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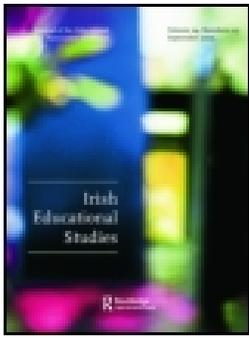
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Professional development for out-of-field post-primary teachers of mathematics: an analysis of the impact of mathematics specific pedagogy training

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Research shows that teachers influence students' attitudes towards; performance in; and perceptions of a subject. Hence, the need to improve the teaching and learning of many curricular subjects has been well documented for many years. This paper focusses on efforts made to develop competence among out-of-field teachers of mathematics and evaluates the impact of one component of a continuous professional development (CPD) programme on teachers' self-efficacy and self-reported teaching styles. As part of this CPD programme, teachers engaged in a series of subject-specific pedagogy workshops and while classroom observations were not feasible they did complete pre- and post-workshop questionnaires to determine the impact that these workshops had on their mathematics teaching efficacy and their reported approach to teaching, both of which researchers consider to be key to effective teaching. Analysis of the quantitative data showed that the workshops led to statistically significant improvements in mathematics teaching efficacy among participants, while analysis of the qualitative data highlighted a shift from procedural or teacher-led approaches to more student-centred approaches that focussed on developing understanding. As such the programme was deemed to have a positive effect on the effectiveness of these teachers.

Keywords: Out-of-field teaching; mathematics teaching efficacy; continuous professional development; teaching styles; teacher effectiveness

1. Introduction

Teachers have been shown to affect students' attitudes towards mathematics (Grouws and Cramer 1989; Mata, Monteiro, and Peixoto 2012); their perceptions and expectations of the subject (Osborne et al. 1997) and their overall achievement in the subject (An, Kulm, and Wu 2004). Such research suggests that teachers influence students' cognitive and affective development in the subject and students' entire mathematical experience could be improved if they were taught by effective teachers. According to Hemmi and Ryve (2015) and Wilson, Cooney, and Stinson (2005) in recent years effective mathematics teaching has come to mean a shift from teacher-centred teaching to teachers placing a much stronger emphasis on teaching for understanding and placing the student at the heart of the learning. Ní Riordáin and

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Hannigan (2009, 4) ascertain that teacher quality and effectiveness is '... one of the most important factors affecting student learning'. Stigler and Hiebert (2004) elaborate on this when they state that if we wish to enhance student engagement and attainment it is critical that we first look to improve the standard of teaching. Hence, the challenge internationally is to improve the quality and effectiveness of our teachers (Anthony and Walshaw 2009; National Council for Curriculum and Assessment 2005; Stigler and Hiebert 2004). However, effective teaching is multi-dimensional and depends on a number of different facets. As such, prior to looking to improve teaching it is important to understand what constitutes effective teaching and how effective teaching can be realised across a variety of different contexts. This paper seeks to first unpack what is meant by the term *effective teaching* and then evaluate an aspect of a professional development programme that sought to achieve this goal of improving standards among teachers of mathematics in an Irish context. This professional development programme, known locally as the Professional Diploma in Mathematics for Teaching [PDMT], has been in place since 2012 but to date, there has been very little formal evaluation of the programme. This is despite Blömeke and Delaney's (2012) exhortation that work needs to be undertaken to develop a better understanding of the opportunities for learning and development that can be accomplished through teacher education. Similarly, Ní Ríordáin, Paolucci, and Lyons (2019) call for more work to be done in relation to the evaluation of professional development programmes and so this paper is addressing this gap in the literature by determining the impact, if any, that aspects of the PDMT had on teacher effectiveness and levels of self-efficacy.

2. Relevant literature

Researchers have proposed a number of different characteristics that underpin effective teaching however, most researchers concur that teacher knowledge is one of the defining features. Ball, Thames and Phelps (2008) suggest that to be an effective teacher one needs high levels of subject matter knowledge and pedagogical content knowledge. They referred to the combination of these two knowledge types as mathematical knowledge for teaching (MKT) and determine that this type of knowledge has a strong bearing on teacher effectiveness. Furthermore, according to Ball and Bass (2000), high levels of MKT enable a teacher to present mathematics as a coherent and connected body of knowledge while Anthony and Walshaw (2009) outline how this knowledge domain is necessary when making key decisions regarding classroom practice and teaching approaches. This idea was further developed by Ní Ríordáin, Paolucci, and Lyons (2019, 129) and they conclude that '... teachers' knowledge base plays a critical role in determining what is done in classrooms, and accordingly, how and what students learn.' Similarly, in the UK, Reynolds and Muijs (1999) found teacher knowledge plays a crucial role in effective teaching practices while in the U.S., Baumert et al. (2010) found a correlation to exist between MKT, classroom pedagogy and student achievement.

In addition to high levels of MKT, the quality of instructional design is another critical dimension of teacher effectiveness. Characteristics of effective instruction design, and in turn effective teaching, include:

- engaging students in the learning process (Noddings 1995);

- challenging students and allowing them to struggle with tasks that are neither repetitive nor routine (Anthony and Walshaw 2009);
- incorporating authentic, real world problems into a mathematics lesson (Grouws and Cramer 1989);
- establishing connections between different curricular topics (Anghileri 2006);
- making effective use of manipulatives in the classroom (O'Meara, Johnson, and Leavy 2019).

