# Insights into the pedagogical practices of out-of-field, in-field, and upskilled teachers of mathematics

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"Out-of-field teaching" is an international phenomenon that seems particularly prevalent in mathematics. Our study is evaluating the impact of a national professional learning program for out-of-field secondary mathematics teachers in Ireland. Using the Productive Pedagogies framework, we compared the pedagogical practices of three pairs of teachers who were either upskilled, still out-of-field, or always in-field. The findings suggest that graduates of the upskilling program are developing pedagogical practices more like those of in-field teachers.

"Out-of-field" teaching is an international phenomenon that involves teachers being assigned to teach subjects that do not match their training or education (Ingersoll, 2002). This practice seems particularly prevalent in the teaching of mathematics. Out-of-field teachers of mathematics typically possess a teaching qualification but have limited advanced studies of mathematics and little or no specific preparation in mathematics pedagogy. There is growing recognition of the need for professional development programs that meet the particular needs of out-of-field teachers (Du Plessis et al., 2014). To date, however, there has been little research on the effectiveness of such programs (Faulkner et al., 2019). This paper reports on aspects of a larger study that is evaluating the impact of a long-term, large-scale, government-funded, nationally-consistent, university-accredited program offered to out-of-field teachers of mathematics in Ireland – the *Professional Diploma in Mathematics for Teaching* (PDMT).

## Background to the Study

In Ireland, concerns about student performance in post-primary school mathematics at the beginning of the 21st century led to the introduction in 2010 of a new curriculum that shifted emphasis towards understanding and problem-solving and away from memorisation and procedures (National Council for Curriculum and Assessment, 2005). Concurrently, the Teaching Council of Ireland (2013) introduced new accreditation requirements for initial teacher education programs. In mathematics, fully qualified teachers must have a degree-level qualification with the specific study of mathematics comprising at least one-third of the degree. There are also minimum credit requirements in analysis, algebra, geometry, and probability and statistics, with additional credits to be obtained in a variety of optional topics. Despite these strict requirements, school principals in Ireland have autonomy in recruiting staff and assigning teachers to subjects and classes, thus leaving open the possibility of placing teachers in out-of-field positions.

Ní Ríordáin and Hannigan (2009) speculated that the phenomenon of out-of-field teaching of mathematics could be a possible obstacle to achieving the goals of the new mathematics curriculum. They conducted a national survey of teachers of mathematics in Irish post-primary schools, collecting data on respondents' teaching assignments, degree qualifications, and the subjects they were qualified to teach according to the requirements specified by the Irish Teaching Council. This survey established that 48% of respondents were teaching mathematics without the necessary subject-specific qualifications. In response to this finding, the Department of Education and Skills (DES) funded the PDMT to develop

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the content and pedagogical content knowledge of out-of-field teachers of mathematics to the level required by the Teaching Council. Six cohorts comprising 1078 teachers participated in the PDMT from 2012-2020.

The PDMT is a 2-year part-time postgraduate program with teachers' tuition fees funded by the DES. Delivery of the program is led by the University of Limerick in conjunction with a national consortium of higher education institutions. PDMT participants teach full-time in their schools while they undertake the program in the evening, on weekends, and during school vacations via a blended learning approach. Ten undergraduate mathematics modules are delivered online in 30-hour blocks across 6-week sessions, with additional face-to-face and online support. Two yearlong mathematics pedagogy modules are delivered face-to-face via weekend workshops and a one-week summer school. These pedagogy modules emphasise classroom practices that support problem-solving and promote conceptual understanding. One of the pedagogy modules also requires participants to complete a supervised action research project on their practice in the mathematics classroom.

An important aim of the PDMT is to develop out-of-field teachers' knowledge of mathematics content and pedagogy. The program additionally aims to support teachers in developing pedagogical practices aligned with the goals of the new mathematics curriculum in Ireland, and this is the focus of the present paper. To gain insights into the latter aspect of the PDMT, we compared video-recorded mathematics lessons taught by teachers who were currently, formerly, or never out-of-field in order to address the following research question: *What similarities and differences can be observed when comparing the pedagogical practices of out-of field, upskilled, and in-field teachers of mathematics?* (Upskilled teachers are those who have completed the PDMT.)

