Impact of a National Professional Development Program on the Beliefs and Practices of Out-of-Field Teachers of Mathematics

Merrilyn Goos
University of Limerick
merrilyn.goos@ul.ie

Máire Ní Ríordáin
University College Cork
maire.niriordain@ucc.ie

Ciara Lane
University of Limerick
<ciara.lane@ul.ie>

Fiona Faulkner
Technological University Dublin
<fiona.faulkner@dit.ie>

'Out-of-field teaching' refers to the practice of assigning teachers to teach subjects that do not match their training or education – an international phenomenon that seems particularly prevalent in mathematics. This paper reports on a study evaluating the impact of a national professional learning program for out-of-field secondary mathematics teachers in Ireland. An online survey investigated teachers' beliefs about mathematics, mathematics teaching and mathematics learning, and changes in teaching practices. These teachers reported largely child-centred beliefs and practices consistent with the problem-solving orientation of the new mathematics curriculum, thus providing some evidence of the program's impact.

'Out-of-field' teaching is an international phenomenon that results in 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. Research highlighting the complexities involved in understanding and addressing out-of-field teaching is beginning to emerge in several countries. For example, researchers representing the Teaching Across Specialisations (TAS) Collective have developed international comparative studies of out-of-field teaching in Australia, Ireland, Germany, Indonesia, the United Kingdom, and the USA (Hobbs & Törner, 2019). In some of these countries, professional learning programs have been developed to upskill out-of-field teachers of mathematics; yet there has been little research to date on the effectiveness of such programs. This paper reports on a study that is evaluating the impact of a long-term, large-scale, government-funded, university-accredited program offered to out-of-field mathematics teachers in Ireland – the Professional Diploma in Mathematics for Teaching (PDMT).

Background to the Study

In Ireland, concerns about underperformance in secondary school mathematics led to the introduction in 2010 of a new curriculum that shifted emphasis away from memorisation and procedures towards understanding and problem-solving (National Council for Curriculum and Assessment, 2005). At around the same time, the Teaching Council of Ireland (2013) introduced new accreditation requirements for initial teacher education programs that prescribe the number of credits to be gained in relation to subject matter knowledge as well as specific topics to be studied. In mathematics, fully qualified teachers must have a degree-level qualification with at least one-third of the degree comprising of the specific study of mathematics. 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. However, school principals have autonomy in advertising for and appointing staff and for assigning teachers to subjects and classes, thus leaving open the possibility of placing teachers in out-of-field positions. The magnitude of this phenomenon was revealed by a national survey of mathematics teachers in Irish secondary schools (Ní Ríordáin &

2019. In G. Hine, S. Blackley, & A. Cooke (Eds.). Mathematics Education Research: Impacting Practice *(Proceedings of the 42nd annual conference of the Mathematics Education Research Group of Australasia)* pp. 316-323. Perth: MERGA.

Hannigan, 2009), which established that 48% of respondents were teaching out-of-field. In response to this finding, the Department of Education and Skills (DES) has funded a national program – the Professional Diploma in Mathematics for Teaching – to develop out-of-field mathematics teachers' content and pedagogical content knowledge.

The PDMT is a 2-year part-time postgraduate program with teachers' tuition fees fully 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. Teachers remain employed in their schools and undertake the program via a blended learning approach consisting of online and face-to-face lectures, tutorials, and workshops. The DES stipulated that the program had to be designed so that graduates would meet the mathematics teaching requirements of the Irish Teaching Council. Thus the content comprises 10 undergraduate mathematics modules presented in 30-hour blocks over six-week sessions, and 2 mathematics pedagogy modules presented via five Saturday workshops and a week-long summer school. Teachers additionally complete a supervised action research project examining their own practice in a mathematics classroom. Six cohorts (around 1100 teachers) have participated in the PDMT since it began in 2012.

An important goal of the PDMT is to develop the knowledge of content and pedagogy required for teaching secondary school mathematics. However, the program also aims to support participants in reflecting on their teaching and developing beliefs and practices aligned with the goals of the new mathematics curriculum in Ireland. In this paper, we analyse responses to a national survey of PDMT graduates in order to address the following research questions: (1) What beliefs about mathematics, and mathematics teaching and learning, are held by formerly out-of-field mathematics teachers who have completed the PDMT? (2) How have these teachers' approaches to teaching mathematics changed since completing the PDMT?

