1] respectively. Irish post-primary students' underperformance in mathematics has been well documented, with alarms raised in relation to the number of students failing mathematics and/or not pursuing mathematics at a higher level (NCCA, 2005; OCED, 2014). The introduction of a new mathematics curriculum in 2010 aimed to address issues relating to students' understanding of mathematical concepts, their ability to apply and problem solve, and to move away from over reliance on rote learning procedures (Project Maths, 2010). Concurrently, developments within teacher education in Ireland have also taken place. The Teaching Council's (2011) Criteria and Guidelines for Programmes of Initial Teacher Education and Curricular Subject Requirements (Post-primary) outline more demanding prerequisites for qualification and registration to teach mathematics at post-primary level in Ireland. Among other requirements, these include an increase in the amount of required third-level mathematical studies (60 credits) and the study of specific topics (e.g., Statistics and Probability).

However, although such stipulations exist, it is at the discretion of the school principal how teachers are deployed within their schools; their only restriction being that employed teachers must be registered with the Teaching Council. The percentage of out-of-field mathematics teachers in Ireland is particularly alarming; research has found that 48% of post-primary teachers who are teaching mathematics are not specifically qualified to do so, and therefore are considered out-of-field teachers of mathematics (Ní Ríordáin & Hannigan, 2011). Whereas qualified mathematics teachers were primarily assigned to higher level classes, and particularly the state examination years, younger and less academically able students were more generally taught mathematics by out-of-field teachers. It is important to re-emphasise that out-of-field mathematics teaching in post-primary education is a global issue, not just one affecting Ireland (Akiba et al., 2007).

To improve the quality of mathematics teaching and to support practicing teachers, continuous professional development (CPD) opportunities were considered an immediate priority by the Government. Accordingly the Professional Diploma in Mathematics for Teaching (PDMT) was developed as a blended-learning, national programme designed to develop out-of-field teachers' content and pedagogical knowledge through 60 credits of mathematics and 15 credits of mathematics pedagogy related material. Applicants to the PDMT must meet the following criteria in order to be considered for a place on it, teachers must be:

- currently teaching mathematics in a post-primary school in Ireland;
- a qualified, post-primary teacher in a discipline other than mathematics; and
- registered with the Teaching Council.

In terms of academic eligibility, there is no specific mathematics requirement for the programme. However, there is an expectation that the teachers applying have mathematics to a standard which is beyond second level, that is, an expectation that they have studied some undergraduate mathematics.

3. Mathematical knowledge and research focus

It is well established that a teacher's knowledge base plays a critical role in determining what is done in classrooms, and accordingly, how and what students learn (Ball et al., 2008; Fennema & Franke, 1992; Shulman, 1986). Shulman's (1986) research provided the foundation for further examination of the knowledge required for teaching. He suggested three key domains in which teachers need to be competent, namely subject matter content knowledge, pedagogical content knowledge and curricular knowledge. A key focus of this research project is on out-of-field teachers' subject matter and curricular knowledge as participants in the PDMT are qualified teachers but lack specific studies in mathematics. Krauss, Baumert, and Blum (2008) utilise Shulman's categories of knowledge for teaching and conceptualise subject matter knowledge as "deep understanding of the contents of the secondary school mathematics curriculum" (p.876).

Central to the work of Ball et al. (2008), and building on Shulman's (1986) research, is the concept of mathematical knowledge for teaching (MKT), a particular knowledge required by

[1] Year 4 is an optional year known as Transition Year (TY). Some schools offer this year, others do not and it is not compulsory for students to complete TY.