Out-of-Field Mathematics Teachers' Beliefs and Practices: an Examination of Change and Tensions Using Zone Theory

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Abstract

This paper describes an empirical study examining action research papers submitted by a group ($n = 81$) of out-of-field mathematics teachers as part of a professional development programme in Ireland. Utilising document analysis, the papers were qualitatively analysed for evidence of teachers' beliefs and practices with respect to the teaching and learning of mathematics. In particular, demonstration of direct transmission and constructivist beliefs and practices was explored. The authors draw on Valsiner's zone theory in conceptualising the 'teacher-as-learner' in this out-of-field context and it provided a means for analysing teachers' development in terms of their beliefs and practices. Findings indicate a prevalence of direct transmission or traditional teaching practices prior to the out-of-field teachers' action research, with some inconsistency with professed constructivist beliefs. There was evidence of a majority shift towards constructivist beliefs and practices post action research for a myriad of reasons, including increased pedagogical confidence in mathematics and the successful experience of constructivist approaches. Findings also highlight the role of reflective self-study in facilitating the creation of productive tensions, as well as the importance of the teachers' interpretation of their zone of free movement in resolving complex issues and enabling out-of-field teachers' development of constructivist beliefs and practices.

Keywords Out-of-field teaching · Mathematics teachers · Action research · Beliefs · Practices

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Introduction

This research paper is concerned with teachers teaching mathematics for which they have no specialisation, often referred to as teaching out-of-field (OOF). OOF teachers are generally defined as those who are qualified teachers but are assigned to teach a subject(s) which is not consistent with their training and/or qualification (Ingersoll, 2002). Teaching OOF can bring many challenges and sometimes opportunities for teachers in these positions. Internationally, the phenomenon of OOF teaching is gaining importance (see Hobbs & Törner, 2019). Of concern to us is examining how an action research component of a professional development programme designed to support the upskilling of OOF mathematics teachers in the Irish context might facilitate the development of OOF mathematics teachers' beliefs and practices. Research on mathematics teachers' beliefs evokes a multifaceted link between a teacher's beliefs and his/her practices in the classroom. Thompson (1992) suggests that conflicting understandings exist in that "… there is support in the literature for the claim that beliefs influence classroom practice; teachers' beliefs appear to act as filters through which teachers interpret and ascribe meanings to their experiences as they interact with children and the subject matter. But, at the same time, many of a teacher's beliefs and views seem to originate in and be shaped by experiences in the classroom" (pp. 138–139). Accordingly, the relationship between teachers' beliefs and their practices is interactive and subject to change. This is compounded for teachers of mathematics who are OOF. Research has highlighted the importance of exploring OOF teachers' lived experiences in order to understand the complexities that they face in teaching such a subject such as mathematics when OOF (Du Plessis, Gillies, & Carroll, 2015; Hobbs, 2013). This paper describes a study of OOF mathematics teachers ($n = 81$) undertaking an action research project into self-chosen aspects of their own practice at second level education (ages 12–18 years) in Ireland. Fundamental to this approach is the idea that mathematics teacher development occurs when teachers are required to address 'hard' questions about their teaching and beliefs (Jaworski, 1998). Facilitating mathematics teachers in implementing an inquiry on their practice can stimulate profound examination into their reasoning and rationale for adopting particular teaching approaches and hence its impact on student learning. Moreover, it can challenge their beliefs and practices (Jaworski, 1998). It is recognised that OOF teaching has been under-researched for some time (Hobbs & Törner, 2019; Ní Ríordáin, Paolucci & O'Dwyer, 2017). For that reason, we are concerned with answering our key research question: how does a self-study action research project impact on the development of OOF mathematics teachers' beliefs and practices? This study provides an opportunity to identify critical culturally specific factors that might have the potential to contribute to work in other OOF contexts and to contribute to our understanding of supporting OOF mathematics teacher professional development.

Out-of-Field Teaching and Professional Development

The phenomenon of out-of-field teaching, also referred to as teaching across specialisations, has received increasing attention from researchers in recent years (Hobbs & Törner, 2019). While OOF teaching is a concern for education in general, it is a critical issue in mathematics education. With the current emphasis on STEM education internationally, it is

essential that students are exposed to the optimum education in mathematics and teacher qualification has been found to effect student achievement (Darling-Hammond & Post, 2000). For example, in Canada, secondary teachers reported lower confidence when teaching out-of-field (Ross, Cousins, Gadalla & Hannay, 1999). According to Du Plessis (2014), confidence and quality teaching are interconnected, with confidence being an important factor in teachers taking risks and exploring new teaching strategies. For example, in Canada, secondary teachers reported lower confidence when teaching out-of-field (Ross et al., 1999). In other words, research informs us that teachers need to be competent and confident in their competence to teach effectively. As such, it is evident that there is an exigent need to upskill OOF teachers and a professional develop programme (PDMT) in the Irish context seeks to fulfil this need.