Each of the characteristics described above contribute to teacher effectiveness and research has found that characteristics of effective teaching are dependent on teachers' level of self-efficacy (Bates, Latham, and Kim 2011; Enochs, 2000; Klassen and Tze 2014). Such findings indicate that self-efficacy is also important for effective teaching. Bandura (1986, 391) defined self-efficacy as:

people's judgements of their capabilities to organize and execute courses of action required to attain designated types of performance. It is concerned not with the skills one has but with the judgement of what one can do with whatever skill one possesses.

Enochs, Smith, and Huinker (2000) elaborated on this idea when they defined mathematics teaching efficacy as mathematics teachers' belief in their ability to teach mathematics effectively. Many studies indicate that there is a direct correlation between teacher self-efficacy and many aspects of teacher effectiveness (Armor et al. 1976; Brookover et al. 1978) while Bates, Latham, and Kim (2011) specifically discuss a relationship between teachers self-efficacy and levels of teacher knowledge. Enochs, Smith, and Huinker (2000) determine that effective mathematics teaching hinges on mathematics teaching efficacy. In addition to this, Czerniak (1990) concludes that teachers with low levels of self-efficacy are inclined to use less effective, teacher-led teaching strategies such as reading directly from a textbook, while Enochs, Smith, and Huinker (2000) claim that the use of inquiry and student-centered approaches are favoured by highly efficacious teachers. Hence, as well as developing the characteristics of effective teaching, it is necessary to look to develop teachers' self-efficacy if we want to improve the standard of mathematics teaching and learning.

Due to the importance of effective teaching, many researchers and teacher educators are keen to develop the characteristics associated with effective teaching among *all* teachers of mathematics. Ní Riordáin and Hannigan (2009) state that to be an effective mathematics teacher, it is necessary to engage in formal training. It is unfair to expect teachers to transfer their knowledge in one particular subject area to the mathematics classroom without such training (Ní Riordáin and Hannigan 2009). While this formal training is available to many in-field mathematics teachers, as part of their pre-service teacher training, this is not the case for out-of-field teachers.

When a teacher engages in teaching a specialisation or year group for which they have no formal qualifications it is known as out-of-field teaching (Weldon 2016). This phenomenon is currently being examined and reported upon to varying degrees in countries worldwide, including Ireland (Ní Riordáin and Hannigan 2009), Australia (McConney and Price 2009), Germany (Bosse and Törner 2013) and South Africa (Steyn and Du Plessis 2007). The system which a country uses to determine if a teacher is 'qualified' varies greatly across countries. In Australia for example, a

qualified teacher can teach any subject regardless of their subject specialisations, in contrast to Germany in which primary teachers are often trained as subject specialists (Hobbs and Törner 2019). In Ireland, the situation is less straight forward. A post-primary teacher is officially qualified in a subject specialisation(s) once they have completed a programme of post-primary initial teacher education and have been awarded the requisite number of credits in the subject area(s). However, the deployment of teachers is a local issue and is influenced by local factors, such as staffing shortages or timetabling issues, which often lead to out-of-field assignments.

Price et al. (2019) report that in Australia out of field teaching is prevalent across many different curricular subjects including geography, physics and mathematics whilst they also report that 34% of all German teachers are considered out of field. Zakaria (2014) reported that in Indonesia 54% of religion teachers are considered out of field while in Ireland this practice was found to be prevalent among teachers of mathematics, with Ní Riordáin and Hannigan (2009) reporting that 48% of mathematics teachers in Ireland were out-of-field. They reported that a variety of different subject teachers, including history, geography and language teachers, were often assigned, by school principals, to teach mathematics. As such, these teachers have not had the opportunity to engage with any formal training in the area of mathematics as recommended by Ball (2001) and Ní Riordáin and Hannigan (2009) and so strategies were needed to provide these teachers with the opportunity to upskill via continuous professional development (CPD) initiatives. Such CPD has been found to empower teachers as it helps them to develop the confidence, knowledge and skills required to teach effectively (Lessing and De Witt 2007).

3. Context: the professional diploma in mathematics for teaching

Stigler and Hiebert (2004) indicate that very little change has occurred in classroom practice in the last century. They believe that is due, in part to the current focus of reform efforts on recruiting more highly qualified teachers as opposed to focussing on ‘... the improvement of teaching – the methods that teachers use in the classroom’ (Stigler and Hiebert 2004, 16). Furthermore, the phenomenon of out-of-field mathematics teaching was identified as a significant contributory factor in the underperforming school mathematics sector internationally (Hoffmann and Richter 2015) and in Ireland (Ní Riordáin and Hannigan 2009) at the beginning of the twenty-first Century, and a potential obstacle to maximising outcomes from then current reforms in post-primary school mathematics.¹ In order to address the issue of out-of-field teaching in Ireland, and to provide the large number of out-of-field mathematics teachers with the required, relevant formal training for mathematics teaching, a non-traditional system of CPD for existing out-of-field mathematics teachers was required. Due to the impact of out-of-field teaching on teacher effectiveness and student performance, as discussed previously, the Irish Government issued a tender for the development of a CPD programme that would upskill out-of-field mathematics teachers in Ireland. The winning bid was developed by the National Centre for Excellence in Mathematics and Science Teaching and Learning (NCE-MSTL), now EPISTEM, at the University of X, and the relevant departments in the University of Y. The bid was submitted by the University X/Y-led consortium of 13 Irish Higher Education Institutions (HEIs), who developed what is now known as the Professional Diploma in Mathematics for Teaching (PDMT). To date, five cohorts of

students, which equates to approximately one thousand out-of-field teachers, have graduated from the programme, with a sixth and final cohort currently in their final year of study.