Conceptualising Teacher Beliefs and their Relationship with Practices

Teachers' beliefs have received considerable attention from researchers in recent decades (Zhang & Morselli, 2016), particularly in light of the relationship between teachers' beliefs and their classroom practices (Beswick, 2012) and resultant impact on students' experience and learning (Kunter, Kleickmann, Klusmann, & Richter, 2013). While no single definition of 'belief' exists, various researchers view beliefs as a cognitive construct, related to knowledge (e.g., Furinghetti & Pehkonen, 2002). Beliefs differ from knowledge, however, in that they incorporate affective and evaluative components, captured by Pajares (1992) as "an individual's judgement of the truth or falsity of a proposition, a judgement that can only be inferred from a collective understanding of what human beings say, intend, and do" (p. 316). Teachers' beliefs about mathematics teaching and learning "develop during the many years teachers spend at school, first as students, then as student teachers and teachers, and over time and use, these beliefs then become robust" (De Vries, Van De Grift, & Jansen, 2014, p. 339).

Beliefs about teaching and learning alone, however, do not fully capture the relationship between teacher beliefs and practices in the mathematics classroom. Beswick (2012) has highlighted the importance of teachers' beliefs about the nature of mathematics in considering the impact on their classroom praxis. Teachers' beliefs about mathematics have been categorised by Ernest (1989) as: the Instrumentalist view (mathematics as an unrelated collection of rules and procedures to be followed), the Platonist view (mathematics as an established and unified body of knowledge), and the Problem-solving view (mathematics as a dynamic and creative process, socially and culturally constructed). In his study of out-of-field mathematics teachers in Germany, Bosse (2014) found a prevalence of the Instrumentalist view of mathematics, with little or no evidence of the problem-solving view.

Perry, Howard, and Tracey (1999) developed and validated a model for teachers' beliefs which incorporates beliefs about mathematics, mathematics teaching, and mathematics learning. From their factor analysis of survey responses made by Head Mathematics Teachers and classroom mathematics teachers they identified two categories of beliefs they labelled as transmission and child-centredness. Transmission beliefs are consistent with a view of mathematics teaching and learning as the transfer of knowledge from teacher to learner and tends to adhere to Ernest's (1989) Instrumentalist and/or Platonist views of mathematics. Child-centred beliefs, on the other hand, reflect a view of learners as actively constructing their own knowledge of mathematics, facilitated by teachers and encompassing a more Problem-solving view of mathematics as described by Ernest. These two categories of beliefs appear in various other models of teachers' beliefs and are not unique to the study by Perry et al. (1999); however, the authors are clear that, unlike in some other perspectives, transmission and child-centredness are conceptualised as independent factors and not as opposite ends of a single belief spectrum. Their model allows for meaningful analysis of teachers' beliefs while taking into account the sometimes contradictory nature of those beliefs (Sosniak, Ethington, & Varelas, 1991).

It is important to research teachers' beliefs as they are critical in shaping classroom practice (Speer, 2005). This is not to deny that inconsistencies also occur between teachers' beliefs and practices, which some researchers suggest might stem from the fact that beliefs are self-reported while practices can be observed (Zhang & Morselli, 2016). Others have highlighted the importance of the teachers' context in determining which beliefs they enact in their practices (Beswick, 2004), including in the context of teaching mathematics out-of-field (Lane & Ní Ríordáin, 2019).

Research Design and Methods

The findings reported in this paper come from a larger online survey examining the perceptions and experiences of mathematics teachers since graduating from the PDMT. As well as collecting information about graduates' personal and professional backgrounds, the survey explored perceptions of their preparedness for teaching mathematics, development of their identity as a teacher of mathematics, beliefs, classroom practices, and perceptions of the effectiveness of the PDMT program. The survey section investigating beliefs was taken from Perry et al. (1999) and consisted of 20 items examining teachers' beliefs about mathematics, mathematics learning, and mathematics teaching. Responses to each belief item were given on a six-point Likert scale: strongly disagree (SD), disagree (D), somewhat disagree (SWD), somewhat agree (SWA), agree (A) and strongly agree (SA). There were two reasons why this scale differed from that used by Perry et al., which had only three response options: disagree, undecided, agree. First, we wanted consistency with the response options offered for other items in our survey, and second, a larger number of response options increases the reliability and validity of the scale (Lozano, García-Cueto, & Muñiz, 2008). Each item was classified as representing either transmission (T) or child-centred (C) beliefs, as in Perry et al. (1999). The survey section investigating classroom practices asked two separate open-ended questions inviting teachers to describe their approach to mathematics teaching before and since completing the PDMT pedagogy workshops.