Research has consistently shown the significance of teachers' Mathematics Content Knowledge (MCK) and Mathematics Pedagogical Content Knowledge (MPCK) to good mathematics teaching. OOF teachers lack these essential components, thus putting both the teachers and their students at a disadvantage (Hobbs, 2013). In creating professional development opportunities, however, research informs us that factors other than teachers' knowledge also need to be considered (e.g. beliefs, motivation, self-regulation and confidence). According to Bosse (2014), OOF mathematics teachers often view mathematics as calculating and solving tasks by following procedures. Given the widely acknowledged relationship between teachers' beliefs and practices (see for example Aelterman, Vansteenkiste, Van Keer, & Haerens, 2016; Beswick, 2004; Ernest, 1989; Thompson, 1992), it follows that OOF teachers' beliefs would impact on their classroom practice, and therefore, any professional development should also pay attention to the enrichment of OOF teachers' beliefs and practices as well as knowledge. While other factors such as motivation, self-regulation, social context etc. can influence a teacher's instructional approach, beliefs can be more malleable than other factors in effecting change in a professional development context (Aelterman et al., 2016). From a study of OOF mathematics teachers' identity, Bosse (2014) advocated the need for OOF mathematics teachers to engage in activities of self-reflection and new mathematical experiences in order to enhance their beliefs about mathematics and ability to reflect on their own practices. The action research component of the PDMT provides the opportunity for the participants to reflect on their mathematics teaching and experience new instructional approaches. Research has demonstrated that where OOF teachers have some control over what they teach, and are supported in the process, while assuming a disposition of teacher as learner, teaching OOF can contribute to the development of their identity (Hobbs, 2013). Accordingly, our research work seeks to investigate the factors that aid in (or hinder) the development of these OOF mathematics teachers' beliefs and practices during their self-study action research experience in order to contribute to the field's understanding of the complexity of out-of-field teaching and make suggestions for the professional development of these teachers.

Teachers' Beliefs and Practices

While beliefs have played a central role in educational research in recent decades, there remains some ambiguity in defining what is meant by 'belief'. Much of the focus in defining beliefs has been on differentiating between beliefs and knowledge

as cognitive constructs. A consensus can be inferred that while interrelated, beliefs differ from knowledge chiefly in their affective and evaluative components (Pajares, 1992). According to De Vries, Van De Grift & Jansen (2014, p. 339) "teachers' beliefs about learning and teaching are propositions that a teacher holds to be true about teaching and learning, they 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". Two belief orientations frequently discussed in the literature in relation to teachers' beliefs about teaching and learning are direct transmission beliefs (also referred to in the literature as teacher-centred or subject-matter oriented beliefs) and constructivist beliefs (also referred to as learning facilitation, learning-centred or student-oriented beliefs) (De Vries et al., 2014; Kunter, Kleickmann, Klusmann, & Richter, 2013). Research has shown that less direct transmission and more constructivist teaching results in improved student learning outcomes (Kunter et al., 2013). Although the two belief orientations may appear contradictory, teachers can possess characteristics from both (De Vries et al., 2014). Indeed, there is evidence from the literature that it is the teacher's context that determines which beliefs about teaching and learning teachers employ in their practice (Beswick, 2004). This has implications for OOF teachers given the complexity of their professional context. Inconsistencies between teachers' professed beliefs and their practices have been pointed out by researchers (see Zhang & Morselli, 2016), with inconsistencies possibly stemming from the fact that teachers' beliefs are self-reported. "What matters in teaching is not so much what people say but what they do" (Zhang & Morselli, 2016, p. 12). Similarly, Ernest (1989) suggested that the teacher's level of consciousness of his/her beliefs about teaching and learning and the extent to which he/she reflects on their practice may also explain some of the disparity between professed beliefs and observed practices. Bosse (2014) has also highlighted this as essential for OOF mathematics teachers to enhance their mathematics beliefs and reflective abilities. However, the context of teachers' practices is also highlighted as one of the main reasons for possible inconsistencies with teachers' beliefs (Beswick, 2004; Ernest, 1989; Zhang & Morselli, 2016) and this context must be considered if we want to re-align teachers' beliefs with their practices or effect change.

To change teachers' practices in the classroom, teachers' beliefs (especially effectiveness and feasibility beliefs) play a key role in the likelihood of teachers adopting an alternative teaching approach (Aelterman et al., 2016). If the proposed practice is perceived by teachers as being ineffective or too challenging to apply in their own classroom context, it is unlikely that the change will be implemented. Guskey (2002, p. 384) proposed a model of teacher change that highlights the importance of "demonstrable results in terms of student learning outcomes" in order to effect a change in teachers' instructional practices. Guskey's model further anticipates that the successful implementation of a new practice will lead to a change in the teacher's pedagogical beliefs. Thus, it is essential that teachers not only possess a particular belief about teaching and learning, but also believe they can enact the proposed corresponding practice in order to evoke change in instructional praxis. This further highlights the significance of context in teachers' beliefs and practices and adds credence to our investigation of OOF teachers' action research for evidence of belief and/or practice change.

Conceptual Framework

In this study, we are interested in analysing the role of OOF mathematics teachers' self-study action research in the development of OOF teachers' beliefs and practices. Due to the significance of context in understanding teachers' beliefs and practices, we draw on sociocultural theory to conceptualise the OOF teachers' learning as it occurs within their social environment. This conceptualization of OOF teaching through a zone theory lens will contribute new insights into the complexity of the OOF phenomenon.

Vygotsky (1978) introduced the notion of zone theory in his work on child development, in which he defines the zone of proximal development (ZPD) as "the distance between the actual developmental level as determined by independent problem-solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (p. 33). Valsiner (1997) reconceptualised Vygotsky's ZPD by situating it in conjunction with the zone of free movement (ZFM) (what is perceived as permitted and accessible in an individual's environment) and the zone of promoted action (ZPA) (all suggested actions both within and outside the individual's ZFM), thus highlighting the social context of development. While Vygotsky and Valsiner's theories applied to child psychology, zone theory has been increasingly adopted by education researchers in examining teacher development (see for example Blanton, Westbrook, & Carter, 2005; Galbraith & Goos, 2003; Goos, 2013). Reinterpreting Valsiner's zones for the 'teacher-as-learner', Goos theorises a teacher's ZPD as "a set of possibilities for development of new knowledge, beliefs, goals and practices created by the teacher's interaction with the environment, the people in it, and the resources it offers" (Goos, 2013, p. 523). In conceptualising the development of OOF teachers' beliefs and practices during the action research process, we evoke Goos' understanding to define the ZPD for OOF teachers as the possibilities for developing new knowledge, beliefs, goals and practices in their OOF teaching generated by the teacher's interaction with their professional environment, colleagues and resources. The ZFM for OOF teachers is considered as the professional context that structures their OOF teaching, while the ZPA refers to the teaching approaches recommended for the OOF subject by teacher education courses, professional development programmes and colleagues. The factors influencing the teachers in this study in terms of their OOF mathematics teaching is further elaborated within the three zones in Table 1. We acknowledge that while suggesting elements within the zones, the three zones are not strictly bounded, cannot fully be predicted and are subject to change (Goos, 2013; Valsiner, 1997).