The PDMT is a part-time programme, which is delivered through a blended learning format over a two-year period. It admitted its first cohort of teachers in September 2012. The Department of Education and Skills (DES) continues to fund the diploma (contract end date is September 2020) as part of the national strategy to support the implementation of the new mathematics curriculum and improve standards in mathematics education in post-primary schools by upskilling out-of-field teachers of mathematics. As a result of this funding, the course is free of charge to all eligible out-of-field teachers of mathematics. Upon graduating from the PDMT, all graduates are recognised as qualified mathematics teachers. It is a Level 8 programme² and offers a total of 75 ECTS³ credits. 60 ECTS credits are awarded for mathematics content modules (5 modules per year worth 6 credits each) while the remaining 15 ECTS credits are awarded for mathematics pedagogy modules (2 modules, one worth 9 credits and the second worth 6 credits). In this way, the PDMT seeks to simultaneously develop teachers' subject matter knowledge and pedagogical content knowledge, so as to equip them with the MKT deemed necessary by Ball et al. (2008), Krauss et al. (2008) and Baumert et al. (2010)

The PDMT is closely aligned with the needs of out-of-field teachers of mathematics, the new mathematics curriculum in Ireland, and the requirements of the Irish Teaching Council for mathematics teaching, and is considered a significant element in the reform of the national mathematics curriculum for post-primary education. The programme was designed by a team of mathematics educators in the University of X. From the outset, and continuing for the duration of the programme, there was engagement by the design team with research on teacher knowledge domains, including Subject Matter Knowledge, Pedagogical Content Knowledge and Mathematics Knowledge for Teaching, in the implementation of the programme (Ball et al. 2008; Heid, Wilson, and Blume 2015; Rowland, Huckstep, and Thwaites 2005; Shulman 1986). Furthermore, the programme is research-based and research-led and seeks to implement best practices in teaching and learning mathematics/mathematics education, mathematics pedagogy, content delivery, assessment and support. It adheres to many of the principles underpinning successful CPD initiatives, as proposed by researchers such as Collinson (2000); Coetzer (2001); and Day and Sachs (2004).

Participants on the PDMT are required to complete the pedagogy elements of the programme concurrently with the mathematics content modules. To achieve this goal they must attend five, 3-hour workshops over the course of the two-year programme. Each of the five pedagogy workshops delivered as part of the PDMT align with a content strand from the post-primary school curriculum. The workshops are run concurrently with a related mathematics content module, as shown in [Table 1](#), and this strategy is used in order to facilitate the development of MKT among these teachers.

These workshops help participants develop the best mathematical pedagogical practices for post-primary mathematics teaching, with a particular focus on the mathematics curriculum in Irish post-primary schools and the characteristics of effective mathematics teaching discussed previously. The intention of the mathematics specific pedagogy workshops is to expose teachers to effective means of teaching and provide them with the skillset necessary to facilitate meaningful learning in their mathematics

Table 1. Details of pedagogy workshops for the PDMT.

	Focus	Associated content module	Timing
Workshop 1	Functions & Calculus	Calculus 1 & 2	January Year 1
Workshop 2	Algebra & Number	Algebra 1 & 2	March Year 1
Workshop 3	Probability	Probability	May Year 1
Workshop 4	Statistics	Statistics	October Year 2
Workshop 5	Geometry & Trigonometry	Geometry	November Year 2

classroom. The workshops are designed so that teachers are actively involved in the learning process in an effort to replicate what students would experience in their mathematics classroom. In addition to the workshops being interactive, engaging and relevant to teachers, they are also designed to allow time for reflection and application. The workshops are grounded in theory and focus on the knowledge and skills required for effective mathematics teaching. Hence, they incorporate activities/problems which allow for critical discussion and development of the teaching methodologies and concepts outlined in [Table 2](#).

Table 2. Sample teaching methodologies incorporated into the pedagogy workshops.

Methodology	Example	Workshop
Active learning methodologies	Conducting experiments to develop conceptual understanding around the concept of theoretical probability	Probability
Promoting interest through active learning	Using code breaking activities to assess students understanding of algebraic substitution	Algebra & Number
Mathematical modelling and applications	Identifying the ideal position to erect a telephone mast so that it is equidistant from three different roads	Geometry & Trigonometry
Real world approaches to teaching mathematics	Investigating claims made by a local sports organisation (GAA) in relation to supporters' level of satisfaction with new technology (Hawkeye) used in games	Statistics
Mathematical thinking	Investigating the rationale behind certain formulae and procedures e.g. determining why a functions turning points occur when the first derivative is zero	Functions & Calculus
ICT as a tool in the mathematics lesson	Using an interactive activity to help teachers construct the sine graph from the unit circle and develop an understanding of the shape and features of the graph	Geometry & Trigonometry
Assessing mathematics learning	Investigating alternative forms of summative assessment such as jigsaw puzzles whereby one must match 5/6 jigsaw puzzles that all contain information about a particular function	Functions & Calculus

While the PDMT as a whole adopts a blended learning approach, the pedagogy modules are all delivered face-to-face so as to allow participants to engage in a hands-on, active learning environment that one would then envisage being replicated in their own classrooms.

4. Research questions

Based on the literature review conducted and the aim of the authors to evaluate the pedagogical dimension of the PDMT, the following research questions were generated for the purpose of this paper:

- (1) Does engaging with mathematics specific pedagogy improve levels of mathematics teaching self-efficacy among out-of-field mathematics teachers?
- (2) What impact, if any, does mathematics specific pedagogy have on the self-reported teaching practices of out-of-field teachers?