## Conceptualising and Evidencing the Impact of Professional Development

Researching the impact of teacher professional development poses methodological and conceptual challenges. Desimone (2009) discussed the strengths, weaknesses, and trade-offs between observations, interviews, and surveys as the most common methods for studying teacher learning, and stressed the importance of choosing data collection methods to match a study's research questions. Adler et al. (2005) also pointed out that a personal investment in teaching makes it difficult for teacher educators to take a critical stance towards the research we do with teachers, and they suggested developing strong theoretical languages in order to distance ourselves from what we are looking at. In the present study, as the authors have the dual roles of researchers and teacher educators in the PDMT, we aimed to achieve this critical distance by situating our research within Desimone's (2009) conceptual framework for studying teacher professional development.

Desimone's (2009) framework has two components. The first component identifies the critical features that define effective professional development in terms of increasing teacher knowledge and skills and improving their practice. Drawing on existing empirical research, Desimone proposed that this set of critical features places emphasis on: (a) content focus, (b) active learning, (c) coherence, (d) duration, and (e) collective participation. The second component of the conceptual framework is "an operational theory of how professional development works to influence teacher and student outcomes" (p. 184). For this component, Desimone proposed a model with the following steps:

1. Teachers experience effective professional development (defined in terms of the set of critical features outlined above).
2. The professional development increases teachers' knowledge and skills and/or changes their attitudes and beliefs.

3. Teachers use their new knowledge and skills, attitudes, and beliefs to improve the content of their instruction or their approach to pedagogy, or both.
4. The instructional changes foster increased student learning. (p. 184)

Desimone (2009) acknowledged that other potentially important factors existed, but these were not incorporated into her model because they have not yet been the subject of much research on the impact of professional development. These factors might include, for example, professional identity (Hobbs, 2012), the role of the principal in providing opportunities for teacher learning (Du Plessis et al., 2015), and the role of curriculum materials and implementation (Remillard & Heck, 2014). Desimone also conceded that her model could be criticised as representing a positivist viewpoint. However, she maintained that the model could still be used in studies with different theoretical perspectives on teacher learning as a means of integrating the knowledge generated by empirical research with "the emerging consensus of what is good professional development" (p. 187).

Desimone (2009) noted that it is rare for a single study to investigate all four elements of her proposed model; in particular, there are significant methodological difficulties in designing evaluations that measure the effects of professional development on student achievement. Research conducted by our larger team has analysed the critical features of the PDMT program (Step 1 in Desimone's model; see Goos et al., 2020) and its effect on the teachers who participated in the program (Steps 2 and 3; see Lane & Ní Ríordáin, 2020; Ní Ríordáin et al., 2017). In this paper, we further examine the impact of the PDMT on teachers' *pedagogical practices* (Step 3) as a key element in Desimone's model of teacher change.

## Research Design and Methods

We would have liked to investigate the effects of the PDMT on participants' classroom teaching approaches by observing lessons taught before and after the teachers experienced the program. However, this was not possible due to resource constraints and the demands of delivering a large, complex program involving 13 higher education institutions. Our research team's earlier analysis of PDMT participants' action research reports indicated that teachers perceived a shift in their pedagogical practices towards more student-centred approaches that emphasised conceptual understanding and problem-solving (Lane & Ní Ríordáin, 2019). To further investigate these teacher self-reports, we designed a cross-sectional study to compare the pedagogical practices of three groups of teachers: (a) those currently teaching mathematics out-of-field (n=2); (b) those who had been upskilled to fully qualified status by completing the PDMT (n=2); and (c) those who had always been fully qualified, in-field teachers of mathematics (n=2). These six teachers were recruited from six different schools.

Teachers were observed by the second author as they taught six junior secondary mathematics lessons in two blocks of three consecutive lessons. These lessons were also video-recorded for later analysis. Pre- and post-lesson interviews were conducted by the second author to obtain teachers' perspectives on lesson objectives, anticipated and actual challenges or successes, knowledge, and confidence levels. Surveys were also administered to the teachers to collect demographic information and data on teacher self-efficacy, job satisfaction, and preparedness for teaching topics in the secondary mathematics curriculum. All data collection was carried out by the second author. This paper draws only on teacher demographic data and the video recordings of lessons they taught.