Essential in the negotiation of teacher change and zone theory is the ZFM/ZPA complex and the notion of *tensions*. The ZFM and the ZPA are both culturally determined, with the ZFM playing a *restrictive* role and the ZPA an *advocative* role—hence the complexity. The ZFM/ZPA complex can be considered as microgenetic, or outside the learner, while the ZPD is ontogenetic, or within the learner (Blanton et al., 2005). For learning to take place, the ZPA must be within the teacher's ZFM, and the ZPA must be consistent with the teacher's ZPD (Galbraith & Goos, 2003). Tensions are created when the teacher's ZPD is inhibited by or misaligns with the ZFM/ZPA complex (Goos, 2013). *Productive tensions* develop when the teacher becomes dissatisfied with the misalignment and seeks to alter their environment (ZFM) or pursues, e.g. professional development opportunities (ZPA) that will realign the

Table 1 Factors influencing teachers' out-of-field mathematics teaching

Zone	Factors influencing OOF mathematics teaching
Zone of proximal development	Mathematics knowledge Mathematics pedagogical knowledge Experience teaching and learning mathematics Beliefs about teaching and learning (in mathematics and in general)
Zone of free movement	Perceptions of students (ability, behaviour, attitudes) School environment (class sizes, timetabling, administration, rooms etc.) Access to resources (technology, teaching materials, etc.) Support (colleagues, school leaders, parents) Curriculum and assessment (syllabus, end of year exams, etc.)
Zone of promoted action	Initial teacher education (non-OOF subject(s)) Professional development (previous courses and current PDMT, Action research supervisor) Curriculum changes (Project Maths) Colleagues (informal interaction)

zones to enable the teacher's development (ZPD). In this study, evidence of misalignment between the teachers' professional environment (ZFM), promoted teaching practices (ZPA) and the teachers' potential for enhanced beliefs and practices will be examined. A change in beliefs/practices through altering their ZFM and/or successfully engaging in promoted teaching practices during their action research will be indicative of productive tensions.

Background to the Study

When comparing OOF research at an international level, it is important to understand the systemic local factors that influence and contribute to the OOF context under investigation (Hobbs & Porsch, 2019). Underperformance in mathematics by secondary students in Ireland has been well documented (Organization for Economic Cooperation and Development [OECD], 2014). A new syllabus was introduced in 2010, with a key aim of promoting student understanding of mathematical concepts through active learning, application and problem-solving (Department of Education and Skills, 2010). In parallel, new criteria and guidelines for teacher education and curricular subject requirements for registration in Ireland have also taken place (Teaching Council, 2011). New prerequisites for qualification and registration to teach mathematics at second level education in Ireland include an increase in the amount of mathematics studied at degree level (60 credits) and the required study of specific topics (e.g. Geometry). Although such requirements exist, choices relating to the deployment of teachers within Irish secondary schools lie with school leaders. Accordingly, teachers may be placed in OOF teaching positions. Research in the Irish context relating to OOF mathematics is extremely worrying, whereby 48% of teachers teaching mathematics at secondary level are not specifically qualified to do so (Ní Ríordáin & Hannigan, 2011). However, it is important to note that OOF mathematics teaching is a world-wide issue (Hobbs & Törner, 2019) and one that needs to be addressed. Accordingly, the research presented in this paper provides some insights into the phenomenon and how a specific professional development programme might support such teachers.

The Professional Diploma in Mathematics for Teaching

Within the Irish context, a Professional Diploma in Mathematics for Teaching (PDMT) was established to upskill OOF mathematics teachers. The programme is delivered nationally by a consortium of third level institutions. The first intake into this programme was in September 2012, and there have been six cohorts of teachers to date. To qualify for entry into the programme, participants must hold a second level teacher qualification and must also be an 'out of field' teacher of mathematics which in the Irish context equates to not meeting the Teaching Council[1]'s subject criteria to teach mathematics. The PDMT is a 2-year, part-time programme comprising both mathematics content (60 ECTS credits) and pedagogy (15 ECTS credits) modules and is funded entirely by the Department of Education and Skills. Teachers completing the PDMT remain in their teaching positions and complete the programme via a blended learning approach consisting of online lectures and tutorials, face-to-face lectures and tutorials, five weekend workshops and a 1-week Summer Institute after year 1 of the programme. Table 2 provides an overview of the structure of the content modules of the programme. Each module[2] is 6 ECTS credits, consisting of 24 hours of lectures and 6 hours of tutorial work, over the duration of 6 weeks. All modules are Level 8 on the National Qualifications Framework.[3]

Table 3 provides an overview of the structure of the pedagogy modules of the programme. Each workshop consists of 3-hour face-to-face contact, the Summer Institute is 5 days of face-to-face lectures and workshops. The Action Research module consists of 120 hours of research/private study and requires teachers to undertake a research project examining their own practice in the mathematics classroom. This takes place over the course of year 2 of the programme. The focus of this paper is on the action research element of the PDMT and the development of OOF teachers' beliefs and practices during their self-study as analysed through the lens of zone theory. In the next section, we discuss action research and its role in teacher professional development.