5. Methodology

5.1. Sample

At present, the PDMT is in its seventh and final year. By 2018, a total of 825 teachers (4 cohorts) graduated from the PDMT with a further 152 teachers completing the programme as part of Cohort 5. These Cohort 5 teachers acted as the sample for this study and they completed the series of pedagogy workshops in November 2017. In order to compare responses, each teacher created a unique identifier, and this was used on both a pre- and a post-workshop questionnaire so that all responses remained anonymous. A total of 207 teachers completed the pre-workshop questionnaire but only 152 of these teachers completed the programme in the two-year time-frame.⁴ Of these 152 teachers, 111 completed the post-workshop questionnaire. In total, 91 teachers completed both the pre- and post-workshop questionnaire, a response rate of 59.8% of all teachers that graduated from Cohort 5. All quantitative comparative analysis is based on the data received from these 91 teachers. Qualitative data was collected via open-ended questions on the questionnaires and the data reported in this paper is based on data from all completed questionnaires. Hence, a larger number of responses were considered when analysing the qualitative data as was the case for the quantitative data, as teachers were not eliminated from the qualitative analysis if they had not completed both the pre- and post-workshop questionnaire.

5.2. Research instrument

While classroom observations may have been the optimal way to address the aforementioned research questions, such observations were not feasible and instead two similar questionnaires were designed and distributed to Cohort 5 teachers (i.e. teachers who commenced the PDMT in 2017) prior to the first pedagogy workshop in the series and again on completion of the fifth and final workshop in the series. The questionnaires were developed by the authors upon review of existing literature

and were based on the framework for evaluation of CPD initiatives proposed by Guskey (2000). This framework is detailed in [Figure 1](#).

This study is part of a much larger research agenda that is cognisant of all levels of Guskey's framework but for the purpose of this paper, the authors will report on the evaluation of one aspect of the programme (the pedagogy workshops) across three levels of the framework, namely Level 1; Level 2 and Level 4.

After the authors drafted the pre- and post-workshop questionnaires, mathematics education specialists in several HEIs in Ireland reviewed them and the feedback was incorporated into the final version of the research instrument. This version of the questionnaires was then piloted with Cohort 4 students and based on the feedback received from these teachers further changes were made to the questionnaire before it was administered to the sample.

The questionnaire distributed prior to the first workshop consisted of five questions. The first three questions garnered information in relation to teachers' prior experience with mathematics specific pedagogy or pedagogy in any other discipline, prior to the PDMT, as well as their beliefs on the need to engage with mathematics specific pedagogy. The fourth question, which is central to this study, investigated how teachers, at that exact point in time, would describe the teaching style/approach they favoured when teaching mathematics.⁵ The fifth and final question, which the authors also analyse in this study investigated teachers' self-efficacy when teaching each of the five strands that are central to the Irish post-primary school mathematics curriculum, namely Statistics and Probability; Geometry and Trigonometry; Number; Algebra and Functions. Teachers were asked to rate their confidence in

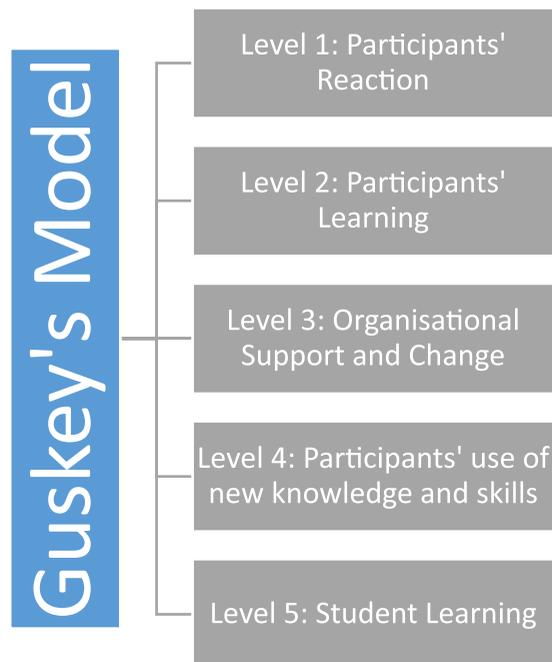


Figure 1: Conceptual Framework Underpinning the Study (see Heid, Wilson, and Blume 2015).

each of the five strands using a three-point scale (Not at all confident; Somewhat confident; Extremely confident). The post-workshop questionnaire consisted of four questions which mirrored four of the questions in the pre-workshop questionnaire, so as to allow for comparison of responses. In the post-workshop questionnaire teachers were first asked if, having completed the pedagogy workshops as part of the PDMT programme, they now felt it necessary for mathematics teachers to engage with subject specific pedagogy. The second question gathered information in relation to the teaching approaches they report now employing having completed the workshops, to enable the authors to determine if the pedagogy workshops had resulted in a change in reported teaching styles. The third question re-examined teachers' self-efficacy across each of the five aforementioned strands while the fourth question required teachers to 'summarise the impact, if any, that the pedagogy workshops had on (a) you [them] as a mathematics teacher; (b) you [their] mathematics teaching. For the purpose of this paper, the authors will focus on the questions relating to teaching styles; self-efficacy (Level 1 of theoretical framework) and the impact that the workshops had on the participants (Level 2 and 4 of theoretical framework).