The Productive Pedagogies framework was selected as a classroom observation instrument that has been theoretically and statistically validated in Australian research (Lingard et al., 2001). Although not specifically designed for mathematics classrooms, it has been used in longitudinal studies of mathematics teaching (e.g., Makar, 2011) as well as in large-scale studies of primary and secondary school lessons in a range of curriculum areas. The 20 items of the Productive Pedagogies framework are shown in Figure 1. The framework has four dimensions, two concerned with the academic outcomes of schooling (left side of Figure 1) and two with the social outcomes (right side of Figure 1). The *Intellectual Quality* dimension emphasises the importance of all students being presented with challenging work. *Connectedness* makes learning meaningful by linking new knowledge to prior knowledge, other subjects in the curriculum, and the world beyond school. *Supportive Classroom Environment* foregrounds relationships and giving students a voice in the classroom, while *Recognition of Difference* provides students with the capacity to act as responsible members of a democratic society. A 5-point rating scale is used to provide an index of the variation in quality of classroom practice for each item.

| | |
|---|---|
| Intellectual Quality<br>Higher order thinking (HOT)<br>Deep knowledge (DK)<br>Deep understanding (DU)<br>Substantive conversation (SC)<br>Problematic knowledge (PK)<br>Meta-language (ML) | Supportive Classroom Environment<br>Student direction (SD)<br>Social support (SS)<br>Academic engagement (AE)<br>Explicit quality performance criteria (EC)<br>Student self-regulation (SS) |
| Connectedness<br>Knowledge integration (KI)<br>Background knowledge (BK)<br>Problem-based curriculum (PBC)<br>Connectedness beyond the classroom (CBC) | Recognition of Difference<br>Cultural knowledge (CK)<br>Inclusivity (I)<br>Narrative (N)<br>Group identities (GI)<br>Active citizenship (AC) |

*Figure 1*. Productive Pedagogies dimensions.

Before observing and video-recording lessons taught by the six teachers, the second author discussed the Productive Pedagogies scoring manual with the first author, who is an experienced user of the Productive Pedagogies framework. Both authors used the scoring manual independently to rate an online video of a junior secondary mathematics lesson, after which they compared their ratings and resolved any differences via further discussion. After the data collection was completed, the second author watched the video-recorded lessons, assigned scores for each item, and calculated mean scores on each dimension for each of the three types of teachers (out-of-field, upskilled, in-field). Similarities and differences between the teachers were further examined for each dimension by inspecting item scores.

## Results

### Demographic Data

Table 1 summarises the gender, years of mathematics teaching experience, and grouping (out-of-field, upskilled, in-field) of the participating teachers. Both out-of-field teachers were female and had taught mathematics for up to 10 years; the other teachers were male with mathematics teaching experience ranging from less than five to more than 16 years. Table 1 also shows the year in which upskilled and in-field teachers gained their mathematics teaching qualifications through the PDMT or initial teacher education program respectively.

Table 1
*Teacher Demographic Characteristics*

| Characteristic | Teacher | | | | | |
|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | T5 | T6 |
| Gender/ Group | M<br>US | M<br>IF | F<br>OOF | M<br>US | F<br>OOF | M<br>IF |
| Years teaching mathematics (year qualified) | 16-20<br>(2018) | 11-15<br>(1999) | <5<br>(n/a) | <5<br>(2018) | 6-10<br>(n/a) | 6-10<br>(2010) |

*Note*. OOF = out-of-field; US = upskilled; IF = in-field

## *Pedagogical Practices*

Table 2 presents the mean scores on the Productive Pedagogies dimensions for each group of teachers over the three lessons for which they were observed. Thus, each mean score is derived from six observations (two teachers × three lessons). One observable trend is that out-of-field, upskilled, and in-field teachers all scored highest on the dimension of Supportive Classroom Environment and lowest on the dimension of Connectedness. The same pattern was found in Makar's (2011) analysis of pedagogical practices in Australian primary school teachers' "regular" mathematics lessons.