Action Research Component of the PDMT

The action research module is undertaken in year 2 of the PDMT. Teachers are required to undertake a project in a chosen area of mathematics education and to submit an action research paper (approx. 6000 words) documenting their project and key learning throughout the process. As part of the assessment process, teachers were also required to submit a project proposal (September, 10%) and research methodology/ethics (January, 20%). Three levels of support were available to the teachers in order to assist them in undertaking their action research projects. These included:

- One full day of a Summer Institute was dedicated to introducing teachers to action research and supporting them in commencing their project through identifying an area of focus and exploring key ideas relating to conducting an action research project,

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[1] The Teaching Council is the professional standards body for the teaching profession in Ireland. All teachers must register with them in order to teach in a school in Ireland. Similarly, all teacher education programmes undergo accreditation and review processes.

[2] Each module runs for 6 weeks in a given semester. 2 modules are offered in Semester 1 (Sept.–Dec.) and 3 modules in Semester 2 (Jan.–May).

[3] Level 8 on the National Qualifications Framework equates to undergraduate third level education.

Table 2 Professional diploma in mathematics for teaching structure—content modules

Module title	Year	ECTS credits	Semester
Calculus 1; Calculus 2	1	6, 6	1
Algebra 1; Algebra 2	1	6, 6	2
Probability	1	6	2
Statistics	2	6	1
Geometry	2	6	1
Calculus 3	2	6	2
History of mathematics	2	6	2
Problem solving and mathematical modelling	2	6	2

- Online support was available through the PDMT programme website such as examples of previous projects, readings, templates and resources (e.g. ethics documentation) for undertaking their action research projects,
- Teachers assigned a specific, university-based supervisor who provided them with guidance and support throughout the process. This support included finalising area of focus and research question(s); guidance in relation to literature and readings; feedback on drafts of assignments required throughout the year; guidance in relation to data collection and analysis; as well feedback on the final write up of the action research project and submission of research paper.

The reasons that teachers conduct action research are varied (Noffke, 2009), but from the literature, it is clear that the reasons for, and influences on, teachers' action research fall chiefly within three dimensions: the personal, the professional and the political. These three dimensions were identified and have been employed by Noffke (2009) as a framework for examining the various methods and purposes of action research without categorising the research hierarchically. The personal dimension of action research deals with the individual conducting the research. In recent years, there has been an increased emphasis on exploring the connection between teachers' beliefs about teaching and learning and teachers' practice (Noffke, 2009). Teachers' beliefs seem to stem from their experiences, personal and educational (Zhang & Morselli, 2016). Research has

Table 3 Professional diploma in mathematics for teaching structure—pedagogy modules

Module title	Year	ECTS credits	Semester
Workshop 1—Calculus & Functions	1	Part of 9[a]	2
Workshop 2—Number & Algebra	1	Part of 9	2
Workshop 3—Probability	1	Part of 9	2
Summer Institute	1	Part of 9	Summer
Action Research (throughout the entire year)	2	6	1&2
Workshop 4—Statistics	2	Part of 9	1
Workshop 5—Geometry	2	Part of 9	1

[a] Part of 9 Credit module—Pedagogy & Research in Mathematics Education

documented the importance of teachers' beliefs in terms of their teaching praxis (e.g. Beswick, 2004; Ernest, 1989). The approach to action research employed in the PDMT is very much grounded on the premise of enquiring into one's own practice with a self-study process. In particular, it was grounded in the idea that OOF mathematics teachers can identify ways 'to improve your practice and then explain how and why you have done so' (McNiff, 2010, p. 6). Additionally, a key focus is on collaborative enquiry (with supervisor, with a critical friend, with pupils), undertaking the project for improvement, and is open in relation to values that underpin teaching and learning in their practice. Therefore, in the case of the PDMT, the action research project consisted of OOF teachers studying their practice with a view to improving it and their understanding of it and ensuring that the process was shared with others (Roche, 2011).

Methods

The study presented in this research paper is largely qualitative in nature and is centred on document analysis of action research papers submitted by OOF mathematics teachers ($n = 576$) enrolled on the PDMT between 2012 and 2016. The action research module ran for the first time in September 2013 (as a year 2 module) and the teachers' papers ($n = 236$) were submitted in July 2014. Teachers who submitted papers in July 2015 ($n = 223$) and 2016 ($n = 117$) are also utilised for the purpose of this study. To analyse all the submitted action research papers, we employed document analysis as a qualitative research method. It entails an organised process for evaluating documents (Kippendorff, 2004). Like any other qualitative approach, it involves assessing data and interpreting it to produce meaning and understanding (Corbin & Strauss, 2008). Document analysis involves both content analysis and thematic analysis and there are several key steps involved (Bowen, 2009), as outlined in the following paragraphs. Of importance to our study is that document analysis provides a means for tracking (or lack of) change and development (Bowen, 2009).

The first step in document analysis entails skimming (Bowen, 2009). This involves a surface level examination of all the available documents; in this case, 576 action research papers. This step primarily focused on identifying the contribution, or not, of a given action research paper to the research question being explored. It was important to establish if a given paper was connected to the conceptual framework and purpose of the research study (Bowen, 2009). For that reason, we were focused on identifying evidence of teachers' beliefs and practices and of teacher-as-learner in their written papers. Following the skimming process, conducted by both authors, 81 papers were deemed of a suitable quality for further analysis in view of the evidence they contained and their connection to the purpose of the research study. A total of 495 papers were not selected due to teachers' beliefs and practices not being *sufficiently explicit* in the papers submitted, and accordingly, they could not contribute to helping us answer our specific research question (Bowen, 2009). Their beliefs and practices were evident in their papers but lacked clarity for us to be able to fully determine whether a change had occurred or not. This is discussed further in the Limitations.