5.3. Data analysis

Upon receipt of the completed questionnaires, the quantitative data was recorded in SPSS and initially analysed using descriptive statistics. The authors then engaged in further statistical analysis in order to compare the pre- and post-workshop responses and the Wilcoxon Signed Rank Test was used to determine any changes in teachers' reported self-efficacy. This test was deemed suitable as the sample size was relatively small; the data was not normally distributed and there were two different time points when the responses from the same group of teachers were collected.

Qualitative data reported in this paper was collected via the open-ended questions that required teachers to self-report on the teaching style they favoured before and after they participated in the PDMT. For those that only completed the pre-workshop questionnaire their responses to questions about their style of teaching prior to commencing the workshop were the only responses analysed so as to enable the authors to get a comprehensive picture of the self-reported teaching styles of teachers prior to embarking on the PDMT while all responses submitted by teachers to this question in the post-workshop questionnaire were also analysed. The qualitative data, gathered via the aforementioned open-ended questions, was transcribed into the computer package NVivo and coded. In this analysis open coding was employed meaning that the researchers did not have pre-determined set of codes but rather independently identified codes and then used thematic analysis. Initially both authors independently read and re-read the responses in order to familiarise themselves with the data before each generated a set of codes. The authors then compared codes and any differences ($n = 2$) in coding were discussed and resolved before the finalised codes were grouped into particular themes. These themes aligned with the research questions the authors sought to address and will be discussed in the next section.

6. Results

The first research question sought to determine the effect, if any, that mathematics specific pedagogy had on out-of-field teachers' levels of self-efficacy across the five

different strands that constitute the Irish post-primary mathematics curriculum. In order to address this research question, the teachers were asked to rate, on a three-point scale, their level of mathematics teaching efficacy across each of the strands. The results are presented in [Figure 2](#) (pre-workshop responses) and [Figure 3](#) (post-workshop responses).

[Figures 2 and 3](#) clearly show that a higher proportion of teachers reported higher levels of mathematics teaching efficacy across 4 of the 5 strands after they engaged in the pedagogy workshops, than was the case beforehand, with minuscule change being recorded in the Geometry and Trigonometry strand. The most notable difference was recorded in the Statistics and Probability strand. Prior to the workshops commencing, 11.0% of the 91 respondents reported that they were extremely confident teaching this content (i.e. high levels of mathematics teaching efficacy) compared to 34.1% of the 91 respondents who reported being of a similar disposition on completion of the workshops. In addition to this, [Figures 2 and 3](#) show that a much smaller percentage of teachers also reported feeling not at all confident in teaching each of the five strands (i.e. low levels of mathematics teaching efficacy) in the post-workshop responses when compared with the pre-workshop responses, with the biggest decrease (from 22.0% to 4.4% of respondents) evident in the Statistics and Probability strand. In order to determine if the differences noted were statistically significant, the authors conducted a Wilcoxon Signed Rank test for each of the five strands. The test revealed a statistically significant improvement in teachers' mathematics teaching efficacy in the strand of Statistics and Probability ($z = -5.171, p < 0.001$) with a medium effect size, using the Cohen (1988) criteria ($r = 0.38$). Unsurprisingly, this was the largest effect size across all five strands. When the Wilcoxon Signed Rank test was conducted for three of the remaining four strands a similar picture emerged, in that the differences were statistically significant, however the effect sizes were not as great as that recorded for Statistics and Probability, as demonstrated in [Table 3](#). In the Geometry and Trigonometry strand the differences noted were not found to be statistically significant ($z = -0.452, p > 0.05$).

These improved levels of mathematics teaching efficacy were also reported by teachers in the open-ended questions in the post-workshop questionnaire. When asked

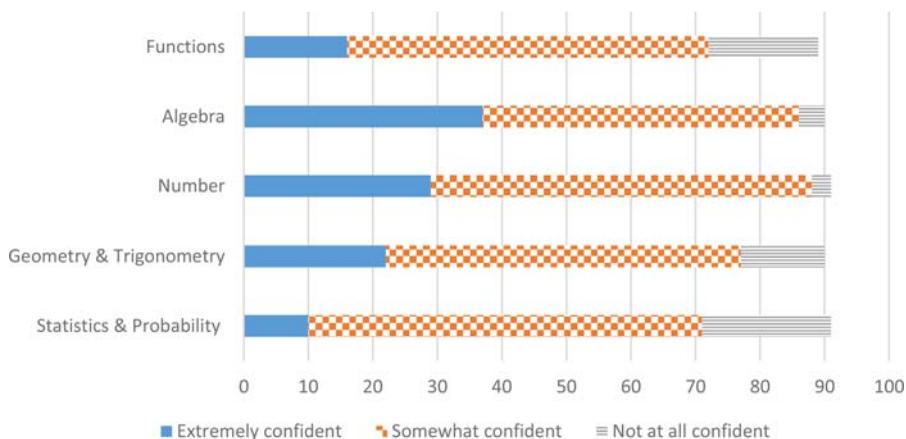


Figure 2. Pre-workshop levels of mathematics teaching efficacy.