Table 2
*Productive Pedagogies Mean Scores*

| Dimension | Teacher Group | | |
|---|---|---|---|
| | Out-of-Field | Upskilled | In-Field |
| Intellectual Quality | 2.64 | 3.00 | 3.61 |
| Connectedness | 1.54 | 1.79 | 1.75 |
| Supportive Classroom Environment | 3.67 | 3.27 | 4.07 |
| Recognition of Difference | 3.10 | 2.23 | 2.57 |

*Note.* A 5-point rating scale was used. Each group comprises two teachers who were observed for three lessons.

Looking across the rows of Table 2 enables comparison between the three groups of teachers on each Productive Pedagogies dimension. In-field teachers had the highest mean scores for the dimensions of Intellectual Quality and Supportive Classroom Environment, while upskilled teachers recorded the highest mean score for Connectedness – although this was very similar to the mean score of the in-field teachers. Out-of-field teachers achieved the highest mean score for the dimension of Recognition of Difference. This may be because they were the only teachers in the sample who taught mixed-ability, rather than streamed, mathematics classes. These two teachers were observed to place particular emphasis on encouraging participation of struggling students, thus highlighting the element of Inclusivity (Figure 1) for this non-dominant group in their classrooms.

Because the PDMT is mainly concerned with teaching mathematics for academic outcomes, we next examine the detail of teachers' pedagogical practices in the corresponding dimensions of Intellectual Quality and Connectedness. Tables 3 and 4 show each teacher's score totals for the three observed lessons for each item of these dimensions. (Score totals are displayed instead of mean scores for ease of comparison across multiple teachers and items.) Pedagogical practices that seem to characterise the greatest difference between teacher groups are highlighted for discussion.

Table 3
*Intellectual Quality Score Totals*

| Item | Out-of-Field | | Upskilled | | In-Field | |
|---|---|---|---|---|---|---|
| | T3 | T5 | T1 | T4 | T2 | T6 |
| Higher Order Thinking | 8 | 8 | 9 | 10 | 8 | 15 |
| Deep Knowledge | 9 | 9 | 11 | 13 | 12 | 15 |
| Deep Understanding | 9 | 12 | 10 | 10 | 12 | 12 |
| Substantive Conversation | 5 | 9 | 5 | 10 | 8 | 9 |
| Problematic Knowledge | 6 | 6 | 5 | 8 | 11 | 12 |
| Meta-language | 5 | 9 | 9 | 8 | 12 | 5 |

*Note.* A 5-point rating scale was used. Each teacher was observed for three lessons.

Within the dimension of Intellectual Quality, the greatest differences – equivalent to at least 6 points across three lessons, or a mean of 2 points per lesson on the 5-point observation scale – occurred on the items representing Higher Order Thinking, Deep Knowledge, and Problematic Knowledge (Table 3). The general trend is for the scores to increase from out-of-field to upskilled to in-field teachers. Also notable is the high Meta-language score for in-field teacher T2, who regularly provided help in the use of mathematical terminology for students who had been identified with low literacy skills.

Figure 2 provides examples of questions posed by Teacher 5 (out-of-field), Teacher 4 (upskilled) and Teacher 6 (in-field) that illustrate differences in the quality of their pedagogies for promoting Higher Order Thinking. According to the Productive Pedagogies classroom observation manual, Higher Order Thinking requires students to manipulate information and ideas in ways that transform their meaning and implications, for example by synthesising, generalising, explaining, or arriving at a conclusion or interpretation. This level of thinking is evident in the question asked by Teacher 6, and to some extent by Teacher 4. However, Teacher 5's question only requires students to rehearse procedural routines.

| T5 (OOF)<br>Solving equations | T4 (US)<br>Simultaneous equations | T6 (IF)<br>Introducing simultaneous equations |
|---|---|---|
| Q. Now what happens if I have the scales and I take 8 away from 12 on the RHS?<br><br>Q. What did she do to both sides of the equation? | Q. How do I get this $-3x$ to become an $x$?<br><br>Q. Can you explain to me what you did? | Q. Which of these equations do you think is the hardest to solve? Why?<br>1) $95x^2 - 2x + 105 = 0$<br>2) $3x + 2y = 8$<br>3) $9x^4 - 39x^3 + 9x^2 - 90x + 3035 = 0$<br>4) $\sqrt[4]{9x^4} - \frac{9}{2}x^3 - 4^{5x} - 87x = 0$ |

*Figure 2.* Examples of teacher questions illustrating variation in promotion of Higher Order Thinking.