The second step involved reading through all 81 papers in greater detail and examination (Bowen, 2009). This phase concerned data familiarisation and involved immersion in the dataset prior to coding and categorising processes. Content analysis

was employed at this stage whereby the focus was on organising data as connected to the research questions and conceptual framework (Kippendorff, 2004). Accordingly, appropriate and illuminating sections of text were selected and highlighted, as relating to evidence of teachers' beliefs and practices. Emphasis was placed on identifying the most appropriate evidence (Bowen, 2009). Both authors engaged in this stage of the analysis to ensure rigour and validity. Subsequently, each paper was classified as either demonstrating evidence of:

- Direct transmission beliefs/practices (DTB/P) prior to undertaking the action research project and DTB/P on completion of the action research project (three papers in total);
- Direct transmission beliefs/practices (DTB/P) prior to undertaking the action research project and Constructivist beliefs/practices (CB/P) on completion of the action research project (71 papers in total);
- CB/P prior to undertaking the action research project and CB/P on completion of the action research project (seven papers in total).

The final step involved interpretation of the research papers (Bowen, 2009). Given that the majority of the papers could be classified as demonstrating evidence of moving from DTB/P to CB/P, it was decided to focus on changes in beliefs and practice (71 papers) and no changes in practices and beliefs (10 papers) of the selected sample. The data was then coded, recording both data-driven and concept-driven codes (Gibbs, 2007). Concept-driven codes were the three tenets of Zone theory (as outlined in Table 1, Goos, 2013). Discursive statements and patterns were gathered at this stage. During this phase, emphasis was placed on identifying key categories that fit the data (Miles & Huberman, 1994). Cross coding was employed to code a piece of data for more than one code. Three rounds of coding by both authors allowed for similar codes to be grouped and re-characterised and redundant codes were set aside. Parent and Child themes (Gibbs, 2007) were employed to further categorise the data and all codes; categories and themes were considered in terms of changes in beliefs and practices, as well as Zone theory. Data within each category was also quantified in terms of frequency; for example, the number of teachers reporting a change in practices, the number of teachers reporting a change in both beliefs and practices, etc. Thereafter, content analysis was utilised to identify meaningful text to illustrate key themes emerging from the data (Bowen, 2009). In order to enhance the data extraction and analysis process to ensure validity, investigator triangulation was employed. Each researcher conducted their own analysis of the data initially and then discussed this analysis in light of codes and themes emerging from the other researcher. A further two iterations of the analysis was undertaken, with a focus on verifying the validity of the findings and to examine the findings in relation to Zone theory (Goos, 2013; Miles & Huberman, 1994). As data were extracted from the action research papers, the authors verified their accuracy in terms of form and context with constant comparison with each other in order to ensure reliability (Silverman, 2017). Thereafter, the data and findings were reviewed with a colleague to validate conclusions and ensure validity and reliability in our findings (Gibbs, 2007).

Ethical approval was granted for a large-scale research project underpinning the PDMT, of which examining the action research component was part of the overall project. Consent was gained from participants on commencement of their studies. To ensure confidentiality, we assigned a specific code to each of the 81 papers utilised in

the final analysis stage. These codes contain the format of *initial belief/practice-post belief/practice-specific number*. For example, the code *DT-C-07* reflects that this paper represents a shift from Direct Transmission to Constructivist beliefs/practices. No data analysis took place until after the teachers had completed the entire programme and graduated in order to ensure minimal risk of teachers thinking participation impacted on grades awarded. The research papers' role in the assessment of a module on an accredited programme is discussed in the following Limitations section.

Limitations

The authors fully acknowledge that the chosen methodology for this study incurs some limitations. The selection of papers in which teachers' reflections on their beliefs and practices were *sufficiently explicit* to address our specific research question (Bowen, 2009) has resulted in a selection bias in our database given that we have only selected 14% of the total papers. This is important to consider given that reflection requires a high-level competence and accordingly the sample may not be representative of the entire population. In order to minimise bias, objectivity has been maintained by using multiple people to code the data, findings were reviewed with a peer and we do not claim that our findings are generalizable to the wider population (Silverman, 2017). In addition, given that the research papers were submitted for the assessment of a module on an accredited programme, it is important to keep this purpose in mind when assessing and interpreting the documents (Bowen, 2009). Thus, the database and the module assessment were not independent. As a result, the teachers may have expressed their beliefs and practices in a social desirable manner and accordingly this needs to be taken into account when interpreting the findings of the study. Similarly, the module was undertaken over the course of one school year by teachers who were working fulltime and engaged in other aspects of study of the PDMT. Therefore, other experiences throughout the period may have influenced teachers' beliefs and practices. We are not claiming that the action research project alone is the cause of change, rather that it may facilitate and illustrate development in beliefs and practices over this period and while undertaking a specific research project connected to their practice. Naturally, other forms of data collection could have been utilised but research has demonstrated that document analysis can be employed effectively as an individual method (e.g. Wild, McMahon, Darlington, Liu, & Culley, 2009). We are not claiming that we have a representative sample and that the findings are generalizable. Rather, this project provides an insight into how an action research project may facilitate changes in the beliefs and practices of OOF mathematics teachers through realisation of tensions and accordingly can support their professional development.