We addressed our first research question by recording frequencies of responses to the 20 beliefs items corresponding to the two factors of transmission and child-centredness. For the second research question, regarding changes in mathematics teaching approaches, we classified the open-ended responses as indicating practices aligned with either transmission or child-centred beliefs, a mixture of these beliefs, no change, or other.

In November 2018, an invitation email was sent to the four graduated cohorts of the PDMT from 2014, 2015, 2016 and 2017, with two follow-up email remainders. The email included an information sheet detailing the purpose and aim of the research while also highlighting that participation was voluntary and that confidentiality would be ensured. Included in the email was a URL for the online survey (developed using SurveyMonkey). In total, 822 PDMT graduates were emailed, with 26 emails bouncing back, most likely due to teachers having changed school and consequently email address. Therefore, the online survey was delivered to 796 email addresses. A total of 224 responses to the online survey were received. However, 6 have been excluded from the analysis due to the respondents not completing any question items (i.e., they accessed the link that generated an ID in the data set but answered no further questions). Accordingly, the sample for the online questionnaire is 218 respondents (27% response rate).

Research Findings

Demographic Data

The sample of 218 teachers consisted of 61% females and 39% males, with 33% of respondents graduating in 2014, 25% in 2015, 26% in 2016 and 13% in 2017 (3% did not respond to this question). A little more than half (57%) were aged 31-40 years, with 20% aged 41-50. The majority (71%) had 6 to 15 years teaching experience, and 70% had 10 years or less experience of teaching mathematics.

Teachers' Self-Reported Beliefs

Table 1 provides a summary of the PDMT graduates' responses to the 20 belief statements included in the online survey. The response rate for each item ranged from 72-75%; that is, not every teacher answered each item in the online survey. Consistent with the study reported by Perry et al. (1999), the statements are grouped to identify beliefs about mathematics, beliefs about mathematics learning, and beliefs about mathematics teaching. Shading is used to identify majority responses favoured by at least half the respondents.

Table 1
Percentage Distribution of PDMT Graduates' Responses to Belief Statements

Belief Statement	SD	D	SWD	SWA	A	SA
Mathematics						
1. Mathematics is computation (T)	4	14	15	45	20	2
2. Mathematics problems given to students should be quickly solvable in a few steps (T)	10	29	29	21	9	2
3. Mathematics is the dynamic searching for order and pattern in the learner's environment (C)	2	5	8	48	30	7
4. Mathematics is no more sequential a subject than any other (C)	11	31	27	19	11	1
5. Mathematics is a beautiful, creative and useful human endeavour that is both a way of knowing and a way of thinking (C)	0	2	2	26	49	21

6. Right answers are much more important in mathematics than the ways in which you get them (T)	50	35	10	3	2	0
Mathematics Learning						
7. Mathematics knowledge is the result of the learner interpreting and organising the information gained from experiences (C)	1	1	2	31	53	12
8. Students are rational decision makers capable of determining for themselves what is right and wrong (C)	1	11	22	38	24	4
9. Mathematics learning is being able to get the right answers quickly (T)	30	39	22	6	3	0
10. Periods of uncertainty, conflict, confusion, surprise are a significant part of the mathematics learning process (C)	1	2	6	28	47	16
11. Young students are capable of much higher levels of mathematical thought than has been suggested traditionally (C)	6	12	17	36	26	3
12. Being able to memorise facts is critical in mathematics learning (T)	4	19	20	35	18	4
13. Mathematics learning is enhanced by activities which build upon and respect students' experiences (C)	0	1	3	21	55	20
14. Mathematics learning is enhanced by challenge within a supportive environment (C)	2	2	2	20	50	24
Mathematics Teaching						
15. Teachers should provide instructional activities which result in problematic situations for learners (C)	1	3	6	29	47	14
16. Teachers or the textbook – not the student – are the authorities for what is right or wrong (T)	20	37	18	19	5	1
17. The role of the mathematics teacher is to transmit mathematical knowledge and to verify that learners have received this knowledge (T)	1	6	10	33	40	10
18. Teachers should recognise that what seem like errors and confusions from an adult point of view are	2	2	7	33	44	12

students' expressions of their current understanding (C)						
19. Teachers should negotiate social norms with the students in order to develop a cooperative learning environment in which students can construct their knowledge (C)	1	4	7	32	47	9
20. It is unnecessary, even damaging, for teachers to tell students if their answers are correct or incorrect (C)	32	36	15	11	5	1