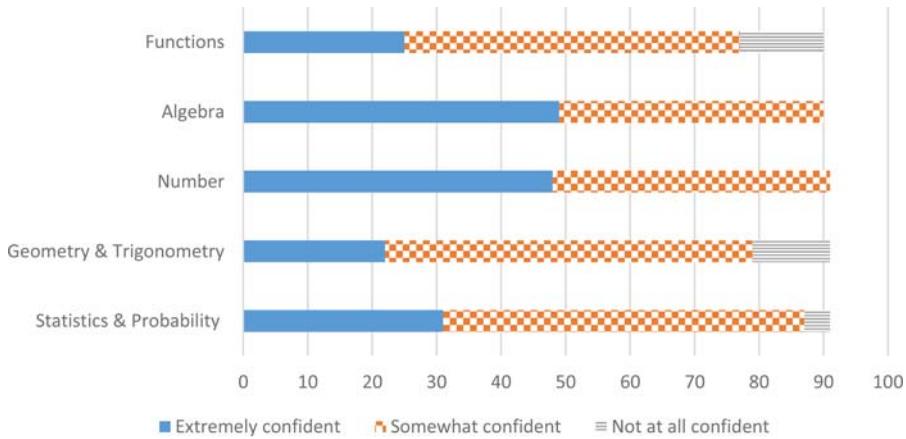


Figure 3. Post-workshop levels of mathematics teaching efficacy.

to outline the impact that they believed the pedagogy workshops had on them as a teacher of mathematics, 47 teachers offered a response. The majority of these respondents stated that the main impact that the workshops had on them was in relation to improved levels of confidence.

T24⁶: Given me more confidence and a better insight into mathematics.

T66: Given me so much more confidence in my teaching ability and my understanding.

T121: As a result of the workshops I am now more confident with teaching and better at maths.

Improved levels of mathematics teaching efficacy were by far the most common theme identified when the qualitative responses to this question were analysed. The second most popular response to this question was that the workshops helped improve their ability as a mathematics teacher.

T102: I am now able to explain background to topics more effectively.

T119: Improved my teaching ability.

Table 3. Wilcoxon signed rank test results for strands of number; algebra and functions.

Strand	<i>z</i> -value	<i>p</i> -value	Effect Size
Statistics & Probability	-5.171	<.001	0.38
Number	-3.317	<.05	0.25
Algebra	-2.412	<.05	0.18
Functions	-2.075	<.05	0.15
Geometry & Trigonometry	-0.452	>.05	N/A

These responses again indicate that teachers now have more belief in their ability to teach effectively, thus it can be concluded that those who were in this category also had improved levels of mathematics teaching efficacy, without stating it in those exact terms. This supports the quantitative findings and suggests that the workshops truly did help to improve teachers' mathematics teaching efficacy.

The second research question central to this study involved determining what changes to teaching practices were reported by teachers, if any, occurred as a result of participation in mathematics specific pedagogy workshops. To address this, both the pre- and post-workshop questionnaire contained an open-ended question where teachers were asked to self-report on their favoured approach to teaching mathematics at that exact point in time. In the pre-questionnaire, only 35 teachers offered a response to this question, suggesting that prior to the workshops many teachers were unable or unwilling to articulate their favoured teaching style/approach. Of those who did offer a response, the two most favoured approaches reported were rote learning/a procedural approach to teaching (28.6% of respondents) and encouraging active learning (22.8% of respondents). Some sample responses from each of these themes were:

T10: Chapter completion followed by exam questions.

T39: Traditional methods – 'talk and chalk'.

T19: Activity based and student-led learning.

In addition to this, only one of the respondents (2.9%) in the pre-workshop questionnaire made any reference to teaching for understanding. However, a somewhat different scenario emerged when the post-workshop questionnaires were analysed. In the post-workshop questionnaires 92 teachers offered a response, a significant increase from the numbers who were able and willing to describe their favoured approaches in the pre-workshop questionnaire. When an iterative approach to qualitative analysis was employed, the predominant teaching approaches described by teachers in the post-workshop responses were active learning methodologies (51.1% of respondents); teaching through the use of real-life applications (17.4% of respondents) and teaching for understanding (14.1% of respondents). Some sample responses from each of these themes were:

T82: Introducing more active learning activities, group work.

T14: Try to link everything now to real life examples.

T26: Use more meaningful and useful examples.

T28: Allow students to develop understanding as to why things/formulas work.

When the pre- and post-workshop responses of the 91 teachers who completed both questionnaires were analysed this difference in self-reported teaching styles became even more apparent. There was a stark difference noted between the reported practices certain teachers incorporated in their mathematics lessons prior to the PDMT and those that they reported incorporating on completion of the PDMT.

Both the responses below are indicative of the type of change reported by a large number of teachers in this study.

T54 [Pre]: assign questions

T54 [Post]: Problem solving and active learning. Lots of practical work particularly with ordinary level and weak classes.

T113 [Pre]: Explanation and revisions

T113 [Post]: More activity based and allowing the students to explore maths more.

A comparison of the emergent themes/strategies between the pre- and post-workshop responses indicates that the mathematics specific pedagogy may have helped/encouraged teachers to shift their emphasis from a procedural and teacher-led approach to mathematics teaching to a more student-centred approach that places an emphasis on meaningful understanding.

7. Discussion

According to Ní Ríordáin, Paolucci, and Lyons (2019, 133) ‘... out of field teachers lack of PCK impacts on affective aspects such as confidence and anxiousness relating to effective teaching’. This finding was also supported by Hobbs (2013). Therefore, in order to promote effective teaching in schools internationally, efforts need to be made to improve MKT and levels of self-efficacy among all teachers of mathematics (Enochs, Smith, and Huinker 2000), regardless of whether they are considered in-field or out-of-field. The PDMT was designed so that out-of-field teachers of mathematics developed their SMK and PCK simultaneously. Due to the correlation between teacher knowledge and teacher self-efficacy (Bates, Latham, and Kim 2011), two constructs that underpin effective teaching, it was anticipated that this approach to professional development would lead to improvements in not only teacher knowledge but also self-efficacy. It was the latter which this study sought to investigate.