For the dimension of Connectedness, the differences between teacher groups were less pronounced – perhaps as a consequence of the lower scores across all three groups (see Table 2). The greatest difference – equivalent to at least 3 points across three lessons, or a mean of

1 point per lesson on the 5-point observation scale – occurred on the item representing Problem-Based Curriculum (Table 4). In line with the Intellectual Quality dimension, the trend here is for scores to increase from out-of-field to upskilled to in-field teachers.

Table 4
*Connectedness Score Totals*

| Item | Out-of-Field | | Upskilled | | In-Field | |
|---|---|---|---|---|---|---|
| | T3 | T5 | T1 | T4 | T2 | T6 |
| Knowledge Integration | 3 | 3 | 4 | 3 | 3 | 3 |
| Background Knowledge | 6 | 7 | 7 | 6 | 6 | 6 |
| Problem-Based Curriculum | 6 | 6 | 7 | 9 | 8 | 10 |
| Connectedness Beyond the Classroom | 3 | 3 | 4 | 3 | 3 | 3 |

*Note.* A 5-point rating scale was used. Each teacher was observed for three lessons.

Figure 3 shows examples of tasks presented by Teacher 3 (out-of-field), Teacher 1 (upskilled) and Teacher 2 (in-field) that illustrate differences in the quality of their pedagogies for promoting a Problem-Based Curriculum. The Productive Pedagogies classroom observation manual defines a problem as a task with no specified correct solution that requires knowledge construction on the part of students. In keeping with the mathematics education research literature, we re-interpreted this definition to mean that a *mathematical problem* is a task for which the student does not know, and needs to construct, the *solution method* (National Council of Teachers of Mathematics, 2000). There is some evidence that this kind of knowledge construction is called for in the tasks offered by Teacher 2 and Teacher 1; however, the task set by Teacher 3 instead requires using well-defined algorithms for algebraic manipulation.

| T3 (OOF) | T1 (US) | T2 (IF) |
|---|---|---|
| Expanding and simplifying<br>$4(x+2)$<br>$6(a+4)+2(2a+3)$ | Introducing patterns<br>x, y, z, x, y, z, x, y, z, …<br>What letter is in the 63rd position? | Introducing Pythagoras' Theorem<br>(Counting up boxes in the squares of the sides) … How many boxes should be in here (the square on the hypotenuse) based on what we did earlier? |

*Figure 3.* Examples of tasks illustrating variation in problem-based lessons

## Conclusion

In this paper, our focus was on the extent to which the PDMT encouraged teachers to take up pedagogical practices that emphasise conceptual understanding and problem-solving, in line with Ireland's new secondary mathematics curriculum. Because it was not possible to collect longitudinal data on PDMT participants, we instead designed a cross-sectional study to identify similarities and differences between these upskilled teachers and other teachers of mathematics who were still out-of-field or had always been in-field. This design does not allow us to make claims about causality in relation to the PDMT, but it does illuminate some interesting comparisons between these three groups of teachers. The groups were *similar* in that out-of-field, upskilled, and in-field teachers all scored highest on Supportive Classroom Environment and lowest on Connectedness, a finding that aligns with previous research using the Productive Pedagogies protocol (Makar, 2011). Some of the *differences* between groups suggested that upskilled teachers (PDMT graduates) might be adopting pedagogical practices more like those of in-field teachers than those who are still teaching mathematics out-of-field, especially in relation to promoting Intellectual Quality and Connectedness. These conclusions can only be tentative, given the small sample, but they suggest that structured lesson observations can usefully supplement upskilled teachers' self-reports of changes in their pedagogical practices arising from participation in a targeted professional development program. In addition, such structured lesson observations may be useful for informing the design of programs to develop out-of-field teachers' (and also pre-service teachers') *knowledge* of mathematics and pedagogical *practices*, particularly in pinpointing specific items within the academic outcomes of schooling that require further consideration (e.g., knowledge integration and connectedness beyond the classroom).

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