Beliefs about mathematics. Almost all PDMT graduates expressed at least some agreement that "mathematics is a beautiful, creative, and useful human endeavour that is both a way of knowing and a way of thinking". Similarly high levels of agreement were recorded with the statement that "mathematics is the dynamic searching for order and pattern in the learner's environment", and there was clear disagreement that "right answers are much more important in mathematics than the ways in which you get them". Each of these response patterns aligns with the child-centred intent of the new secondary mathematics curriculum in Ireland, and is similar to the findings reported in the study of Perry et al. (1999). However, two-thirds of respondents agreed that "mathematics is computation", suggesting a transmission orientation that was also observed to a somewhat lesser extent in the study of Australian secondary school mathematics teachers reported by Perry et al.

Beliefs about mathematics learning. A very high proportion of respondents agreed with the following statements aligned with child-centred beliefs: "mathematics learning is enhanced by activities which build upon and respect students' experiences", "mathematics knowledge is the result of the learner interpreting and organising the information gained from experiences", and "mathematics learning is enhanced by challenge within a supportive environment". Respondents largely rejected the view that "mathematics learning is being able to get the right answers quickly". Yet there were equivocal views about the importance of memorisation, with 43% of teachers expressing some level of agreement – again mirroring the contradictory transmission response pattern found in the Perry et al. (1999) study.

Beliefs about mathematics teaching. A large majority of PDMT graduates agreed that teachers should "provide instructional activities which result in problematic situations for learners", "recognise that what seem like errors and confusions from an adult point of view are students' expressions of their current understanding", and "negotiate social norms with the students in order to develop a cooperative learning environment in which students can construct their knowledge", and disagreed that the teacher or textbook are the authorities for what is right or wrong. On the other hand, there was equally strong agreement that the role of the teacher is to "transmit mathematical knowledge and to verify that learners have received this knowledge": 83% of PDMT graduates expressed agreement with this transmission-oriented practice compared with 48% of Mathematics Head Teachers and 61% of mathematics classroom teachers in the Perry et al. (1999) study.

Teacher Practices and Connection with Beliefs

Table 2 summarises the categorisation of teachers' responses to the open-ended questions "How would you describe your approach to mathematics teaching prior to/since completing the PDMT pedagogy workshops?" The response rate was 47% for the first question (102 responses) and 48% for the second question (104 responses).

Table 2
Percentage Distribution of PDMT Graduates' Descriptions of Mathematics Teaching Approaches Before and After Completing Pedagogy Workshops

Teaching Approach	Before PDMT	After PDMT
Transmission	56	5
Child-centred	23	51
Mixed	9	11
No change	9	26
Other	3	7

Typical *transmission* approaches reported by teachers included "chalk and talk", "board work", "follow the book", and "learning steps in a procedure". Responses categorised as *child-centred* referred to approaches such as "problem-solving", "teaching for understanding", "group work", "concrete examples", and "investigation". *Mixed* responses reported some combination of these approaches. Some of the *no change* responses explicitly indicated that no new teaching approaches were learned in the PDMT. Nevertheless, Table 2 shows teachers who responded to these questions reporting a substantial decrease in transmission-oriented mathematics teaching practices (from 56% to 5%) after completing the PDMT pedagogy workshops, and a corresponding increase in child-centred approaches (from 23% to 51%). Even if all who reported no change in their teaching approach (26%) were in fact maintaining transmissive practices, this would still indicate a clear shift towards the problem-solving orientation promoted by the new mathematics curriculum in Ireland.

Conclusion

Although the PDMT was designed with the primary goal of developing out-of-field teachers' knowledge of mathematics content and pedagogy, attention is also given to enhancing teachers' beliefs and classroom practices in ways that align with the intent of the new secondary school mathematics curriculum emphasising problem-solving and conceptual understanding. The first finding from our survey of PDMT graduates is that these teachers report beliefs about mathematics, mathematics teaching, and mathematics learning that could be described as largely child-centred. We have no data that can shed light on these teachers' beliefs before they undertook the PDMT, and so it is not possible to make any claims about changes in their reported beliefs. However, it is interesting to note the contrast with findings obtained by Bosse (2014) in Germany, where there was little evidence of out-of-field mathematics teachers holding problem-solving beliefs. In addition, our findings mirror the largely child-centred beliefs of Australian secondary school mathematics teachers in the study conducted by Perry et al. (1999), even though some teachers may have responded to the set of beliefs statements in contradictory ways. The second finding from the survey suggests that PDMT graduates perceived a substantial change in their mathematics teaching practices, shifting from transmission towards more child-centred approaches. These findings, while limited to self-reports, provide some evidence of the impact of a national professional development program designed to support out-of-field teachers of secondary school mathematics.