This study showed that formal training in the area of mathematics pedagogy for out-of-field teachers can have a significant impact on their levels of mathematics teaching efficacy. In four of the five post-primary mathematics strands, teachers reported higher levels of mathematics teaching efficacy in the post-workshop questionnaire, compared with the levels reported before the workshops commenced. Swars et al. (2007) found that methods courses can have a significantly positive impact on pre-service teachers’ levels of self-efficacy and this study now confirms that this too is the case for out-of-field teachers who engage in subject-specific professional development. As previously discussed, self-efficacy has been shown to underpin many facets of effective teaching. According to Tschannen-Moran and McMaster (2009), self-efficacy can influence ones’ behaviour and motivation as well as how successful they are in their role. Hence, a programme such as the PDMT, and in particular the pedagogy aspect of this programme, which has been shown to influence teachers’ mathematics teaching efficacy can, in turn, have a knock-on effect on how successful these teachers are in the classroom and can help to develop competent and effective teachers from a pool of teachers once considered out-of-field. Therefore, professional development opportunities, such as that offered

by the PDMT, which focus on developing out-of-field teachers MKT are necessary and can lead to improvements in teachers' mathematics teaching efficacy. Research has also shown a correlation to exist between teaching efficacy and instructional change (De Mesquita and Drake 1994; Timperley and Phillips 2003). Whether or not such instructional change occurred in conjunction with the increase in levels of teaching efficacy that were reported in this study was the focus of the second research question of this study.

Stigler and Hiebert (2004) suggest that efforts to improve the teaching and learning of mathematics need to focus on changing classroom practices. Such findings were supported by Lessing and De Witt (2007). Similarly, Ball and Forzani (2011) state there is a critical need to develop a professional learning infrastructure to support out-of-field teachers in developing their teaching practices. This study suggests that the PDMT is one way in which this goal can be achieved. The findings to emerge from this study show that providing out-of-field teachers with subject specific pedagogy workshops, in this case in the discipline of mathematics, can result in a change to the practices teachers report employing in the classroom. The findings show that there was a significant difference in the reported approaches to teaching and learning before the workshops commenced and the approaches reported after the conclusion of the workshops. On completion of the workshops a large number of teachers reportedly demonstrated many of the characteristics of effective instructional design discussed earlier. For example, teachers reported an increase in the use of authentic real-world problems and greater student engagement in the learning process after they had engaged with the mathematics specific pedagogy offered as part of the PDMT. This is in line with the findings of Lessing and De Witt (2007) who found that when CPD was grounded in research, as the PDMT was, more than 90% of the participants in their study agreed that the initiative led to a change in the methods they employed in the classroom. In this study, teachers not only agreed that the pedagogy workshops changed their approach to teaching but demonstrated that it yielded a change by providing very different descriptions of their teaching style in the pre- and post-workshop questionnaires. The majority of teachers in this study reportedly moved from a traditional, teacher-led style of teaching to a more student-centred, enquiry-based style that placed a strong emphasis on developing students' conceptual understanding. Green and Mertova's (2016) study devised a scale ranging from 'transactionists' to 'transformalists' whereby the 'transactionists' are in agreement with the proposed change and can see its benefits while the 'transformalists' actually implements the change at hand. The change in practices reported by teachers indicate that the teachers within this research are transformalists as they not only see the benefits of the change, but actually report implementing a different teaching style upon completion of the workshop series. In essence, this study showed that when provided with formal training, out-of-field teachers felt capable and confident to move from an approach that would have been favoured in Ireland pre-2010, and which would have been a frame of reference for many of these teachers (Kennedy 1999), to an approach that is now advocated by the revised Irish mathematics curriculum. These newly advocated approaches and teaching characteristics are in line with the approaches identified as key to effective mathematics teaching and learning discussed earlier in the paper (Anghileri 2006; Anthony and Walshaw 2009; O'Meara, Johnson, and Leavy 2019; Blanton and Kaput 2005; Noddings 1995; Galbraith et al. 2007). This indicates that professional development

opportunities, which place a strong emphasis on developing pedagogical content knowledge as well as content knowledge, for out-of-field teachers, such as the PDMT, can play a significant role in improving the self-efficacy and effectiveness of teachers of mathematics and can have a positive influence on teachers' ability and willingness to improve their teaching practices.

8. Conclusion

The need to improve the teaching and learning of mathematics has been well documented for many years. One way of doing this is to increase the number of effective and competent teachers of mathematics in schools. This paper specifically focussed on efforts made to develop competence among out-of-field teachers of mathematics and to evaluate the impact of a professional development programme for upskilling these teachers. Although out-of-field teaching is not a new phenomenon, it is an under-investigated and reported upon the phenomenon, with some countries just beginning thorough investigations into it and potential means of overcoming it (Bosse and Törner 2013; McConney and Price 2009; Ní Ríordáin and Hannigan 2009; Steyn and Du Plessis 2007; Weldon 2016). Ireland is one such country which has not only come to report and highlight the issue of out-of-field teaching, but has also set about addressing the issue through the implementation of a part-time professional development programme for out-of-field teachers. The findings from this paper indicate that components of this professional development programme can have impact on teachers' mathematics teaching efficacy, a construct that has been found to underpin effective teaching. In this study teachers' self-efficacy significantly improved in four of the five strands that constitute the post-primary syllabus in Ireland, with the greatest impact felt in the area of Statistics and Probability. In addition, and possibly as a consequence of the improved levels of teaching efficacy, the study found that the pedagogy workshops, which were a fundamental and compulsory element of the PDMT, led to a shift in the reported approaches to teaching and learning among this cohort. On completion of the workshops, the vast majority of teachers reported that their preferred teaching style was different to that which they employed prior to commencing the course. The teaching styles reportedly favoured by teachers upon completion of the workshops were much more aligned with the strategies proposed in research detailing best practice in mathematics education. For example, in recent years numerous calls have been made by academics for teachers to engage in more student-led, activity-based teaching that promotes understanding and it was these teaching styles that teachers reported using on completion of the PDMT. This marked a significant shift from the procedural approach to teaching which the majority reported using prior to the workshops commencing. This is another positive finding for the PDMT to emerge from this study and supports Lessing and De Witt's (2007) inference that effective CPD can be of benefit to teachers by helping to develop their confidence levels and teaching skills.