Findings

In this section, we present findings in relation to our research question. We have chosen to incorporate the discussion of these findings within this section also, due to the qualitative nature of the study. To answer our research question, we first describe and

discuss what the development or lack of development in OOF mathematics teachers' self-reported beliefs and practices entails. In analysing the 81 papers in which teachers explicitly reported on their beliefs and practices prior to and upon completion of their action research, we found a prevalence of direct transmission practices reported in their teaching and learning of mathematics prior to the action research (91%), while the remainder reported prior constructivist practices. The OOF teachers' reflections on their practices at the outset of the action research indicated that, for the majority, the OOF teachers were teaching in a "*traditional style*" (DT-C-23). For example, DT-C-09 articulates this as "I now realise I was very much trying to control the learning environment and making sure that students were able to do the maths questions. This was how I was taught maths. I am not sure if they fully understood the maths or enjoyed my lessons. I think that I was afraid of the class getting out of control or getting caught out as maths is not my first subject". For this teacher, his prior experience of learning mathematics didactically and a lack of mathematical content and pedagogical knowledge limited his ZPD, while the out-of-field context framed his ZFM in maintaining a strict teacher-centred approach, which is in contrast to promoted constructivist practices (ZPA). However, is direct-transmission practice a reflection of these OOF teachers' beliefs about teaching and learning, or is this at odds with their beliefs (bearing in mind the self-reported nature of these beliefs) and inhibiting the OOF teachers' development as mathematics teachers? We seek to explore this through a zone theory lens. Throughout this section, we differentiate between teachers who reported a change in their beliefs and practices or practices only. To clarify this differentiation, a breakdown of the 81 papers that contributed to our analysis of belief/practice development is outlined in Table 4.

OOF Teachers' Development of Constructivist Practices

Our analysis of the 74 cases in which the OOF teachers reported prior direct transmission practices (Table 4) indicates that 27 of these teachers (approx. 36%) simultaneously reported constructivist beliefs prior to the action research. Thus, these OOF teachers' direct transmission practices were inconsistent with their professed constructivist beliefs. In our study, 13 teachers (out of these 27) accredited their out-of-field context (ZFM) specifically, as the reason for the direct-transmission approaches they employed prior to their action research. They referred to employing constructivism in their teaching of the subjects for which they were initially qualified (ZPD/ZFM), but not in their OOF teaching of mathematics, for example: "As I am a Science teacher, I practice co-operative learning on a regular basis in various science classes. On

Table 4 Evidence of direct transmission and constructivist beliefs and practices

	Pre action research		Post action research	
	Beliefs	Practices	Beliefs	Practices
Direct transmission	36	74	3 (− 33)	3 (− 71)
Constructivism	34	7	67 (+ 33)	78 (+ 71)
Total	70	81	70	81

reflection of my teaching, I could clearly see that this strategy does not prevail in my mathematics classroom, with the content being delivered in a more teacher-centred manner" (DT-C-22). While Zhang and Morselli (2016) proposed that it is the self-reporting nature of beliefs that belie the practice, it should be remembered that these teachers are reporting both beliefs *and* practice, and therefore, the inconsistency is not between the professed and the observed. As such, our findings appear to support Beswick's (2004) assertion that the teacher's context determines which beliefs about teaching and learning they employ in practice. While the teacher (DT-C-22) uses constructivist practices in the rest of her teaching, in the context of teaching mathematics out-of-field she employs direct-transmission. Other contextual factors (such as time, curriculum, school constraints) were also identified in the papers as reasons for the OOF teachers' direct transmission practices. This finding indicates the existence of tensions between these teachers' potential for developing their beliefs and practices in their OOF teaching of mathematics (ZPD) and the ZFM/ZPA complex of their current professional environment.

For these 27 teachers, the development that emerged through the action research project was in the form of a *realignment* of beliefs and practices. This realignment would seem to have manifested for two reasons. Firstly, engaging in reflection of their teaching at the outset of the action research led these teachers to become acutely aware of the inconsistency between their beliefs and practices. They identified a mismatch between their constructivist ideology (ZPD) and the reality of covering content and preparing students for the end of school examinations (ZFM). One teacher articulated this saying: "Whilst I always aim to incorporate my values into my teaching they often get pushed aside in the frenzy to get a topic covered before the end of class/week, etc." (DT-C-48). Thus, engaging in an action research project as part of their studies afforded these OOF teachers an opportunity to think about their beliefs and practices (ZPD) in their professional context (ZFM) as articulated by the following teacher (DT-C-69): "This action research project had allowed me the chance to self-evaluate and reflect on my teaching. Something I know we all do but not maybe into the depth and level of reflection that can create a great significant level of change". The importance of this first stage in the realignment of the OOF teachers' beliefs and practices is, as Ernest (1989) states, in bringing the teacher's beliefs about teaching and learning to a conscious level and this self-reflection for OOF teachers was also encouraged by Bosse (2014). This stage could be said to be the moment at which the tension between their ZPD and the ZFM/ZPA complex started to become a *productive tension* (Goos, 2013), as the OOF teachers recognised their dissatisfaction with the misalignment between their beliefs and their contextually constrained practices.

Secondly, the perceived success of the constructivist practices the OOF teachers employed in their action research was instrumental in the realignment of their practices with their beliefs. For example, one teacher implemented the array model and algebra tiles through group work in her teaching of Algebra, a topic in which she had previously struggled to evoke student understanding, stating that her students found it difficult. However, "…as a result of my findings and also improved confidence due to my continual professional development I have now changed my approach to teaching algebra" (DT-C-57). This finding supports the assertions of Guskey (2002) and Aelterman et al. (2016) on the importance of perceived effectiveness and feasibility for teachers to accept and adopt an alternative teaching approach. In addition, in our study, gaining confidence and knowledge in the alternative constructivist approach to teaching mathematics also played

a key role for these OOF teachers in aligning their beliefs and practices and resolving the zonal tensions. Out of these 27 OOF teachers, more than half (59%) cited improved confidence as a factor in adopting constructivist practices in their future teaching. A lack of knowledge of teaching strategies relevant to their OOF teaching is common among OOF teachers (Hobbs, 2013). For some teachers in this study, their experience of action research increased their pedagogical knowledge of teaching strategies pertinent to their OOF teaching and positively impacted their self-efficacy beliefs about teaching mathematics, a finding that is consistent with previous research on the relationship between teacher qualification and confidence (Du Plessis, 2014; Ross et al., 1999). This increase in confidence and pedagogical knowledge has implications for the future praxis of these teachers given the vital role of teachers' self-efficacy and competence in the quality of teaching and learning (Hobbs, 2013).