References

Beswick, K. (2004). The impact of teachers' perceptions of student characteristics on the enactment of their beliefs. In M.J. Hoines & A.J. Fuglestad (Eds.), *Proceedings of the 28th conference of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 111–118). Bergen, Norway: PME.

Beswick, K. (2012). Teachers' beliefs about school mathematics and mathematician's mathematics and their relationship to practice. *Educational Studies in Mathematics, 79*(1), 127–147.

Bosse, M. (2014). The practice of out-of-field teaching in mathematics classrooms. *Proceedings and agenda for research and action, 1st Teaching Across Specialisations (TAS) collective symposium* (pp. 33–34). Porto, Portugal: TAS Collective.

De Vries, S., Van De Grift, W., & Jansen, E. (2014). How teachers' beliefs about learning and teaching relate to their continuing professional development. *Teachers & Teaching*, *20*(3), 338–357.

Ernest, P. (1989). The impact of beliefs on the teaching of mathematics. In P. Ernest (Ed.), *Mathematics teaching: The state of the art* (pp. 249–254). London: Falmer Press.

Furinghetti, F., & Pehkonen, E. (2002). Rethinking characterizations of beliefs. In G. Leder, E. Pehkonen, & G. Törner (Eds.), *Beliefs: A hidden variable in mathematics education?* (pp. 39–57). Dordrecht: Kluwer.

Hobbs, L., & Törner, G. (Eds.). (2019). *Examining the phenomenon of "teaching out-of-field": International perspectives on teaching as a non-specialist*. Singapore: Springer Nature.

Ingersoll, R. M. (2002). *Out-of-field teaching, educational inequality and the organization of schools: An exploratory analysis*. Seattle, WA: University of Washington, Center for the Study of Teaching and Policy.

Kunter, M., Kleickmann, T., Klusmann, U., & Richter, D. (2013). Professional competence of teachers: Effects on instructional quality and student development. *Journal of Educational Psychology, 105*(3), 805–820.

Lane, C., & Ní Ríordáin, M. (2019). Out-of-field teachers' beliefs and practices: An examination of change and tensions using zone theory. *International Journal of Science and Mathematics Education*. DOI https://doi.org/10.1007/s10763-019-09964-5

Lozano, L. M., García-Cueto, E., & Muñiz, J. (2008). Effect of the number of response categories on the reliability and validity of rating scales. *Methodology: European Journal of Research Methods for the Behavioral and Social Sciences*, *4*(2), 73–79.

National Council for Curriculum and Assessment (2005). *Review of mathematics in post-primary education – A discussion paper*. Dublin: NCCA.

Ní Ríordáin, M., & Hannigan, A. (2009). *Out-of-field teaching in post-primary mathematics education: An analysis of the Irish context*. Limerick, Ireland: NCE-MSTL. Retrieved from http://epistem.ie/wp-content/uploads/2015/04/Out-of-field-teaching-in-post-primary-Maths-Education.pdf

Pajares, F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research*, *62*(3), 307–332.

Perry, B., Howard, P., & Tracey, D. (1999). Head mathematics teachers' beliefs about the learning and teaching of mathematics. *Mathematics Education Research Journal, 11*(1), 39–53.

Sosniak, L. A., Ethington, C. A., & Varelas, M. (1991). Teaching mathematics without a coherent point of view: Findings from the IEA Second International Mathematics Study. *Journal of Curriculum Studies, 23*(2), 119–131.

Speer, N. M. (2005). Issues of methods and theory in the study of mathematics teachers' professed and attributed beliefs. *Educational Studies in Mathematics*, *58*(3), 361–391.

Teaching Council (2013). *Teaching Council registration: Curricular subject requirements (post-primary) for persons applying for registration on or after 1 January 2017*. Retrieved 9 November 2018 from https://www.teachingcouncil.ie/en/Publications/Registration/Documents/Curricular-Subject-Requirments-after-January-2017.pdf

Zhang, Q., & Morselli, F. (2016). Teacher beliefs. In G. Kaiser (Ed.), *Attitudes, beliefs, motivation and identity in mathematics education: An overview of the field and future directions* (pp.11–14). Cham: Springer.