The authors are cognisant of the fact that there are some limitations with this study. Firstly, the quantitative findings were limited by the fact that only 91 of the 152 Cohort 5 teachers completed the pre- and post-questionnaire. Ideally, the response rate would have been larger. Secondly, there was potential for response bias due to self-reported nature of the survey, particularly when reporting changes in teaching practices. In this instance, subjects may have reported changes in practices

that were in line with what they thought the researchers wanted to hear. This can result in teachers' description of their approach to teaching being quite different from the reality of what happens in the classroom (O'Shea and Leavy 2013). According to Randall and Fernandes (1991) this has been an issue for self-reported surveys for many decades.

Despite these limitations, the research outlined in this study is timely and topical and provides useful insights into the effective upskilling of out-of-field mathematics teachers. The authors believe that this study highlights the important contribution that this professional development programme played in developing the skills necessary for competent and effective teaching among a group of out-of-field teachers. It offers a template for other countries who wish to address the issue of out-of-field teaching across any discipline, or simply want to improve the teaching standards among in-field teachers. Krauss et al. (2008) ascertained that a correlation existed between teachers' MKT and student achievement and so the authors are in no doubt that it is post-primary students of these teachers, as well as the teachers themselves, who will reap the rewards of the improved levels of mathematics teaching efficacy and the change in teaching style reported by these teachers on the PDMT programme.

The authors are aware that there is still much work to be done to fully evaluate the PDMT. Firstly, research needs to be conducted to determine if the PDMT as a whole was successful in achieving its goals. If deemed a success the reasons for this also need to be considered. Was it that it was formally planned and grounded in research, as suggested by Collinson (2000)? Was it that it was a programme that ran over a sustained period of time as opposed to isolated inputs, as suggested by Lessing and De Witt (2007)? Was it that it focussed on the specific needs of the clientele i.e. out-of-field teachers, as suggested by Muijs et al. (2004)? Or was it a combination of these features? These questions need to be considered and addressed so that the key principles that underpinned the possible success of the PDMT can be identified and the programme can then act as a template for other, similar initiatives internationally. Secondly, this study highlighted significant differences in teachers' self-reported levels of mathematics teaching efficacy and teaching strategies. The self-reported nature of the study may be considered a limitation, as discussed previously. Therefore, a further study that involves classroom observation and interviews with students of these teachers would be extremely beneficial and would give further insight into the extent of the change in efficacy and practices of these teachers as a result of engagement with the PDMT and such a project is currently ongoing.

However, despite the need for more research, this particular study offers insights into understanding how teachers, in particular out-of-field teachers, best learn and how teacher educators can support them to develop as competent teachers. Ní Ríordáin, Paolucci, and Lyons (2019) called for appropriate professional learning opportunities to support out-of-field teachers and this study indicates that the PDMT is one such professional development programme that is fit for purpose in improving teachers' self-efficacy. The study highlights that the pedagogy workshops, which were a core part of the PDMT, played a significant role in enhancing teachers' self-efficacy; improving the approach to teaching mathematics; and in turn developing effective mathematics teachers. Therefore, the design of the PDMT, and in particular these workshops, can act as a template for researchers and teacher educators worldwide who want to improve the standard of teaching and learning in mathematics, or

other subject areas, in the average classroom. As mentioned at the outset, Stigler and Hiebert (2004, 12) state ‘If we want to improve student learning, we must find a way to improve teaching in the average classroom’ and this study indicates that the PDMT may offer a mechanism to do just that.

Notes

1. In 2008 a new mathematics curriculum was introduced in Irish post-primary schools which aimed to focus more on students’ understanding of mathematical concepts and abilities to problem solve as opposed to the former curriculum focus on procedural skills and rote learning.
2. The Bologna process, which was developed in 1999 and is now used by 45 countries, is a standardized accreditation process for higher education. It was put in place so that countries had a mechanism to relate national frameworks to each other allowing for international transparency, international recognition of awards and international mobility of learners and graduates. The system consists of 10 levels with each level being associated with a certain number of ECTS credits depending on the programme demands.
3. ECTS stands for the European Credit Transfer and Accumulation System. This is an academic credit system based on the estimated student workload required to achieve the objectives and learning outcomes of a module or programme of study.
4. There was a mechanism in the PDMT structure that allowed teachers to complete the course over three years via deferrals and this was the reason for this drop in numbers.
5. The question posed to teachers was ‘How would you describe your approach to mathematics teaching currently (e.g. how do you teach mathematics/what is your typical maths class like/what teaching approaches or classroom practices do you favour etc.)’
6. The teachers who completed the pre-workshop questionnaire were each assigned a ‘respondent number’ for reporting purposes and the same number was used when reporting post-workshop responses. Hence, the teacher numbers reported range from T1 to T207.

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