OOF Teachers' Development of Constructivist Beliefs and Practices

In relation to the remaining 47 OOF teachers who reported direct transmission practices prior to their action research, 36 of these teachers also reported prior direct transmission beliefs. It was unclear from the other 11 teachers whether their beliefs about teaching and learning could be categorised as direct transmission or constructivist and therefore we can only report on a change to more constructivist practices by those teachers. Thus, we focus on the 36 OOF teachers who professed prior direct transmission beliefs as well as practices and the development of these OOF teachers. The majority, 33 teachers, reported a change to constructivist beliefs and practices after completing the action research project (DT-C), while 3 teachers adhered to direct transmission beliefs and practices (DT-DT). Our analysis of the 33 (DT-C) OOF teachers' papers indicates that they had perceived their role as one of providing examples and solutions to questions, getting students to practice questions, and structuring the learning environment to support students working individually in the classroom (ZPD/ZFM). For example, one teacher wrote: "Many educators over the years have successfully taught students to solve equations by applying a stringent set of rules in order to get the desired outcome." (DT-C-38). These OOF teachers frequently referred to the fact that the introduction of the new mathematics curriculum (Project Maths) (ZPA) and its emphasis on constructivist teaching and learning was at odds with their own experience, both as a learner and teacher (ZPD). Indeed, some of these OOF teachers were not entirely convinced of the effectiveness or feasibility of some of the new approaches, as articulated by the following: "Initially I was sceptical of the benefits of peer tutoring in a maths classroom. In particular, does it benefit the student acting as the tutor, do they gain from this experience or just recite information they already knew." (DT-C-12). Again, this is reminiscent of the findings of Guskey (2002) and Aelterman et al. (2016) on the importance of teachers' effectiveness and feasibility beliefs in adopting new practices. For most of the OOF teachers however (26/33), there was evidence of a genuine tension within their own thinking before they engaged in the action research process, and their awareness of the need to adopt constructivist teaching and learning practices (ZPA). One of these teachers expressed this tension as: "Thirty years ago rote learning was the way every student was taught and I feel this worked then because curricula changed rarely and advances in technology and science were not as widespread as they are today. Our students however are training for jobs that don't yet exist and therefore need to be able to transfer their

skills to these jobs" (DT-C-38). These OOF teachers had become more acutely aware of the importance of real-life applications, contexts and problem-solving skills for mathematics learning and life-long learning as a result of recent curricular changes (Department of Education and Skills, 2010) and realised that their own practices did not align with this. For example, one teacher stated: "As a student of the Professional Diploma in Mathematics for Teaching, the use of GeoGebra had been mentioned as part of pedagogy workshops, summer school and lectures. I had also heard some of my colleagues using it as part of their lessons and it had been mentioned regularly in our subject meetings. I felt ashamed that I did not know the merits of this "thing" called GeoGebra especially as a young teacher." (DT-C-06). This particular OOF teacher was aware of the mathematics software through her professional development and from colleagues (ZPA) but had never used the software herself. This led to feelings of inadequacy and a 'tension' between her own OOF teaching knowledge and practices and the practices recommended by professional development workshops and colleagues. As such, this teacher took the opportunity to incorporate GeoGebra into her mathematics teaching during her action research project. Goos and Geiger (2010) stated that transforming teachers' practices can be difficult to achieve in a planned intervention or professional development context, and pre-existing tensions can play a key role in the successful transformation of teachers' practices. This was certainly true for these (26) OOF teachers in our study as their pre-existing awareness of tensions meant they were already conscious of the need to change their OOF teaching practices and indeed were aware (to an extent) of the promoted practices they needed to adopt.

All 33 teachers (including those with some cynicism of constructivism) appeared to engage in the action research in a positive manner, willing to try these new, promoted approaches in their own classes (ZFM). Perhaps one of the key factors in their developing beliefs was this willingness to persevere with the approach during their action research, even when encountering difficulties: "At many stages throughout the year it is often tempting to take the easier option of resorting back to rote learning techniques as it can often seem more effective at times. However, the results from this action research have proven to me the immense benefits that can arise as a result of alternative teaching methods." (DT-C-38). This perseverance in pursuing their professional development through the action research was an important facet in transferring the existing tensions into productive tensions. Similar to the first group of OOF teachers discussed, these 33 teachers became convinced of the effectiveness of their new approaches when they experienced their benefits first hand. For example, one teacher wrote: "I now realise the extreme importance of creating a learning environment where active learning methodologies are highly embedded." (DT-C-45). This finding suggests that, as proposed by Guskey's (2002) model of teacher change, the successful implementation of a new practice can lead to a change in the teacher's pedagogical beliefs. Furthermore, in light of the successful implementation, the OOF teachers appeared to reinterpret their perception of their students' needs as learners and the feasibility of constructivist practices in their professional context (ZFM). This reinterpretation of their ZFM thus resolving the ZFM/ZPA complex enabled the development of these OOF teachers' beliefs and practices. This may suggest that while the ZFM has been described as microgenetic, or outside the learner (Blanton et al., 2005), the learner's *perception* or interpretation of their ZFM plays a key role in aligning the ZPA within their ZFM and in resolving tensions that inhibit the learner's development.

OOF Teachers' Lack of Development to Constructivist Beliefs/Practices

Only three OOF teachers professed an adherence to direct-transmission beliefs and practice on completion of their self-study so opportunities for comparison between development and lack of development cases are minimal. While seven other OOF teachers could be classified as no development cases also, those teachers do not strictly fit with the analytical lens of zone theory we employed as the teachers reported constructivist beliefs and practices prior to the action research as well as on completion. As such there is less evidence of the 'teacher-as-learner' and no evidence of tensions to be examined. Therefore, we can only examine the three DT-DT teachers in order to gain some insight into the reasons why development of constructivist beliefs/practices did not occur.

The three OOF teachers who adhered to direct transmission beliefs and practices pre and post action research were all aware of the tension between their own practices and the promoted constructivist practices prior to the action research, but there was less evidence that these teachers felt compelled to align with the promoted actions and no dissatisfaction evident with regard to their current practices. One teacher stated that she was sceptical about the "realistic achievability" (ZFM) of using the constructivist approaches advocated by Project Maths (ZPA) as "the old reliable methods that have been getting me results for years" (DT-DT-03). A willingness to persevere with the new approach during their action research, even when encountering difficulties, was a key factor that we identified for the OOF teachers in transforming tensions into productive tensions. This perseverance was less evident in the DT-DT papers. For example, when this teacher (DT-DT-03) experienced difficulties during the action research in terms of students' access to computers/internet at home and in school (ZFM), she did not pursue the approach in order to resolve the ZFM/ZPA complex. A second teacher implemented a teaching strategy in her action research that reinforced her commitment to direct transmission, adapting the new syllabus' problem-solving recommendations (ZPA) to her perceived professional context (ZFM) rather than vice versa: "The majority of students choose direct instruction as their preferred method of learning. I feel that the online tutorials suit this mechanism of learning very well, as they give a clear explanation of the topics covered, with key instructions of how to approach and solve maths problems and key examples to clarify the theory covered" (DT-DT-01). The teacher remained focussed on her role as instructor and on giving the knowledge to students rather than facilitating student learning and student autonomy, thus inhibiting her own ZPD. The reinterpretation of the promoted actions to 'fit' with their beliefs about teaching and learning also differed from the previously discussed cases and may be a factor in the adherence to direct transmission. It would appear for these teachers, the promoted constructivist practices were not consistent with the OOF teachers' developmental potential (ZPD) which is a key requirement in order for teacher change to occur (Galbraith & Goos, 2003). The third DT-DT case was different from the previous two in that the teacher could see the benefit to her students in the constructivist approach to problem-solving employed in her action research, but she found the required approach too time-consuming and admitted to being "hesitant to engage in extra burdens unless it is explicitly stated within a syllabus" (DT-DT-02). Despite positive findings from her study in relation to constructivism, she appears to reject these outcomes as sufficient reason to implement similar strategies again due to her

perception of the curriculum and the contextual time constraints, thus rendering the ZFM/ZPA complex unresolved. This particular OOF teacher's lack of constructivist belief development despite the successful implementation of a constructivist approach is somewhat inconsistent with previous research (Aelterman et al., 2016; Guskey, 2002). The reason for this consistency may be due to the teacher's inability to reinterpret her perception of her ZFM in light of these findings, which we found to be an important component in resolving tensions and realigning the ZFM/ZPA complex for the OOF teachers who developed constructivist beliefs and practices.

Conclusion

This paper set out to examine the development of OOF mathematics teachers' beliefs and practices during self-study action research through a zone theory lens. Our analysis focussed on OOF mathematics teachers who self-reported their beliefs and practices pre and post self-study action research. The majority of these OOF teachers reported direct transmission practices prior to the action research with a predominant shift to constructivist beliefs and practices or a realignment of practices with constructivist beliefs post action research. A minority of OOF teachers adhered to direct transmission beliefs and practices. Our findings highlight the importance of self-reflection for OOF teachers, particularly in highlighting inconsistencies between the OOF teachers' beliefs and practices. The significance of confidence and pedagogical knowledge in developing constructivist practices is also a key finding with implications for the professional development of OOF teachers. Existing tensions between the OOF teachers' ZPD and the ZFM/ZPA complex coupled with the experience of constructivist teaching that was effective and feasible in their own contexts were vital in creating productive tensions for the OOF teachers, thereby leading to a change in practices and beliefs (Guskey, 2002). The authors also suggest that the teachers' ability to reinterpret their perception of their ZFM (for example in terms of students' abilities and needs or curricular constraints) was essential in resolving the ZFM/ZPA complex and thereby facilitating the teachers' development. This was one of the main differences found between OOF teachers who developed constructivist beliefs and those that retained direct transmission beliefs—the latter tending to adapt the promoted approaches to fit their perception of their ZFM rather than vice versa. Willingness to engage in constructivist practices and perseverance despite difficulties were also found to be crucial in the OOF teachers' development or lack thereof.

While the OOF context is currently lacking in-depth research, there has been increased interest recently in this pervasive educational obstacle (Du Plessis et al., 2015; Hobbs, 2013; Ní Ríordáin et al., 2017). There is an exigent international requirement to not only conduct research on, but also offer solutions to, the OOF predicament in which significant numbers of teachers find themselves (Hobbs & Törner, 2019). Our research provides an innovative perspective on this complex issue. While limited in terms of generalizability, our study highlights the importance of addressing OOF mathematics teachers' beliefs and practices in a professional development programme. The widespread existence of direct-transmission beliefs and practices in relation to teaching and learning, manifested among OOF mathematics teachers in this study, is a firm indictment for the need to address this issue. The authors suggest that self-study

action research can be valuable in upskilling OOF mathematics teachers, specifically in transforming beliefs and innovating practice. While this study focussed on OOF mathematics teachers, there are obvious connotations here for OOF teachers in other subject areas, as well as for in-field teachers of mathematics. Further research is required to fully understand the professional development benefits of action research in the OOF context, not only in the demesne of beliefs and practice, but also in terms of pedagogical knowledge, confidence and accordingly, the enhancement of teaching quality at second level.

Compliance with Ethical Standards

Ethical approval was granted for a large-scale research project underpinning the PDMT, of which examining the action research component was part of the overall project. Consent was gained from participants on commencement of their studies.

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